

## **Retrofitting thermal performance of building envelope and extension of Secha Sadan, Bhubaneswar**

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**Abstract:** The built environment is responsible for 40% of the global energy demand. Efforts are to be made in existing buildings, namely in office buildings, which are statistically more energy consuming than residential buildings. One of the main components of achieving a more sustainable built environment is to improve the performance of the existing building stock by retrofitting to increase the energy efficiency and improve quality of life (Low Carbon Innovation Coordination Group 2012). The retrofit of building envelope can help in saving 50–60% of the buildings' energy consumption used for HVAC purposes. Secha Sadan is a 50 year old government office building in Bhubaneswar. Proposing a building envelope retrofitting for this structure will not only help in reducing the energy consumption of this structure but would also shed light on how this can be implemented in other such existing government office buildings in Bhubaneswar. The existing envelope has been documented and analyzed using U-Value calculations and simulation softwares like OPAQUE and Form it. A number of envelope retrofitting techniques have been studied and shortlisted through literature, desktop and case studies to propose the best strategies. It was found that 40% savings can be achieved by the retrofit strategy implemented. Also the live proposal of an extension of the existing block to accommodate a new division has been taken into consideration. An attempt has been made to design this block appropriately keeping in mind the required thermal performance standards.

**Keywords:** Building Envelope, Retrofitting, Thermal Performance, Insulation

### **1. THESIS PROPOSAL**

#### **1.1. Background**

India is the 7th largest country in the world and home to over 1 billion people living across five different climatic zones. India is a rapidly growing economy with construction sector contributing to around 7.74% to the total GDP of the country. Commercial and residential development remains a priority for the construction industry due to its market potential/market demand/profit margins. These sectors also consume a large amount of energy over their life cycle, thus becoming one of the major sources of GHG emissions. Literature and current policy framework suggest that energy saving and its conservation is of prime importance to the government of India. The government is in a continuous process of suggesting and implementing policy frameworks to manage the energy usage from various sectors including the buildings sector. The government came out with a suggestive list of voluntary and mandatory programs and policies such as Energy Conservation Building Code (ECBC) for commercial buildings, Standards and Labelling

(S&L) program for appliances, Star rating program for existing building etc. to monitor and optimize the energy consumption from the sector.

## 1.2. Statement of problem

Retrofitting of building envelope to improve thermal performance refers to how well a building responds to the changes in external temperature during daily and seasonal cycles with respect to the building envelope (walls, roof, floor, windows, doors, skylights and other openings).

## 1.3. Aim of the paper

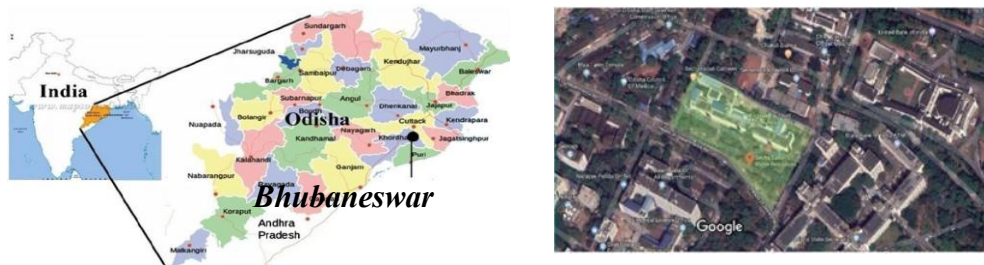
To Retrofit Existing old government office Building to improve the Thermal performance of the building to achieve thermal comfort

## 1.4. Objectives of thesis

- To study the principles of retrofitting technologies.
- To energy audit the existing govt. building and analyze current energy consumption.
- To find out different technologies and components of the building and ways to implement them.
- To formulate the application of retrofitting components to the building.
- To simulate and analyze the post retrofitting conditions and furnish final report.

## 1.5. Description of the project or the study area

### 1.5.1. Location and climatic zone classification



**Figure 1 location of site**

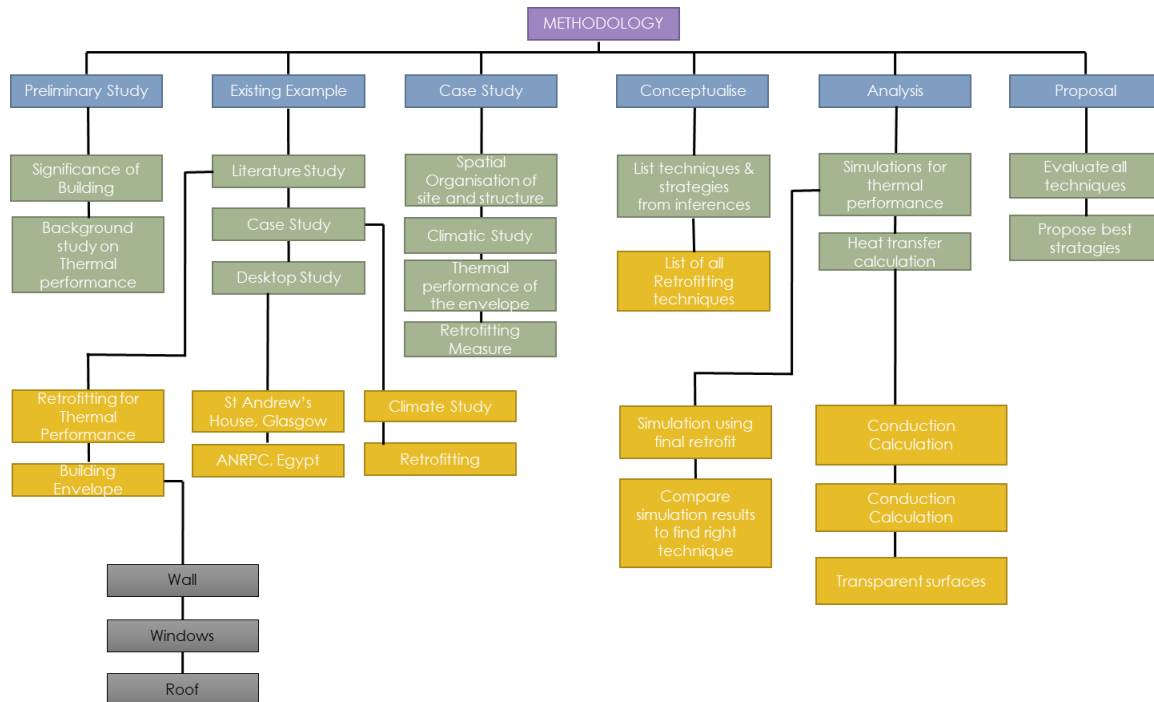
The office building is located in Bhubaneswar, Odisha. Secha Sadan (Water resources department) Bhubaneswar, Odisha was established in the year 1993.

### 1.5.2. Typology of the project or study area



**Figure 2 Secha Sadan building**

### 1.5.3. Proposed methodology



### 1.5.4. Limitation of the thesis

- Project is limited to providing thermal insulation to building envelope.
- There are some assumptions in the simulation modelling.
- For example, the data of internal gains from occupants, lighting and other appliances are taken from benchmarks and typical scenarios.
- The embodied energy is not simulated, which may be considered a limitation.

## 2. INTRODUCTION

A building once operational, continues to consume energy and increase its carbon footprint throughout its life. Retrofitting existing buildings can lead up to 15-20 % savings over the benchmark energy consumption. Retrofitting existing buildings to ensure energy efficiency and mitigate GHG emissions has been identified as one of the most effective mechanism by governments of various countries to reduce their energy consumption and mitigate GHG emissions.

In India major stock of office buildings was built before the implementation and access to modern energy saving technologies. According to the 17th EPS report published, it was estimated that electricity demand is estimated to increase by 37.5% by 2021-22 over a baseline of 2016-17. An ECBC Cell has been established in BDA to ensure energy efficiency in the buildings in the city through implementation of Odisha ECBC Code, 2011. A consultation meeting has been held to discuss and take feedback of all the major stakeholders vendor list has prepared who provide ECBC Compliant materials in state.

Studying the historical growth in consumption levels and population growth projections until the year 2018, it has been assessed that the energy consumption in Bhubaneswar in 2013 can be ascertained under the highest growth scenario as 1570.10 MU. The guidelines on “Retrofitting Existing commercial Buildings” presents a step by step

approach to access the saving potential in the existing building and then stimulate implementable options and method to achieve required numbers in term of energy savings and GHG mitigation

### 3. LITERATURE REVIEW

#### 3.1. Building Envelope

A building envelope is the physical separator between the conditioned and unconditioned environment of a building. The building envelope of a house consists of its roof, sub floor, exterior doors, and windows and of course the exterior walls. A building envelope is normally referred to as either 'tight' or 'loose'. A loose envelope allows air to flow more freely through the building, whereas a tight envelope restricts air or controls how it is admitted. From an energy efficiency point of view, the envelope design must take into consideration both the external and internal heat loads, as well as daylighting benefits. External loads include mainly solar heat gains through windows, heat losses across the envelope surfaces, and unwanted air infiltration in the building

#### 3.2. Heat transfer in building

Heat transfer takes place through walls, windows, and roofs in buildings from higher temperature to lower temperature in three ways-conduction, convection, and radiation.

Table 1 Definition

|                   | CONDUCTION                                     | CONVECTION                         | RADIATION                                                 |
|-------------------|------------------------------------------------|------------------------------------|-----------------------------------------------------------|
| <b>DEFINITION</b> | The transfer of heat through a solid material. | The transfer of heat by moving air | The transfer of heat In the form of electromagnetic waves |

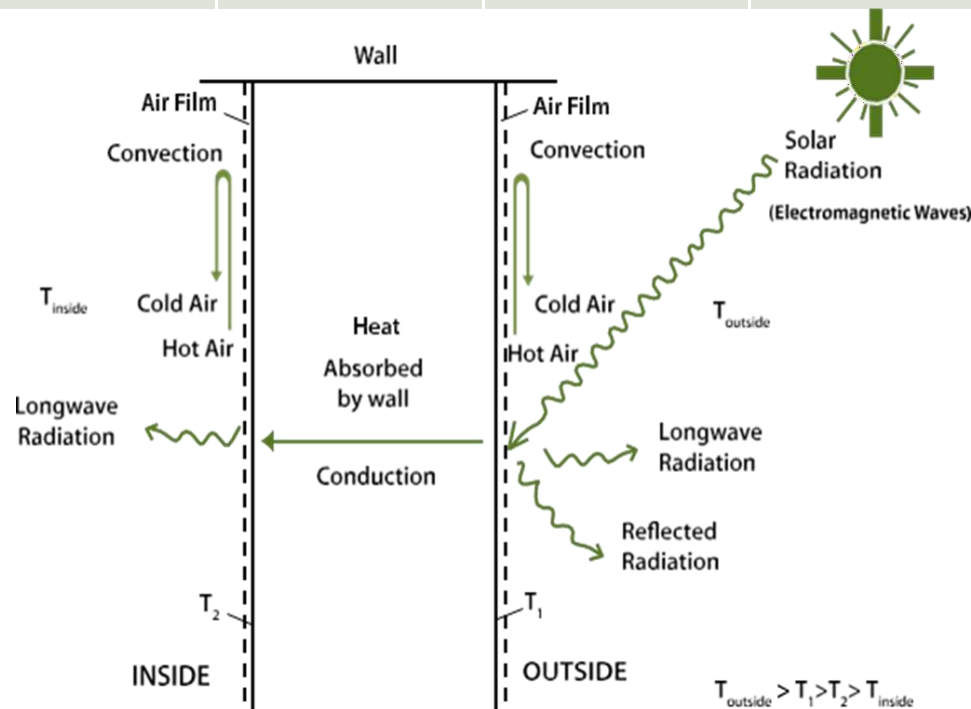


Figure 3 wall section showing heat transfer

#### 3.3. Thermal properties

### 3.3.1. Thermal Conductivity of insulating materials

Thermal conductivity, also known as Lambda ( $\lambda$ ), is the measure of how easily heat flows through a specific type of material, independent of the thickness of the material in question. The lower the thermal conductivity of a material, the better the thermal performance. It is measured in Watts per Meter Kelvin (W/mK).

### 3.3.2. R-Values

The R-value is a measure of resistance to heat flow through a given thickness of material. So the higher the R-value, the more thermal resistance the material has and therefore the better its insulating properties.

$$R = l / \lambda$$

Where:

$l$  is the thickness of the material in meters and  $\lambda$  is the thermal conductivity in W/mK. The R-value is measured in meters squared Kelvin per Watt (m<sup>2</sup>K/W)

### 3.3.3. U-Values

The U value of a building element is the inverse of the total thermal resistance of that element. The U-value is a measure of how much heat is lost through a given thickness of a particular material, but includes the three major ways in which heat loss occurs – conduction, convection and radiation.

$$U = 1 / [R_{si} + R_1 + R_2 + \dots + R_{so}]$$

In practice this is a complicated calculation, so it is best to use U-Value calculation software.

## 3.4. Retrofitting Envelope

### 3.4.1. Opaque Wall

Insulation of walls is also important for reducing conduction losses especially where significant difference exist between inside and outside temperature. Many insulation materials require an Air Barrier and Weather Resistive Barrier to prevent air and moisture movement into and out of the conditioned space, as well as for maintaining their installed R-value. Opaque Wall Assembly U-Factor and Insulation R-value Requirements (ECBC Table 4.2).

| Climate Zone   | Hospitals, Hotels, Call Centers (24-Hour)                      |                                                           | Other Building Types (Daytime)                                 |                                                           |
|----------------|----------------------------------------------------------------|-----------------------------------------------------------|----------------------------------------------------------------|-----------------------------------------------------------|
|                | Maximum U-factor of the overall assembly (W/m <sup>2</sup> ·K) | Minimum R-value of insulation alone (m <sup>2</sup> ·K/W) | Maximum U-factor of the overall assembly (W/m <sup>2</sup> ·K) | Minimum R-value of insulation alone (m <sup>2</sup> ·K/W) |
| Composite      | U-0.440                                                        | R-2.10                                                    | U-0.440                                                        | R-2.10                                                    |
| Hot and Dry    | U-0.440                                                        | R-2.10                                                    | U-0.440                                                        | R-2.10                                                    |
| Warm and Humid | U-0.440                                                        | R-2.10                                                    | U-0.440                                                        | R-2.10                                                    |
| Moderate       | U-0.440                                                        | R-2.10                                                    | U-0.440                                                        | R-2.10                                                    |
| Cold           | U-0.369                                                        | R-2.20                                                    | U-0.352                                                        | R-2.35                                                    |

Table 2 opaque wall assembly recommendation

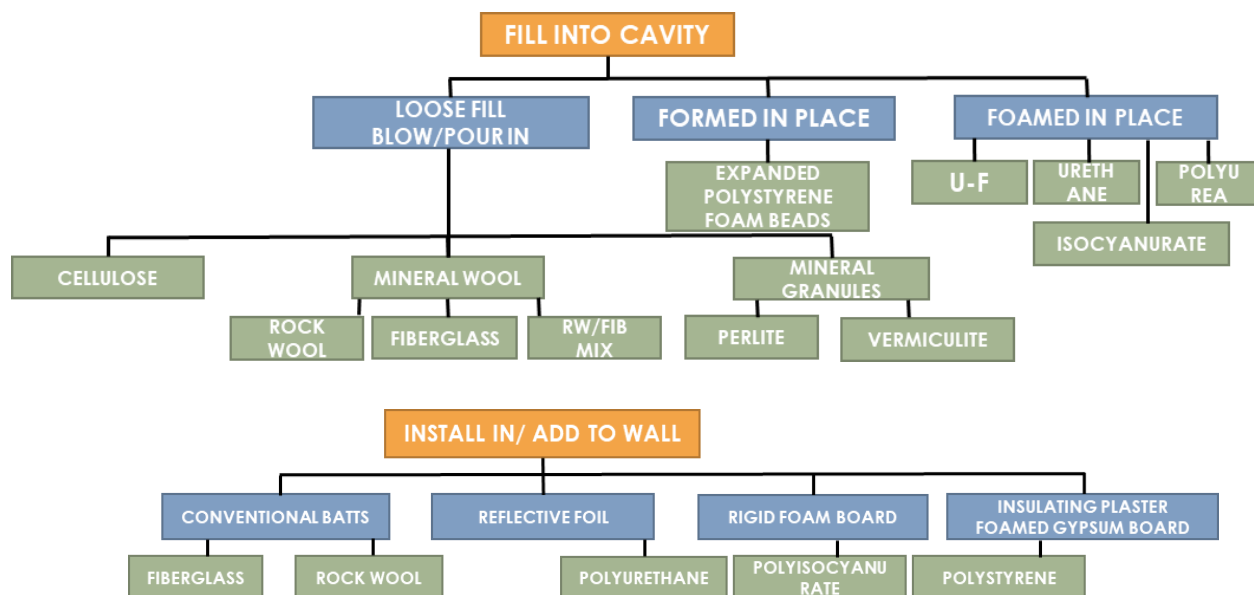


Table 3 recommended materials by IGBC

| Material                   | U-value (W/m <sup>2</sup> K) | Thickness (mm) |
|----------------------------|------------------------------|----------------|
| Extruded Polystyrene (XPS) | 0.028                        | 60             |
| Glass Wool stuffing        | 0.25                         | 150            |
| Expanded Polystyrene (EPS) | 0.30                         | 100            |
| Air (Still)                | 0.20                         | 30             |

### 3.4.2. Roof

Roof can be insulated either over the deck or under the deck. Generally, over deck insulation is preferred, so as to avoid the absorption and retention of heat by the concrete surface. Under deck insulation can also be considered but the thickness of insulation should be higher.

Table 4 Recommendation for roof

| Climate Zone   | 24-Hour use buildings Hospitals, Hotels, Call Centers etc.      |                                                            | Daytime use buildings Other Building Types                      |                                                            |
|----------------|-----------------------------------------------------------------|------------------------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------|
|                | Maximum U-factor of the overall assembly (W/m <sup>2</sup> · K) | Minimum R-value of insulation alone (m <sup>2</sup> · K/W) | Maximum U-factor of the overall assembly (W/m <sup>2</sup> · K) | Minimum R-value of insulation alone (m <sup>2</sup> · K/W) |
| Composite      | U-0.261                                                         | R-3.5                                                      | U-0.409                                                         | R-2.1                                                      |
| Hot and Dry    | U-0.261                                                         | R-3.5                                                      | U-0.409                                                         | R-2.1                                                      |
| Warm and Humid | U-0.261                                                         | R-3.5                                                      | U-0.409                                                         | R-2.1                                                      |
| Moderate       | U-0.409                                                         | R-2.1                                                      | U-0.409                                                         | R-2.1                                                      |
| Cold           | U-0.261                                                         | R-3.5                                                      | U-0.409                                                         | R-2.1                                                      |

### 3.4.3. Fenestration

Most large commercial buildings are dominated by cooling loads, so window selection for commercial buildings is usually an exercise in maximizing daylighting and keeping summer heat out. Today's best windows block heat transfer more than five times better than single-pane glass, the standard windows of just two decades ago. High-performance

windows are not only a wise investment for new construction, but sometimes can be cost-effectively retrofitted, especially when timed with planned replacement and downsizing of HVAC equipment. Glazing products (windows, skylights, etc.) can be specified to reduce solar heat gain and control light levels and glare. As a rule of thumb, double glazing should always be preferred over single glazing since facades with double glazing not only offers superior thermal performance but can also help in significantly reducing unwanted external noise of traffic.

Windows are affected by many factors, which in turn affect the comfort and energy performance of buildings. Understanding these factors is critical to designing buildings that meet the needs of building owners and users. Once these factors are identified, a designer can then apply the appropriate technology to address them.

**Table 5 Fenestration global recommendation**

|  <b>Most Efficient 2019</b><br>Southern Zone Required Properties (mostly cooling)                                                                          |                                                                                                                                                                         |                                                                                           |                                                                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| U-factor                                                                                                                                                                                                                                    | Solar Heat Gain Coefficient (SHGC)                                                                                                                                      | Visible Transmittance (VT)                                                                | Air Leakage (AL)                                                      |
| Windows: $U \leq 0.40$<br>Skylights: $U \leq 0.60$                                                                                                                                                                                          | Windows: $SHGC \leq 0.25$<br>Skylights: $SHGC \leq 0.28$                                                                                                                | Windows: VT=No Requirement<br>Skylights: VT=No Requirement                                | Windows: $AL \leq 0.30$<br>Skylights: $AL \leq 0.30$                  |
| <i>EWC Recommendation:</i> A low U-factor is useful during cold days when heating is needed. A low U-factor is also helpful during hot days when it is important to keep the heat out, but it is less important than SHGC in warm climates. | <i>EWC Recommendation:</i> A low SHGC is the most important window property in warm climates. For superior energy performance, use windows with a SHGC of 0.25 or less. | <i>EWC Recommendation:</i> Select windows with a higher VT to maximize daylight and view. | <i>EWC Recommendation:</i> Select windows with an AL of 0.30 or less. |

### 3.5. Insulation Strategies

**Table 6 minimum U value for wall and roof**

| Climatic zones                        | 24-Hour use buildings<br>(Hospitals, Hotels, Call Centers etc.)       |                                                                  | Daytime use buildings<br>(Other Building Types)                       |                                                                  |
|---------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------|
|                                       | Maximum U - factor of the overall assembly ( $W/m^2 \cdot ^\circ C$ ) | Minimum R - value of insulation alone ( $m^2 \cdot ^\circ C/W$ ) | Maximum U - factor of the overall assembly ( $W/m^2 \cdot ^\circ C$ ) | Minimum R - value of insulation alone ( $m^2 \cdot ^\circ C/W$ ) |
| Composite, Hot & Dry and Warm & Humid |                                                                       |                                                                  |                                                                       |                                                                  |
| Roof Assembly                         | 0.261                                                                 | 3.50                                                             | 0.409                                                                 | 2.10                                                             |
| Wall Assembly                         | 0.440                                                                 | 2.10                                                             | 0.440                                                                 | 2.10                                                             |

**Table 7 measures for reduction of heat gain**

| Measures                                                                     | Wall                                                                                                                                                                                             | Roof                                                                    | Window                                                                       |
|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Minimize Conduction Losses                                                   | Use insulation with low U-factor                                                                                                                                                                 | Use insulation with low U-factor                                        | Use material with low U-factor                                               |
| Minimize Convection Losses                                                   | Reduce air leakage using a continuous air barrier system                                                                                                                                         | Reduce air leakage using a continuous air barrier system                | Use prefabricated windows and seal the joints between windows and wall       |
| Minimize Moisture Penetration                                                | Reduce water infiltration- use continuous drainage plane<br>Reduce air transported moisture- use continuous air barrier<br>Reduce moisture diffusion into the wall – use vapor barrier/retarder* | Watertight Airtight: continuous air barrier Use vapor barrier/retarder* | Use prefabricated windows and seal the joints between windows and walls      |
| Minimize Radiation Losses                                                    | Use light colored coating with high reflectance                                                                                                                                                  | Use light colored coating with high reflectance                         | Use glazing with low Solar Heat Gain Coefficient (SHGC); Use shading devices |
| * See the discussion about where to place a vapor barrier/retarder. (Fig. 7) |                                                                                                                                                                                                  |                                                                         |                                                                              |

| Form                                                                                                                                      | Method of Installation                                                                                                                                                                                                                                                                                                                                      | Where Applicable                                                                                                                                                                                                                                                                                                                                                                                             | Advantages                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Blankets: Batts or Rolls, Fiberglass, Rock wool                                                                                           | <ul style="list-style-type: none"> <li>Fitted between studs, joists and beams. Insulation must be protected by an air barrier membrane in order to maintain the installed R-value (conductive loops &amp; wind washing)</li> <li>The air barrier can be installed over exterior and/or interior sheathing and must be continuous</li> </ul>                 | <ul style="list-style-type: none"> <li>Unfinished walls, floors and ceilings</li> </ul>                                                                                                                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>Easy installation, suited for standard stud and joist spacing, which is relatively free from obstructions</li> </ul>                                                |
| Loose-Fill: Spray-applied Rock wool, Fiberglass, Cellulose Polyurethane foam                                                              | <ul style="list-style-type: none"> <li>Blown into place or spray applied by special equipment. Insulation must be protected by an air barrier membrane in order to maintain the installed R-value (conductive loops &amp; wind washing)</li> <li>The air barrier can be installed over exterior and/or interior sheathing and must be continuous</li> </ul> | <ul style="list-style-type: none"> <li>Enclosed existing wall cavities or open new wall cavities</li> <li>Unfinished attic floors and hard to reach places</li> </ul>                                                                                                                                                                                                                                        | <ul style="list-style-type: none"> <li>Commonly used insulation for retrofits (adding insulation to existing finished areas)</li> <li>Good for irregularly shaped areas and around obstructions</li> </ul> |
| Rigid Insulation: Extruded polystyrene foam (XPS), Expanded polystyrene Foam (EPS or Beadboard), Polyurethane foam, Polyisocyanurate foam | <ul style="list-style-type: none"> <li>Interior applications: Must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety</li> <li>Exterior applications: Must be covered with weather-proof facing or continuous Air and Weather Resistive Barrier (WRB)</li> </ul>                                                | <ul style="list-style-type: none"> <li>Basement walls, Exterior walls under finishing (Some foam boards include a foil facing which will act as a vapor retarder. Additionally, some insulation materials- e.g. XPS and closed cells polyurethane foams—are vapor retarders. Please read the discussion about where to place, or not to place a vapor retarder)</li> <li>Unvented low slope roofs</li> </ul> | <ul style="list-style-type: none"> <li>High insulating value for relatively little thickness</li> <li>Can block thermal short circuits when installed continuously over frames or joists</li> </ul>        |
| Reflective Systems: Foil-faced paper, Foil-faced polyethylene bubbles, Foil-faced plastic film, Foil-faced cardboard                      | <ul style="list-style-type: none"> <li>Foils, films, or papers: Fitted between wood-frame studs joists, and beams</li> </ul>                                                                                                                                                                                                                                | <ul style="list-style-type: none"> <li>Unfinished ceilings, walls, and floors (for wall applications, must consider that most foil faced systems act as a vapor retarder)</li> </ul>                                                                                                                                                                                                                         | <ul style="list-style-type: none"> <li>Easy installation: All suitable for framing at standard spacing</li> <li>Bubble-form suitable if framing is irregular or if obstructions are present</li> </ul>     |

#### 4. DESKTOP STUDY

##### 4.1. Alexandria National Refining & Petrochemicals Co.(ANRPC)

Alexandria National Refining & Petrochemicals Co. (ANRPC) is a refinery based **office building in El-Max, Alexandria, Egypt**. The company has an administrative building. It was designed in 1995 and construction in 2000 finished.



Figure 12 location of project and Building

##### 4.1.1. Building typology

Office Building

| Floors       | Functions                   |
|--------------|-----------------------------|
| Ground floor | Meeting Room – Reception    |
| 1st floor    | Chairman + Managerial Board |
| 2nd floor    | Engineering Departments     |
| 3rd floor    | Human Resources Departments |
| 4th floor    | Financial Departments       |

Total construction area of 3370 Sq.m.

22% reduction in both energy consumptions and Carbon emissions.

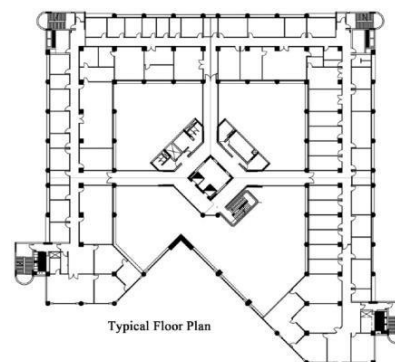


Figure 13 plan

#### 4.1.2. Energy Data for the building

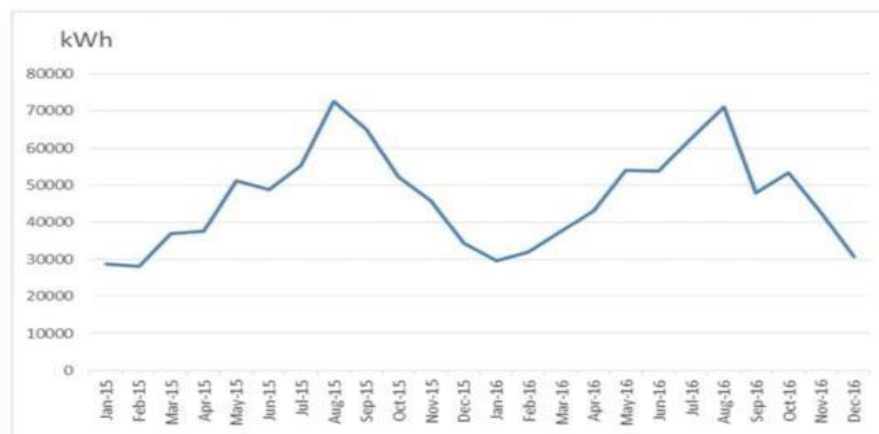
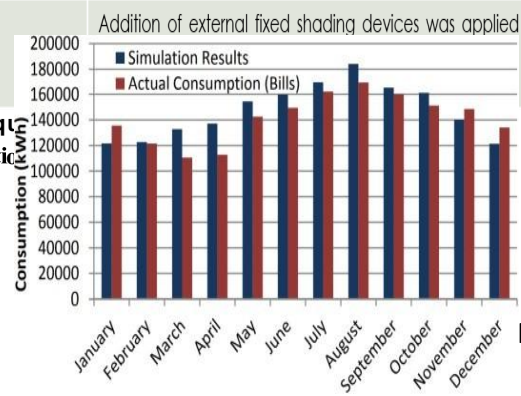
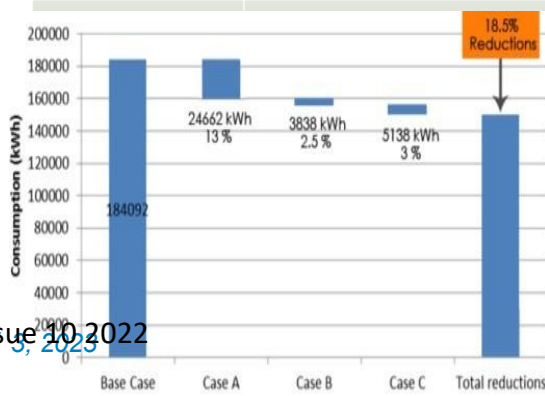


Figure 14 Electricity consumption pattern

| ELEMENTS              | DESCRIPTION                                                                                                                                          |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ventilation           | The building uses mechanical ventilation                                                                                                             |
| Building Dimension    | 60m x 67m and height 20m                                                                                                                             |
| Exterior Shading      | unshaded externally with large area of fixed curtain walls                                                                                           |
| Glazing               | Tinted blue double glazed curtain walls<br><b>u-value = 2.7 W/m<sup>2</sup> K</b>                                                                    |
| WWR                   | All elevations = 80% ,north and north west elevations = 90%                                                                                          |
| Exterior walls        | not insulated, 20cm brick wall, 2cm interior and exterior paint , u-value of 1.5 W/m <sup>2</sup> K.                                                 |
| Unshaded windows area | north-east elevation is 880 Sq.m, the north-west is 1098 Sq.m ,the south-west is 1072 Sq.m and the south-east is 960 Sq.m.                           |
| Roof                  | 3130 Sq.m roof assembly consists of 20cm reinforced concrete roof, interior paint and insulation material having a u-value of 0.5 W/m <sup>2</sup> K |

Table 8. Strategy Used

| CASES | AREA OF RETROFIT                                                                                            | TECHNIQUE APPLIED                                                                                                                                                                                          |
|-------|-------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A     | WWR adjustments (to accommodate the requirements of the Egyptian code for improvement of energy efficiency) | WWR <b>changed to 30%</b> for all elevations except for the north elevation which was kept as it is.                                                                                                       |
| B     | Thermal characteristics of the building envelope                                                            | improved its u-value by addition of 20cm insulation to external walls, also glazing was changed to triple glazed clear with argon fill instead of blue double glazing with air fill as well as green roof. |



## 5. CASE STUDY

### 5.1. Vastukar design studio, Bhubaneswar

#### 5.1.1. Building Location

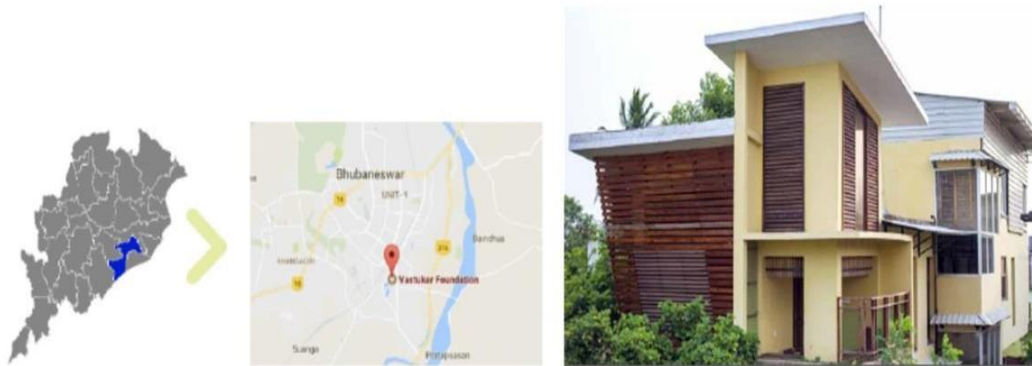


Figure 17 Building Location

#### 5.1.2. Building Basics

| Location         | Bhubaneswar, Odisha              |
|------------------|----------------------------------|
| Climate Zone     | Warm and Humid                   |
| Site Area        | 308 Sq.m.                        |
| Built-up Area    | 453 Sq.m. (48% of plot area)     |
| Coordinates      | 20.2482° N, 85.8378° E           |
| Number of Floors | 2 Floors                         |
| Building Use     | Office space                     |
| Constructed      | 2015                             |
| Certified        | 2016                             |
| Building Owner   | Ar. S.S. Ray, director, Vastukar |
| Certification    | SVA Griha rating- 5 star (47/50) |

#### 5.1.3. Building Strategy

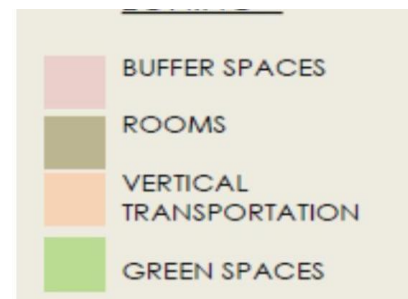
| EAST FACADE                                                                                                                                        | WEST FACADE                                                                                   | NORTH FACADE                                                                                                                                                                                         | SOUTH FACADE                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
|                                                                   |              |                                                                                                                    |            |
| <b>Table 12 Comparative Analysis</b>                                                                                                               |                                                                                               |                                                                                                                                                                                                      |                                                                                               |
| Wall area exposed to the solar radiation is 17.6m <sup>2</sup>                                                                                     | Wall area exposed to the solar radiation is 48.2m <sup>2</sup> .                              | Wall area exposed to the solar radiation is 17.6m <sup>2</sup> .                                                                                                                                     | Wall area exposed to the solar radiation is 150m <sup>2</sup> .                               |
| WWR 26% which is less than 40% allows less amount of light penetrating through fenestrations.                                                      | WWR 15% which is less than 40% allows less amount of light penetrating through fenestrations. | WWR 65% which is more than 40% allows ample amount of light penetrating through fenestrations.                                                                                                       | WWR 15% which is less than 40% allows less amount of light penetrating through fenestrations. |
| Wall thermal conductivity (K)<br>0.17 W/m k                                                                                                        | Wall thermal conductivity (K)<br>0.40 W/m k                                                   | Wall thermal conductivity (K)<br>0.48 W/m k                                                                                                                                                          | Wall thermal conductivity (K)<br>0.40 W/m k                                                   |
| Wooden cladding over the glass opening is used to penetrate the radiation in to the room.                                                          | There is no opening in the conference hall in the ground floor towards west side.             | Appropriate design of openings and shading devices help to keep out sun and wind or allow them into the building. Ventilation lets in the fresh air and exhausts hot room air, resulting in cooling. | The size of windows are less compared to other sides decrease radiation                       |
| Awning shading devices are suitable for all orientations. It is effective solar shading but reduce the daylight in summer and gain heat in winter. |                                                                                               |                                                                                                                                                                                                      |                                                                                               |



Figure 18 ground floor plan



Figure 19 First floor plan



|                                                    | FACADE                                                              |                            |                                 |                             | FENESTRATION                |                                                | ROOF           |
|----------------------------------------------------|---------------------------------------------------------------------|----------------------------|---------------------------------|-----------------------------|-----------------------------|------------------------------------------------|----------------|
|                                                    | NORTH                                                               | SOUTH                      | EAST                            | WEST                        | WINDOW GLAZING              | W.W.R.                                         | COOL ROOF      |
| CASE STUDY 1<br>GODREJ BHAVAN, MUMBAI              |                                                                     |                            |                                 |                             |                             |                                                |                |
|                                                    | ALLUMINIUM CLADING                                                  | ALLUMINIUM CLADING         | ALLUMINIUM CLADING              | ALLUMINIUM CLADING          | DOUBLE GLAZED               | 60%                                            | Terrace garden |
| CASE STUDY 2<br>VASTUKAR DESIGN STUDIO, BHUBNESWAR |                                                                     |                            |                                 |                             |                             |                                                |                |
|                                                    | iron hollow sections, creepers, plywood, buildtec sheet, stone wall | Wooden louvers, stone wall | plywood, low voc paints, glass, | vertical green wall, glass, | Single Glazed, Wooden frame | 26% EAST<br>15% WEST<br>65% NORTH<br>15% SOUTH | ALBIDO PAINT   |

#### 5.1.4. SUMMARY

It was observed that facade on the south, east and west should be shaded by any shaded device and must be insulated properly to have a lower U value. Windows must be double glazed for good thermal performance and air leakage must be checked in air conditioned spaces. Green roof is better option as it gives a satisfactory decrease in surface temperature. Insulation can be applied to the exterior as the project is not of any heritage importance, which will also leave the internal space unharmed.

### 6. SITE ANALYSIS

#### 6.1. Secha Sadan(Water Resources Department), Bhubaneswar

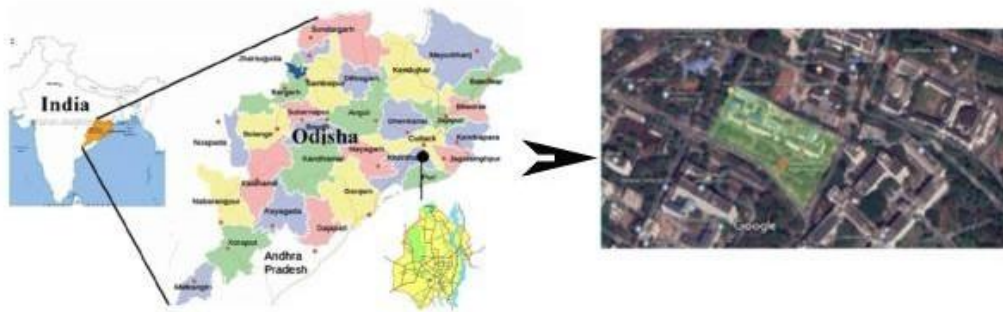


Figure 20 Location

#### 6.2. Building Basics



**SECHA SADAN  
(WATER RESOURCES DEPARTMENT)  
Bhubaneswar, Odisha  
ESTD. 1993**

**Type-** Institutional (office building)

**Total area-** 3.5 Acres (approx.)

**Built-up area-** 12000 Sq.m (approx.)

**No of floors-** 3

**No of rooms-** Around 270

Figure 21 Building View

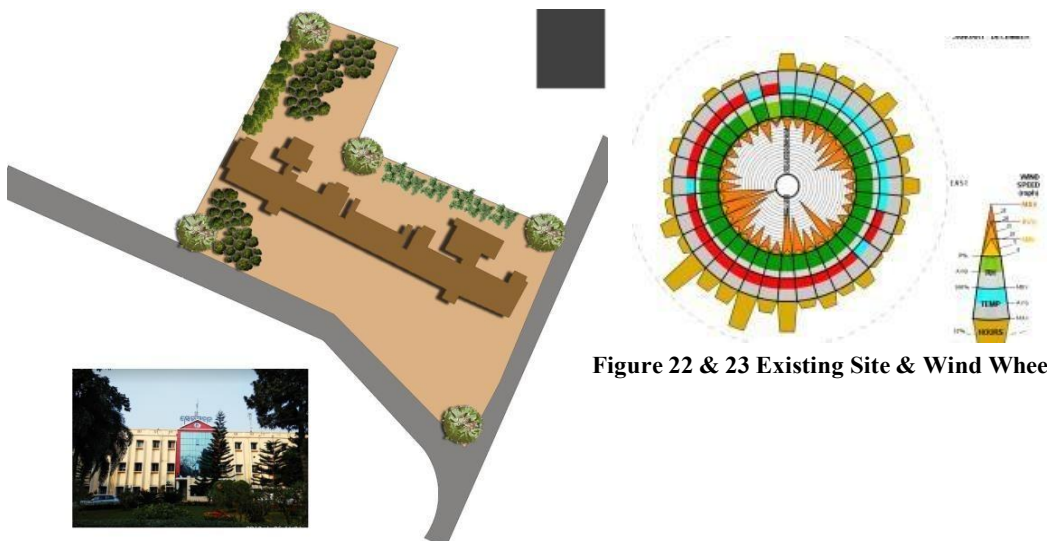


Figure 22 & 23 Existing Site & Wind Wheel



Figure 24. Site section AA



Figure 25. Site section AA

### 6.3. Site proximity

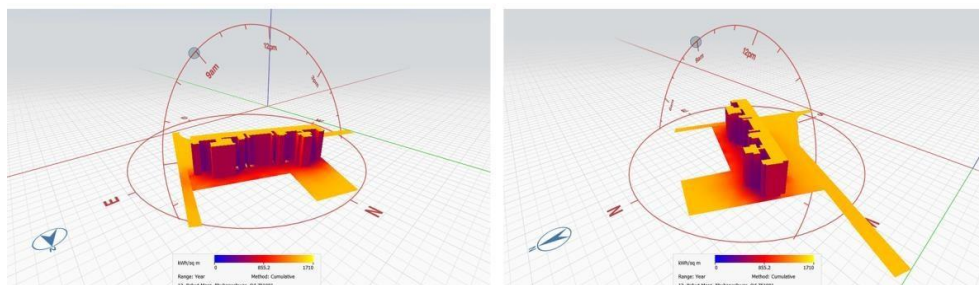


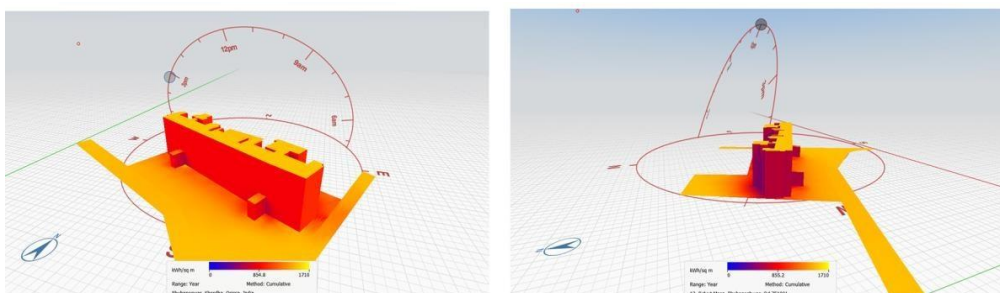
Figure 26 Proximity

### 6.4. Problems

- The South side of the office gets heated up which brings uncomfortable situations.
- The air conditioners are split and window type and they demand a lot of maintenance.
- Not much daylight enters into the building and current lights are not energy efficient.
- Uncontrolled thermal performance.
- Building is installed with older technology hence does not fit the energy saving compliance

### 6.5. Solar Insolation

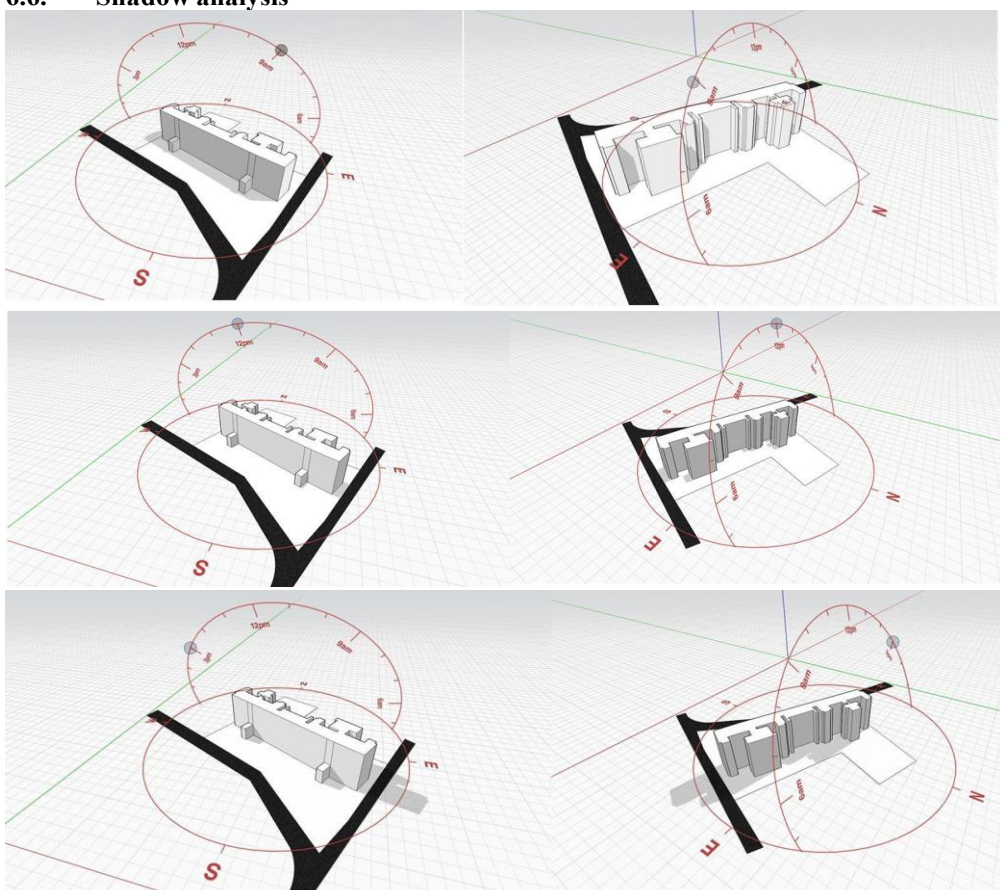




**Figure 27 Insolation simulation**

South-West Facade receives maximum insolation in year cumulative, followed by NW, SE and in the last NE. South-West Facade being the longest and front facade needs Envelope Retrofitting to increase thermal performance of the building.

## 6.6. Shadow analysis

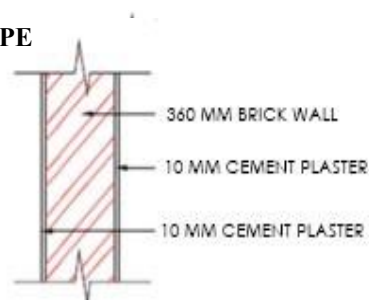


**Figure 28 Shadow Analysis**

## 7. THERMAL PERFORMANCE OF THE ENVELOPE

### 7.1. Wall

$L_1 = 0.01M$ ,  $K_1 = 0.721 W/M.K$   $L_2 = 0.36M$ ,  
 $K_2 = 0.811 W/M.K$ ,  $L_3 = 0.01M$ ,  $K_3 = 0.721 W/M.K$ ,  
 $h_i = 8.3 W/M^2.K$ ,  $h_o = 22.7 W/M^2.K$ ,  
 $RT = 1/8.3 + 0.01/0.721 + 0.36/0.811 + 0.01/0.721 +$   
 $1/22.7 = 0.636$ ,  $U = 1/RT = 1/0.636 = 1.57$



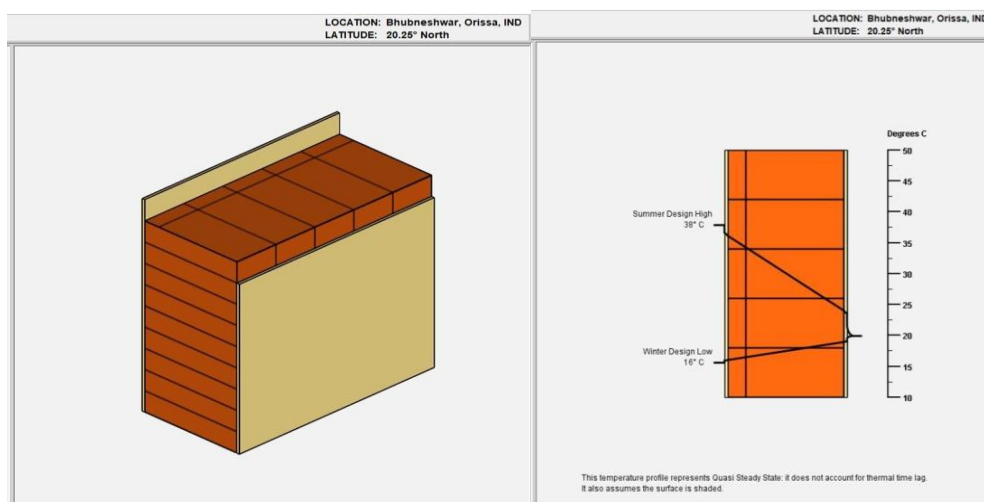


Figure 29 wall cut view and wall section

## 7.2. Roof

$L_1 = 0.01\text{M}$ ,  $K_1 = 0.721\text{ W/M.K}$   $L_2 = 0.15\text{M}$ ,  $K_2 = 1.580\text{ W/M.K}$   $L_3 = 0.01\text{M}$ ,  
 $K_3 = 0.721\text{ W/M.K}$   $h_i = 6.1\text{ W/M}^2\text{.K}$ ,  $h_o = 22.7\text{ W/M}^2\text{.K}$

$$RT = 1/6.1 + 0.01/0.721 + 0.15/1.580 + 0.01/0.721 + 1/22.7 = 0.331$$

$$U = 1/RT = 1/0.331 = 3.02$$

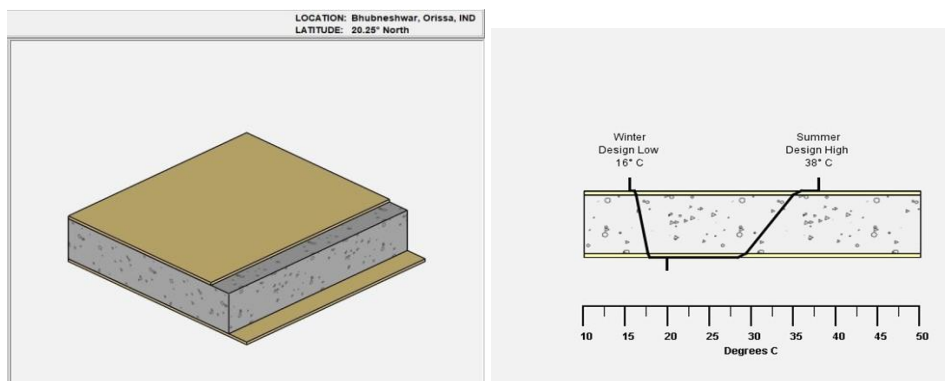


Figure 30 Roof cut view and section

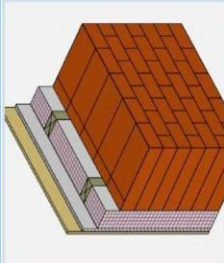
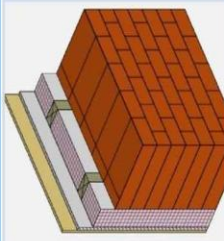
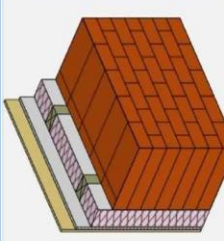
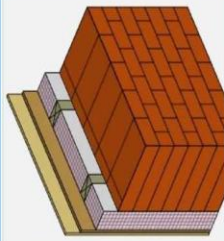
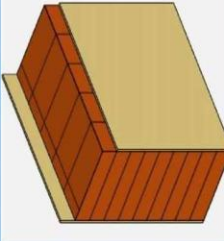
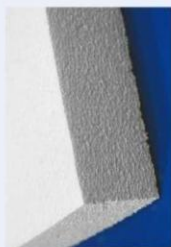
## 7.3. Fenestration

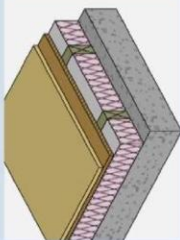
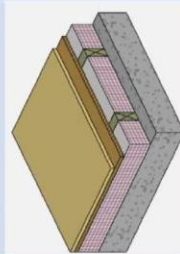
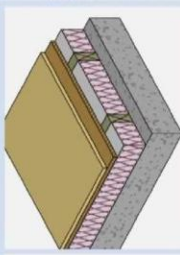
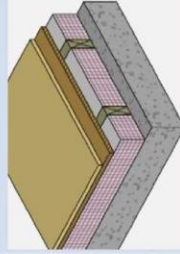
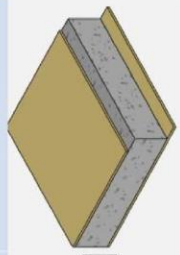
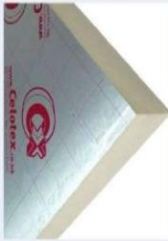
Uncoated single-glazed windows are considered to be the weakest thermal component in the building envelope, transmitting large amounts of heat into and out of a building.

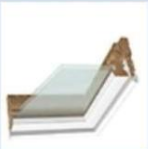
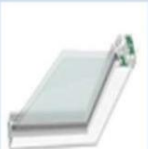


Figure 31 Window

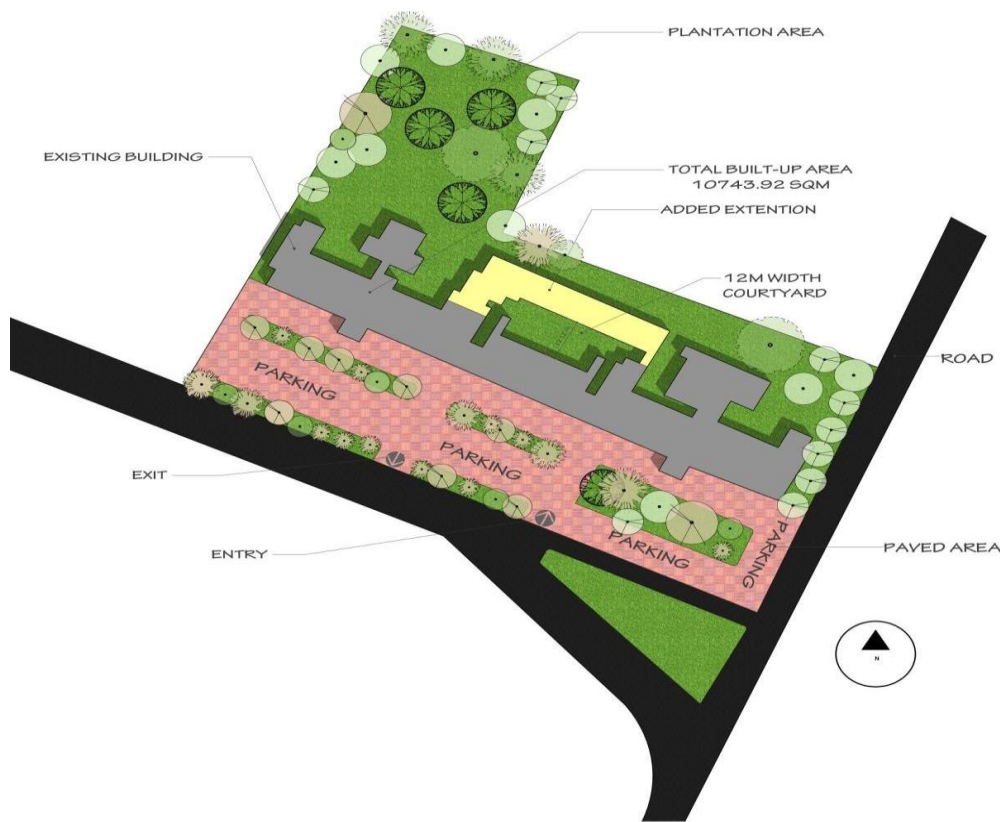
## 7.4. Comparative analysis

|                            | CASE 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | CASE 2                                                                                | CASE 3                                                                               | CASE 4                                                                              | BASE CASE                                                                         |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------|-------|-------------------|-------|-----------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|----------------------------|----------------|------|----------------|-------|-------------------|-----------------|-----------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------|---------|------------------------|------|-----------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|--------------|----------------|------|----------------|-------|-------------------|--------------|-----------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------|------------------|-------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------|-----------|------------------------|-----|------|-------|-------|-----|--------------|-------|------|-----------------|-------|------|---------|------|-----|-----------------|------|------|------------------|-----|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----|-------|-----------------|------|------|-------|-------|-----|-----------------|------|------|------------------|-----|------|--|
| 3D SECTION                 |                                                                                                                                                                                                                                                                                                                                                                                                                  |    |    |    |  |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| MATERIALS                  | <table><tr><th>Material</th><th>mm</th><th>R Value</th></tr><tr><td>Inside Air Film (wall)</td><td>0.0</td><td>0.12</td></tr><tr><td>Brick</td><td>360.0</td><td>0.4</td></tr><tr><td>Studs (wood)</td><td>101.6</td><td>0.78</td></tr><tr><td>Expanded Polystyrene (EPS)</td><td>101.6</td><td>2.54</td></tr><tr><td>Gypsum Board</td><td>15.9</td><td>0.1</td></tr><tr><td>Plaster (dense)</td><td>12.7</td><td>0.02</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material                                                                              | mm                                                                                   | R Value                                                                             | Inside Air Film (wall)                                                            | 0.0            | 0.12  | Brick             | 360.0 | 0.4       | Studs (wood) | 101.6                                                                                                                                                                                                                                                   | 0.78                  | Expanded Polystyrene (EPS) | 101.6          | 2.54 | Gypsum Board   | 15.9  | 0.1               | Plaster (dense) | 12.7      | 0.02 | Outside Air Film                                                                                                                                                                                                                                         | 0.0                   | 0.04  | <table><tr><th>Material</th><th>mm</th><th>R Value</th></tr><tr><td>Inside Air Film (wall)</td><td>0.0</td><td>0.12</td></tr><tr><td>Brick</td><td>360.0</td><td>0.4</td></tr><tr><td>Studs (wood)</td><td>101.6</td><td>0.78</td></tr><tr><td>Blown Fibre</td><td>101.6</td><td>2.54</td></tr><tr><td>Gypsum Board</td><td>16.0</td><td>0.03</td></tr><tr><td>Plaster (dense)</td><td>12.7</td><td>0.02</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material | mm             | R Value | Inside Air Film (wall) | 0.0  | 0.12      | Brick | 360.0                                                                                                                                                                                                                                                    | 0.4                   | Studs (wood) | 101.6          | 0.78 | Blown Fibre    | 101.6 | 2.54              | Gypsum Board | 16.0      | 0.03  | Plaster (dense)                                                                                                                                                                                                                                      | 12.7                  | 0.02  | Outside Air Film | 0.0   | 0.04           | <table><tr><th>Material</th><th>mm</th><th>R ...</th></tr><tr><td>Inside Air Film (wall)</td><td>0.0</td><td>0.12</td></tr><tr><td>Brick</td><td>360.0</td><td>0.4</td></tr><tr><td>Studs (wood)</td><td>101.6</td><td>0.78</td></tr><tr><td>Batt Insulation</td><td>101.6</td><td>2.03</td></tr><tr><td>Plywood</td><td>15.9</td><td>0.1</td></tr><tr><td>Plaster (dense)</td><td>12.7</td><td>0.02</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material          | mm    | R ...     | Inside Air Film (wall) | 0.0 | 0.12 | Brick | 360.0 | 0.4 | Studs (wood) | 101.6 | 0.78 | Batt Insulation | 101.6 | 2.03 | Plywood | 15.9 | 0.1 | Plaster (dense) | 12.7 | 0.02 | Outside Air Film | 0.0 | 0.04 | <table><tr><th>Material</th><th>mm</th><th>R ...</th></tr><tr><td>Plaster (dense)</td><td>10.0</td><td>0.02</td></tr><tr><td>Brick</td><td>360.0</td><td>0.4</td></tr><tr><td>Plaster (dense)</td><td>10.0</td><td>0.02</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material | mm | R ... | Plaster (dense) | 10.0 | 0.02 | Brick | 360.0 | 0.4 | Plaster (dense) | 10.0 | 0.02 | Outside Air Film | 0.0 | 0.04 |  |
| Material                   | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | R Value                                                                               |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Inside Air Film (wall)     | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0.12                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Brick                      | 360.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.4                                                                                   |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Studs (wood)               | 101.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.78                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Expanded Polystyrene (EPS) | 101.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2.54                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Gypsum Board               | 15.9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0.1                                                                                   |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Plaster (dense)            | 12.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0.02                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Outside Air Film           | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0.04                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Material                   | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | R Value                                                                               |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Inside Air Film (wall)     | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0.12                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Brick                      | 360.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.4                                                                                   |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Studs (wood)               | 101.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.78                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Blown Fibre                | 101.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2.54                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Gypsum Board               | 16.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0.03                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Plaster (dense)            | 12.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0.02                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Outside Air Film           | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0.04                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Material                   | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | R ...                                                                                 |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Inside Air Film (wall)     | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0.12                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Brick                      | 360.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.4                                                                                   |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Studs (wood)               | 101.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.78                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Batt Insulation            | 101.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2.03                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Plywood                    | 15.9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0.1                                                                                   |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Plaster (dense)            | 12.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0.02                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Outside Air Film           | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0.04                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Material                   | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | R ...                                                                                 |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Plaster (dense)            | 10.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0.02                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Brick                      | 360.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.4                                                                                   |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Plaster (dense)            | 10.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0.02                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Outside Air Film           | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0.04                                                                                  |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| SIMULATION RESULTS         | <table><tr><td>Total Thickness (mm):</td><td>490.2</td></tr><tr><td>Total R Value:</td><td>2.48</td></tr><tr><td>Total U Value:</td><td>0.403</td></tr><tr><td>Decrement Factor:</td><td>0.06</td></tr><tr><td>Time Lag:</td><td>10.0</td></tr></table>                                                                                                                                                                                                                                             | Total Thickness (mm):                                                                 | 490.2                                                                                | Total R Value:                                                                      | 2.48                                                                              | Total U Value: | 0.403 | Decrement Factor: | 0.06  | Time Lag: | 10.0         | <table><tr><td>Total Thickness (mm):</td><td>490.3</td></tr><tr><td>Total R Value:</td><td>2.95</td></tr><tr><td>Total U Value:</td><td>0.339</td></tr><tr><td>Decrement Factor:</td><td>0.06</td></tr><tr><td>Time Lag:</td><td>9.58</td></tr></table> | Total Thickness (mm): | 490.3                      | Total R Value: | 2.95 | Total U Value: | 0.339 | Decrement Factor: | 0.06            | Time Lag: | 9.58 | <table><tr><td>Total Thickness (mm):</td><td>490.2</td></tr><tr><td>Total R Value:</td><td>2.48</td></tr><tr><td>Total U Value:</td><td>0.403</td></tr><tr><td>Decrement Factor:</td><td>0.06</td></tr><tr><td>Time Lag:</td><td>10.09</td></tr></table> | Total Thickness (mm): | 490.2 | Total R Value:                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2.48     | Total U Value: | 0.403   | Decrement Factor:      | 0.06 | Time Lag: | 10.09 | <table><tr><td>Total Thickness (mm):</td><td>490.2</td></tr><tr><td>Total R Value:</td><td>2.28</td></tr><tr><td>Total U Value:</td><td>0.439</td></tr><tr><td>Decrement Factor:</td><td>0.06</td></tr><tr><td>Time Lag:</td><td>10.14</td></tr></table> | Total Thickness (mm): | 490.2        | Total R Value: | 2.28 | Total U Value: | 0.439 | Decrement Factor: | 0.06         | Time Lag: | 10.14 | <table><tr><td>Total Thickness (mm):</td><td>380.0</td></tr><tr><td>Total R Value:</td><td>2.085</td></tr><tr><td>Total U Value:</td><td>0.34</td></tr><tr><td>Decrement Factor:</td><td>-9.47</td></tr><tr><td>Time Lag:</td><td></td></tr></table> | Total Thickness (mm): | 380.0 | Total R Value:   | 2.085 | Total U Value: | 0.34                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Decrement Factor: | -9.47 | Time Lag: |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total Thickness (mm):      | 490.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total R Value:             | 2.48                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total U Value:             | 0.403                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Decrement Factor:          | 0.06                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Time Lag:                  | 10.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total Thickness (mm):      | 490.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total R Value:             | 2.95                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total U Value:             | 0.339                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Decrement Factor:          | 0.06                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Time Lag:                  | 9.58                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total Thickness (mm):      | 490.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total R Value:             | 2.48                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total U Value:             | 0.403                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Decrement Factor:          | 0.06                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Time Lag:                  | 10.09                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total Thickness (mm):      | 490.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total R Value:             | 2.28                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total U Value:             | 0.439                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Decrement Factor:          | 0.06                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Time Lag:                  | 10.14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total Thickness (mm):      | 380.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total R Value:             | 2.085                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Total U Value:             | 0.34                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Decrement Factor:          | -9.47                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| Time Lag:                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                       |                                                                                      |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| ECBC REQUIREMENT           | Maximum assembly U value = 0.40                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Maximum assembly U value = 0.40                                                       | Maximum assembly U value = 0.40                                                      | Maximum assembly U value = 0.40                                                     | Maximum assembly U value = 0.40                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| COMPLIANCE                 | NO                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | YES                                                                                   | YES                                                                                  | NO                                                                                  | NO                                                                                |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |
| INSULATION                 |                                                                                                                                                                                                                                                                                                                                                                                                                |  |  |  | NO                                                                                |                |       |                   |       |           |              |                                                                                                                                                                                                                                                         |                       |                            |                |      |                |       |                   |                 |           |      |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                |         |                        |      |           |       |                                                                                                                                                                                                                                                          |                       |              |                |      |                |       |                   |              |           |       |                                                                                                                                                                                                                                                      |                       |       |                  |       |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |       |           |                        |     |      |       |       |     |              |       |      |                 |       |      |         |      |     |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                      |          |    |       |                 |      |      |       |       |     |                 |      |      |                  |     |      |  |

|                           | CASE 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | CASE 2                                                                               | CASE 3                                                                              | CASE 4                                                                              | BASE CASE                                                                         |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------|-------|-------------------|-------|-----------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|------------------|----------------|------|----------------------|-------|-------------------|-----------------|-----------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------|-------|---------------------------|------|-----------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|--------------|----------------|------|------------------|-------|-------------------|----------------------|-----------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------|------------------|------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------|-----------|---------------------------|-----|------|----------|-------|------|--------------|-------|------|-------------|-------|------|----------------------|------|------|-----------------|------|------|------------------|-----|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----|-------|---------------------------|-----|------|----------|-------|------|--------------|-------|------|----------------|-------|-----|----------------------|------|------|-----------------|------|------|------------------|-----|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----|-------|---------------------------|-----|------|-----------------|-------|------|----------|-------|------|-----------------|------|------|----------|-------|------|-----------------|------|------|------------------|-----|------|
| 3D SECTION                |                                                                                                                                                                                                                                                                                                                                                                                                                      |    |    |    |  |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |          |                |       |                           |      |           |          |                                                                                                                                                                                                                                                          |                       |              |                |      |                  |       |                   |                      |           |       |                                                                                                                                                                                                                                                          |                       |       |                  |      |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |      |           |                           |     |      |          |       |      |              |       |      |             |       |      |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |          |    |       |                           |     |      |          |       |      |              |       |      |                |       |     |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |    |       |                           |     |      |                 |       |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| MATERIALS                 | <table><tr><th>Material</th><th>mm</th><th>R ...</th></tr><tr><td>Inside Air Film (ceiling)</td><td>0.0</td><td>0.16</td></tr><tr><td>Concrete</td><td>150.0</td><td>0.11</td></tr><tr><td>Studs (wood)</td><td>110.0</td><td>0.85</td></tr><tr><td>Insulation Board</td><td>110.0</td><td>3.67</td></tr><tr><td>Fiberboard Sheathing</td><td>20.0</td><td>0.29</td></tr><tr><td>Plaster (dense)</td><td>20.0</td><td>0.04</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material                                                                             | mm                                                                                  | R ...                                                                               | Inside Air Film (ceiling)                                                         | 0.0            | 0.16  | Concrete          | 150.0 | 0.11      | Studs (wood) | 110.0                                                                                                                                                                                                                                                    | 0.85                  | Insulation Board | 110.0          | 3.67 | Fiberboard Sheathing | 20.0  | 0.29              | Plaster (dense) | 20.0      | 0.04  | Outside Air Film                                                                                                                                                                                                                                         | 0.0                   | 0.04  | <table><tr><th>Material</th><th>mm</th><th>R ...</th></tr><tr><td>Inside Air Film (ceiling)</td><td>0.0</td><td>0.16</td></tr><tr><td>Concrete</td><td>150.0</td><td>0.11</td></tr><tr><td>Studs (wood)</td><td>110.0</td><td>0.85</td></tr><tr><td>Polystyrene Foam</td><td>110.0</td><td>2.75</td></tr><tr><td>Fiberboard Sheathing</td><td>20.0</td><td>0.29</td></tr><tr><td>Plaster (dense)</td><td>20.0</td><td>0.04</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material | mm             | R ... | Inside Air Film (ceiling) | 0.0  | 0.16      | Concrete | 150.0                                                                                                                                                                                                                                                    | 0.11                  | Studs (wood) | 110.0          | 0.85 | Polystyrene Foam | 110.0 | 2.75              | Fiberboard Sheathing | 20.0      | 0.29  | Plaster (dense)                                                                                                                                                                                                                                          | 20.0                  | 0.04  | Outside Air Film | 0.0  | 0.04           | <table><tr><th>Material</th><th>mm</th><th>R ...</th></tr><tr><td>Inside Air Film (ceiling)</td><td>0.0</td><td>0.16</td></tr><tr><td>Concrete</td><td>150.0</td><td>0.11</td></tr><tr><td>Studs (wood)</td><td>110.0</td><td>0.85</td></tr><tr><td>Blown Fibre</td><td>110.0</td><td>2.75</td></tr><tr><td>Fiberboard Sheathing</td><td>20.0</td><td>0.29</td></tr><tr><td>Plaster (dense)</td><td>20.0</td><td>0.04</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material          | mm   | R ...     | Inside Air Film (ceiling) | 0.0 | 0.16 | Concrete | 150.0 | 0.11 | Studs (wood) | 110.0 | 0.85 | Blown Fibre | 110.0 | 2.75 | Fiberboard Sheathing | 20.0 | 0.29 | Plaster (dense) | 20.0 | 0.04 | Outside Air Film | 0.0 | 0.04 | <table><tr><th>Material</th><th>mm</th><th>R ...</th></tr><tr><td>Inside Air Film (ceiling)</td><td>0.0</td><td>0.16</td></tr><tr><td>Concrete</td><td>150.0</td><td>0.11</td></tr><tr><td>Studs (wood)</td><td>110.0</td><td>0.85</td></tr><tr><td>Bed insulation</td><td>110.0</td><td>2.2</td></tr><tr><td>Fiberboard Sheathing</td><td>20.0</td><td>0.29</td></tr><tr><td>Plaster (dense)</td><td>20.0</td><td>0.04</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material | mm | R ... | Inside Air Film (ceiling) | 0.0 | 0.16 | Concrete | 150.0 | 0.11 | Studs (wood) | 110.0 | 0.85 | Bed insulation | 110.0 | 2.2 | Fiberboard Sheathing | 20.0 | 0.29 | Plaster (dense) | 20.0 | 0.04 | Outside Air Film | 0.0 | 0.04 | <table><tr><th>Material</th><th>mm</th><th>R ...</th></tr><tr><td>Inside Air Film (ceiling)</td><td>0.0</td><td>0.16</td></tr><tr><td>Plaster (dense)</td><td>150.0</td><td>0.11</td></tr><tr><td>Concrete</td><td>150.0</td><td>0.11</td></tr><tr><td>Plaster (dense)</td><td>10.0</td><td>0.02</td></tr><tr><td>Concrete</td><td>150.0</td><td>0.11</td></tr><tr><td>Plaster (dense)</td><td>10.0</td><td>0.02</td></tr><tr><td>Outside Air Film</td><td>0.0</td><td>0.04</td></tr></table> | Material | mm | R ... | Inside Air Film (ceiling) | 0.0 | 0.16 | Plaster (dense) | 150.0 | 0.11 | Concrete | 150.0 | 0.11 | Plaster (dense) | 10.0 | 0.02 | Concrete | 150.0 | 0.11 | Plaster (dense) | 10.0 | 0.02 | Outside Air Film | 0.0 | 0.04 |
| Material                  | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | R ...                                                                                |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Inside Air Film (ceiling) | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.16                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Concrete                  | 150.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.11                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Studs (wood)              | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.85                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Insulation Board          | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3.67                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Fiberboard Sheathing      | 20.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.29                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Plaster (dense)           | 20.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Outside Air Film          | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Material                  | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | R ...                                                                                |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Inside Air Film (ceiling) | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.16                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Concrete                  | 150.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.11                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Studs (wood)              | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.85                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Polystyrene Foam          | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2.75                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Fiberboard Sheathing      | 20.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.29                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Plaster (dense)           | 20.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Outside Air Film          | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Material                  | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | R ...                                                                                |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Inside Air Film (ceiling) | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.16                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Concrete                  | 150.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.11                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Studs (wood)              | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.85                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Blown Fibre               | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2.75                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Fiberboard Sheathing      | 20.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.29                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Plaster (dense)           | 20.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Outside Air Film          | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Material                  | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | R ...                                                                                |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Inside Air Film (ceiling) | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.16                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Concrete                  | 150.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.11                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Studs (wood)              | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.85                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Bed insulation            | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2.2                                                                                  |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Fiberboard Sheathing      | 20.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.29                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Plaster (dense)           | 20.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Outside Air Film          | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Material                  | mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | R ...                                                                                |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Inside Air Film (ceiling) | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.16                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Plaster (dense)           | 150.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.11                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Concrete                  | 150.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.11                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Plaster (dense)           | 10.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.02                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Concrete                  | 150.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0.11                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Plaster (dense)           | 10.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.02                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Outside Air Film          | 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.04                                                                                 |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| SIMULATION RESULTS        | <table><tr><td>Total Thickness (mm):</td><td>300.0</td></tr><tr><td>Total R Value:</td><td>3.6</td></tr><tr><td>Total U Value:</td><td>0.277</td></tr><tr><td>Decrement Factor:</td><td>0.21</td></tr><tr><td>Time Lag:</td><td>-8.67</td></tr></table>                                                                                                                                                                                                                                                 | Total Thickness (mm):                                                                | 300.0                                                                               | Total R Value:                                                                      | 3.6                                                                               | Total U Value: | 0.277 | Decrement Factor: | 0.21  | Time Lag: | -8.67        | <table><tr><td>Total Thickness (mm):</td><td>300.0</td></tr><tr><td>Total R Value:</td><td>4.05</td></tr><tr><td>Total U Value:</td><td>0.247</td></tr><tr><td>Decrement Factor:</td><td>0.21</td></tr><tr><td>Time Lag:</td><td>-8.62</td></tr></table> | Total Thickness (mm): | 300.0            | Total R Value: | 4.05 | Total U Value:       | 0.247 | Decrement Factor: | 0.21            | Time Lag: | -8.62 | <table><tr><td>Total Thickness (mm):</td><td>300.0</td></tr><tr><td>Total R Value:</td><td>2.99</td></tr><tr><td>Total U Value:</td><td>0.334</td></tr><tr><td>Decrement Factor:</td><td>0.22</td></tr><tr><td>Time Lag:</td><td>-7.84</td></tr></table> | Total Thickness (mm): | 300.0 | Total R Value:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2.99     | Total U Value: | 0.334 | Decrement Factor:         | 0.22 | Time Lag: | -7.84    | <table><tr><td>Total Thickness (mm):</td><td>300.0</td></tr><tr><td>Total R Value:</td><td>2.59</td></tr><tr><td>Total U Value:</td><td>0.386</td></tr><tr><td>Decrement Factor:</td><td>0.22</td></tr><tr><td>Time Lag:</td><td>-7.66</td></tr></table> | Total Thickness (mm): | 300.0        | Total R Value: | 2.59 | Total U Value:   | 0.386 | Decrement Factor: | 0.22                 | Time Lag: | -7.66 | <table><tr><td>Total Thickness (mm):</td><td>170.0</td></tr><tr><td>Total R Value:</td><td>0.34</td></tr><tr><td>Total U Value:</td><td>2.922</td></tr><tr><td>Decrement Factor:</td><td>0.58</td></tr><tr><td>Time Lag:</td><td>-4.99</td></tr></table> | Total Thickness (mm): | 170.0 | Total R Value:   | 0.34 | Total U Value: | 2.922                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Decrement Factor: | 0.58 | Time Lag: | -4.99                     |     |      |          |       |      |              |       |      |             |       |      |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |          |    |       |                           |     |      |          |       |      |              |       |      |                |       |     |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |    |       |                           |     |      |                 |       |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total Thickness (mm):     | 300.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                           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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total R Value:            | 3.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total U Value:            | 0.277                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Decrement Factor:         | 0.21                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Time Lag:                 | -8.67                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total Thickness (mm):     | 300.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total R Value:            | 4.05                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total U Value:            | 0.247                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Decrement Factor:         | 0.21                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Time Lag:                 | -8.62                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total Thickness (mm):     | 300.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total R Value:            | 2.99                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total U Value:            | 0.334                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Decrement Factor:         | 0.22                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Time Lag:                 | -7.84                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total Thickness (mm):     | 300.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total R Value:            | 2.59                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total U Value:            | 0.386                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Decrement Factor:         | 0.22                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Time Lag:                 | -7.66                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total Thickness (mm):     | 170.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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                                                                                                                                                                                                                                                                                                                                                                                                                                           |                   |      |           |                           |     |      |          |       |      |              |       |      |             |       |      |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |          |    |       |                           |     |      |          |       |      |              |       |      |                |       |     |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |    |       |                           |     |      |                 |       |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total R Value:            | 0.34                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Total U Value:            | 2.922                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |          |                |       |                           |      |           |          |                                                                                                                                                                                                                                                          |                       |              |                |      |                  |       |                   |                      |           |       |                                                                                                                                                                                                                                                          |                       |       |                  |      |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |      |           |                           |     |      |          |       |      |              |       |      |             |       |      |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |          |    |       |                           |     |      |          |       |      |              |       |      |                |       |     |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |    |       |                           |     |      |                 |       |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Decrement Factor:         | 0.58                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |          |                |       |                           |      |           |          |                                                                                                                                                                                                                                                          |                       |              |                |      |                  |       |                   |                      |           |       |                                                                                                                                                                                                                                                          |                       |       |                  |      |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |      |           |                           |     |      |          |       |      |              |       |      |             |       |      |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |          |    |       |                           |     |      |          |       |      |              |       |      |                |       |     |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |    |       |                           |     |      |                 |       |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| Time Lag:                 | -4.99                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                      |                                                                                     |                                                                                     |                                                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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                                                                                                                                                                                   |          |    |       |                           |     |      |          |       |      |              |       |      |                |       |     |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |    |       |                           |     |      |                 |       |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| ECBC REQUIREMENT          | Maximum assembly U value = 0.33                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Maximum assembly U value = 0.33                                                      | Maximum assembly U value = 0.33                                                     | Maximum assembly U value = 0.33                                                     | Maximum assembly U value = 0.33                                                   |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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  |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| COMPLIANCE                | YES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | YES                                                                                  | YES                                                                                 | NO                                                                                  | NO                                                                                |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                  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                                                                                                                                                                                   |          |    |       |                           |     |      |          |       |      |              |       |      |                |       |     |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |    |       |                           |     |      |                 |       |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |
| INSULATION                |                                                                                                                                                                                                                                                                                                                                                                                                                    |  |  |  | NO                                                                                |                |       |                   |       |           |              |                                                                                                                                                                                                                                                          |                       |                  |                |      |                      |       |                   |                 |           |       |                                                                                                                                                                                                                                                          |                       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |          |                |       |                           |      |           |          |                                                                                                                                                                                                                                                          |                       |              |                |      |                  |       |                   |                      |           |       |                                                                                                                                                                                                                                                          |                       |       |                  |      |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |      |           |                           |     |      |          |       |      |              |       |      |             |       |      |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |          |    |       |                           |     |      |          |       |      |              |       |      |                |       |     |                      |      |      |                 |      |      |                  |     |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |    |       |                           |     |      |                 |       |      |          |       |      |                 |      |      |          |       |      |                 |      |      |                  |     |      |

|                            | CASE 1                                                                              | CASE 2                                                                             | CASE 3                                                                            | CASE 4                                                                            | BASE CASE                                                                         |
|----------------------------|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| 3D SECTION                 |  |  |  |  |  |
| NAME                       | Double-Glazed, Clear Glass                                                          | Double-Glazed, Low-solar-gain Low-E Glass                                          | Triple-Glazed, High-solar-gain Low-E Glass                                        | Triple-Glazed, Low-solar-gain Low-E Glass                                         | Single-Glazed, Clear Glass                                                        |
| PROPERTY (METAL FRAME)     | U VALUE- 0.71-0.99<br>SHGC- 0.41-0.55<br>VLT- >0.60                                 | U VALUE- 0.56-0.70<br>SHGC- 0.25<br>VLT- 0.51                                      | U VALUE- 0.21<br>SHGC- 0.41<br>VLT- 0.41                                          | U VALUE- ≤0.22<br>SHGC- ≤0.25<br>VLT- ≤0.40                                       | U VALUE- 1.04<br>SHGC- 0.86<br>VLT- 0.90                                          |
| PROPERTY (NON METAL FRAME) | U VALUE- 0.41-0.55<br>SHGC- 0.41-0.60<br>VLT- >0.60                                 | U VALUE- 0.23-0.30<br>SHGC- 0.25<br>VLT- 0.51                                      | U VALUE- 0.19<br>SHGC- 0.41<br>VLT- 0.41                                          | U VALUE- ≤0.21<br>SHGC- ≤0.25<br>VLT- ≤0.40                                       | NA                                                                                |
| U VALUE (ECBC)             | Maximum U value<br>3.00                                                             | Maximum U value<br>3.00                                                            | Maximum U value<br>3.00                                                           | Maximum U value<br>3.00                                                           | Maximum U value<br>3.00                                                           |
| VLT(ECBC)                  | Minimum VLT= 0.27                                                                   | Minimum VLT= 0.27                                                                  | Minimum VLT= 0.27                                                                 | Minimum VLT= 0.27                                                                 | Minimum VLT= 0.27                                                                 |
| SHGC(ECBC) Effective       | Maximum SHGC<br>Non north=0.27<br>North=0.50                                        | Maximum SHGC<br>Non north=0.27<br>North=0.50                                       | Maximum SHGC<br>Non north=0.27<br>North=0.50                                      | Maximum SHGC<br>Non north=0.27<br>North=0.50                                      | Maximum SHGC<br>Non north=0.27<br>North=0.50                                      |
| COMPLIANCE                 | YES<br>NORTH                                                                        | YES<br>NON NORTH                                                                   | YES<br>NORTH                                                                      | YES<br>NON NORTH                                                                  | NO                                                                                |

## 8. STRATEGY ANALYSIS

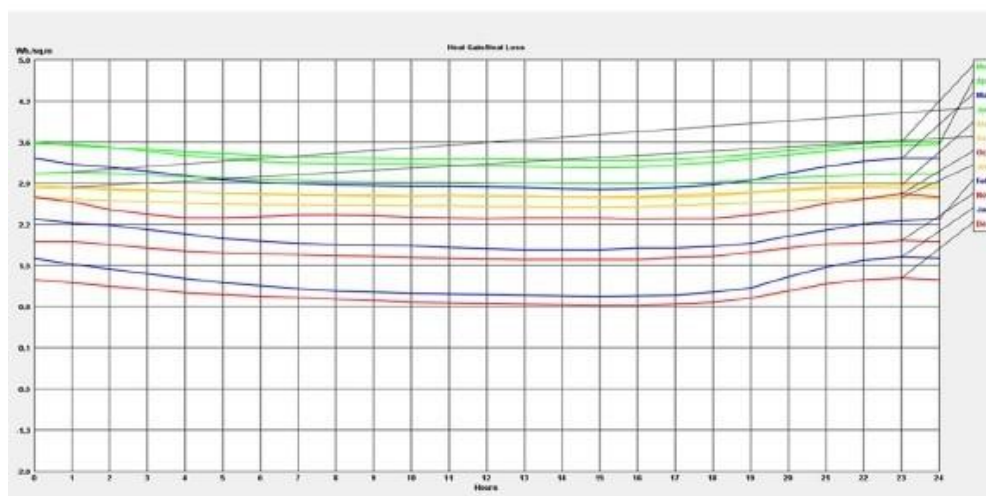


**Figure 32. Site plan**

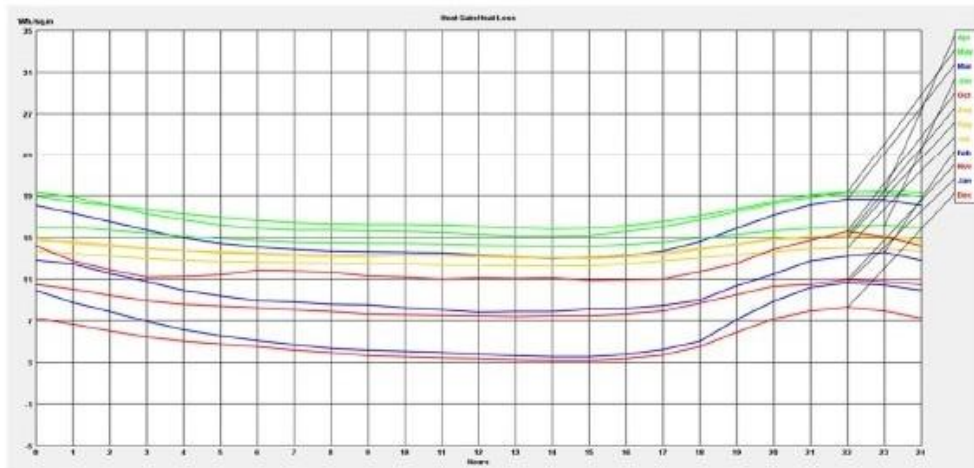
## 9 RESULT

## 9.1 Heat Gain Simulations

## HEAT GAIN SIMULATION RESULT OF YEAR



**BEFORE RETROFITTING : 7 to 19.2 Wh/sq.m**



## AFTER RETROFITTING : 1 to 3.6 Wh/sq.m




**EnEff:ResBuild India**  
 Toolkit for energy efficient residential buildings in India



**Project:** Retrofitting for Energy Efficiency

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**Building:**

**Address of project:**  
Keshari Nagar, Bhubaneswar

**Occupant/Owner:**  
Government of Odisha

**Building parameters:**  
 Building type: Residential building  
 Total building area: 10,213.92 m<sup>2</sup>  
 Climatic zone: Bhubaneswar (Warm & Humid)  
 Created with: EnEffResBuild:India Version 1.0.1.0

**Table of results - Electrical energy in kWh/m<sup>2</sup>yr\*:**

|                   | This building | Reference building |
|-------------------|---------------|--------------------|
| Internal lighting | 12.58         | 12.58              |
| Common lighting   | 1.64          | 1.64               |
| Parking lighting  | 0.00          | 0.00               |
| Cooling           | 8.20          | 22.03              |
| Heating           | 0.00          | 0.00               |
| Hot water         | 11.29         | 11.29              |
| Ceiling fans      | 0.72          | 0.72               |
| Appliances        | 0.28          | 0.28               |

---

**Consumption of electrical energy in kWh/m<sup>2</sup>yr\*:**

\*The consumption is related to the building area:

This building: 20 kWh/m<sup>2</sup>yr



Reference: 34 kWh/m<sup>2</sup>yr

**Savings: 40%**

Energy shares considered for the loan application certificate:

|                                            |                                             |                                               |                                                  |
|--------------------------------------------|---------------------------------------------|-----------------------------------------------|--------------------------------------------------|
| <input type="checkbox"/> Internal lighting | <input type="checkbox"/> Parking lighting   | <input type="checkbox"/> Heating              | <input checked="" type="checkbox"/> Ceiling fans |
| <input type="checkbox"/> Common lighting   | <input checked="" type="checkbox"/> Cooling | <input checked="" type="checkbox"/> Hot water | <input checked="" type="checkbox"/> Appliances   |

---

**Qualitative parameters (0 out of 6 measures are applied in this building):**

|                                                                     |                                                                                |
|---------------------------------------------------------------------|--------------------------------------------------------------------------------|
| <input type="checkbox"/> Daylit area in the core area is 20% to 40% | <input type="checkbox"/> Presence detection or photo sensors for outdoor and s |
| <input type="checkbox"/> Solar street lights                        | <input type="checkbox"/> Efficient water pumps                                 |
| <input type="checkbox"/> Efficient transformers                     | <input type="checkbox"/> Tailored user manual                                  |

---

**Issuer:**

**5/7/2020**  
Date

**Signature**

## Acknowledgments

This paper and the research behind it would not have been possible without the exceptional support of my supervisor, Ar. Archana S. Her enthusiasm, knowledge and exacting attention to detail have been an inspiration and kept my work on track from my first encounter with the topic to the final draft of this paper. My colleagues in my university have also looked over my transcriptions and answered with unfailing patience numerous questions about the language. The generosity and expertise of one and all have improved this study in innumerable ways and saved me from many errors; those that inevitably remain are entirely my own responsibility.

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