EXPERIMENTAL INVESTIGATION ON CONCRETE BY USING PARTIAL AND FULL REPLACEMENT OF WASTE BROKEN GLASS AS COURSE AGGREGATE

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ABSTRACT

Waste glass powder (WGP) used in concrete making leads to greener and ecofriendly environment. In shops and bus body coaches nearby Karur, many waste glass cuttings go to wastes which are not recycled at present and usually delivered to landfills for disposal. Using WGP in concrete is an interesting possibility for economy on waste disposal sites and conservation of natural resources. This project examines the possibility of using WGP as a replacement in fine aggregate for a new concrete. Natural sand was partially replaced (10%, 30%, 50% and 100%) with WGP. Compressive strength, Tensile strength (cubes and cylinders) Flexural strength and pull out strength up to 28 days of age were compared with those of concrete made with natural fine aggregates. Fineness modulus, specific gravity, moisture content, water absorption, bulk density, percentage of voids and percentage of porosity(loose and compact) state for sand (S) studied. The test results indicates that it is possible to manufacture concrete containing waste glass powder (WGP) with characteristics similar to those of natural sand aggregate concrete provided that the percentage of WGP as fine aggregate is limited to 10-20% respectively.

1. INTRODUCTION

Concrete is the most widely used construction material. Concrete is a composite construction material composed of cement, water and aggregates (Coarse aggregates and Fine aggregates). It is difficult to point out another material of construction which is as versatile as concrete.

Cement concrete is the material of choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required.

It is associated with every human activity that it touches every human being in his day to day living. Cement concrete is one of the seemingly simple but actually complex materials. Many of its complex behaviors are yet to be identified to employ this material more advantageously and economically.

Cement concrete is a site – made material unlike other materials which is used in construction and as such can vary to a great extent in its quality, properties and performance owing to the use of natural materials except cement.

From materials of varying properties to make concrete of stipulated qualities an intimate knowledge of the interactions of various ingredients that goes in making of cement concrete is required to be known. In any country, construction accounts for about sixty percent of the plan outlay. Out of this, cement and concrete production would account for more than fifty percent. Today in India the annual consumption of concrete is in the order of 178 million tons. Hence in this context the knowledge of concrete and innovations in cement concrete production assumes importance.

In Tamil Nadu Karur is one of the best and largest bus body coaches in India. Here more than 50 body coaches are there. So this body coaches are daily dumping more than 100 – 200 m^3 glass waste in the road side trenches. So, this glass waste cannot be replaced in any work. So, I decided to replace glass waste as fine aggregate in concrete.

The whole demand of sand is depending on river sand extracted for construction such as manufacture of cement concrete. The uncontrolled extraction of sand, river beds become lower than the mean sea level for miles and make river banks become unstable. In addition from the abundant of glass waste powder, it can make the aesthetic values for environmental view. Therefore, the glass waste powder can be utilized in construction. The use of glass waste powder as an abundant material by replacing river sand might bring some changes in physical properties and also particularly in the mechanical properties of the concrete.

The reuse of the waste glass is one of the important issues in many countries due to the Increment in solid waste in the environment. The waste glass is considered as an important solid waste that can be found in the majority of world's countries and is being not much affected by weather conditions and its existence leading to environmental problem Caijun et al (2007). Thus the suitable solutions must be found to overcome this problem. Accordingly, valuable researches have been conducted to show the possibility of using the waste glass as a building material and adding it as a partial replacement to the concrete mixture without affecting the concrete quality.

Therefore the concrete can be produced within acceptable properties. Many studies aim to replace fine aggregate by certain percentage of crushed waste glass as a fine aggregate to be added to the concrete mixture. In addition, these studies focus on the possibility of using the waste glass as partial or wholly alternative for the conventional concrete materials, that give double outcomes, the first is reducing the depletion of the wealth of nature resources. Secondly, reducing the environmental risks by producing non-conventional concrete that is called the glascrete.

2. LITERATURE REVIEW

Glass is one of the oldest man-made materials. It is produced in many forms such as packaging or container glass, flat glass, and bulb glass, all of which have a limited life in their manufactured forms and therefore need to be recycled so as to be reusable in order to avoid environmental problems that would be created if they were to be stockpiled or sent to landfills. The construction industry has shown great gains in the recycling of industrial by-products and waste including waste glass materials.

Quantities of waste glass have been rising rapidly during the recent decades due to the high increase in industrialization and the considerable improvement in the standards of living but unfortunately the majority of these waste quantities are not being recycled but rather abandoned causing certain serious problems such as the waste of natural resources and environmental pollution.

The utilization of waste glass as a high value material has received a considerable attention recently. Waste glass became a major problem for municipalities nationwide due to the austere changes in the environmental legislations. A matter that is positively encouraging the use of waste glass in different construction applications.

This chapter presents a review for some of the available literature related to the usage of waste glass in construction and non-construction applications, but it is specifically focused on the utilization of waste glass as both fine aggregates and cementitious Material in the concrete system. A considerable attention is directed towards the possible alkali-silica reaction and the common ways to mitigate its adverse effects.

Recycling of this waste by converting it to aggregate components could save landfill space and also reduces the demand for extraction of natural raw material for construction activities. Here a quick review for some of the previous research studies concerned with the waste glass as an aggregate material but from different points of view and perspectives.

Meyer et al. [2001] discussed the various steps that need to be taken by recyclers to collect the glass, separate it from the other materials, clean it and crush it to obtain the appropriate grading to meet the specifications for specific applications as aggregate in concrete, either in commodity products, with the only objective being to utilize as much glass as possible or in value-added products that makes full use of the physical and esthetic properties of color-sorted crushed glass.

The potential applications are basically limitless and it is expected that the commercial production of specialty glass concrete products will have a major impact on the economics of glass recycling throughout the United States.

Reindl (2003) reported that the glass cullet could be exploited in a variety of uses, including road construction aggregate, asphalt paving, concrete aggregate, building applications (glass tiles, bricks, wall panels, ... etc), fiber glass insulation, glass fiber, abrasive, art glass, landscaping, reflective beads, hydraulic cement, and other applications. The critical requirement in all these applications is that, the correct characteristics and physical properties of the glass cullet for the targeted application should be well understood and defined.

Zainab and Enas [2004] investigated the properties of concretes containing waste glass as fine aggregate. The strength properties and the alkali silica reaction (ASR) expansion were analyzed in terms of waste glass content. An overall quantity of 80 kg of crushed waste glass was partially replacing sand at 10%, 15% and 20% within a 900 kg of concrete mixes. The results proved 80% pozzolanic strength activity given by waste glass after 28 days.

The flexural strength and compressive strength of specimens with 20% of waste glass content were 10.99% and 4.23% respectively higher than the ordinary control specimen results at 28 days. The mortar bar tests showed that the fine crushed waste glass helped reduces the expansion of concrete by 66% as compared with the ordinary control mix.

Topçu and Canbaz [2004] considered waste glass as coarse aggregates in the concrete mix. The effects of waste glass on workability and strength of the concrete with fresh and hardened concrete tests were analyzed. As a result of the study conducted, waste glass was determined not to have a significant effect upon the workability of the concrete and only slightly in the reduction of its strength.

Waste glass cannot be used as aggregate without taking into account its ASR properties. As for cost analysis, it was determined to lower the cost of concrete productions. This study considered the fact that the waste glass could be used in the concrete as coarse aggregates without the need for a high cost or rigorous energy.

Weitz (2005) reported that the American Association of State Highway and Transportation Officials (AASHTO) had recognized the use of recycled materials in pavement and created a new specification titled –Glass Cullet Use for Soil Aggregate Base Course. The specification illustrates that when properly processed, glass cullet can be expected to provide adequate stability and load support for use as road or highway bases. Crushed glass cullet that has been used as aggregate in road construction or bituminous concrete pavements is popularly known as glassphalt.A number of field trials of glass phalt pavements have been carried out since 1971. It was observed that holds heat longer than conventional asphalt. This may be advantageous when road works are carried out in cold weather or when long transport distances are required. Furthermore, the glass particles will increase the reflectivity of the road surface; therefore, improve the night-time road visibility.

Use of waste glass in concrete

A lot of studies have been conducted about the possibility of using ground waste glass since 1960s, 1970s and 1980s, as aggregates or cement replacement (Pike et al. (1960), Schmidt et al (1963), Phillips et al (1972) and Johnston (1974).

However these studies were not accuracy. In the past 10 years, the use of glass as cement concrete aggregates has again come under investigation due to high disposal costs for waste glasses and environmental regulations.

Use of waste glass powder as cement replacements

A waste that contains a high content of silica (SiO_2) could be added to cement as pozzolanic constituent. Finely ground glass has appropriate amorphous silica (SiO_2) content to react with dissolved calcium hydroxide in the presence of water, consequently forming hydrated compounds in a similar way to pozzolanic materials such as pulverized-fuel ash (PFA), ground-granulated blast furnace slag (GGBS) and silica fume (SF). Pozzolanicity of glass powder (GP) was first studied in 1973.However the most important works have been conducted in the last 10 years. Published research works have shown that glass powder will react in a pozzolanic manner in the cementitious systems and contribute to the strength development of concrete (Reindl.2003).

Shayan (2002) studied the strength development using fined glass powder (GP) at long-term compared with silica fume (SF). This series consists of control mix with reactive fine aggregate and other mixes that contained 10% SF, 20% GP or 30% GP as a partial replacement by weight of cement. The series also contained another mix proportioned with 30% GP but as fine aggregate

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replacement. Figure 2.2 shows the strength development of each combination over 270 days. The results indicated that the 10% SF replacement produced higher strength than the GP replacements, but they also showed that GP mixes continue to develop further strength with time indicating its pozzolanic activity. It was stated by Shayan that the observed decrement in compressive strength of GP mixes was due to the lower cement content rather than the nature of GP. He also indicated that when 30% of sand was replaced by GP, the 90-dayCompressive strength was similar to that of SF specimens.

3. MATERIALS AND METHODLOGY

Materials used

Cement concrete is a site – made material unlike other materials of construction and as such can vary to a great extent in its quality, properties and performance owing to the use of natural materials except cement. From materials of varying properties, to make concrete of stipulated qualities an intimate knowledge of the interactions of various ingredients that go in the making of cement concrete is required to be known.

3.2 Cement

Cement is a material that has adhesive and cohesive properties enabling it to bond mineral fragments into a solid mass. Cement consists of silicates and aluminates of lime made from limestone and clay (or shale) which is ground, blended, fused in a kiln and crushed to a powder. Cement chemically combines with water (hydration) to form a hardened mass. Typical Portland cements are mixtures of tricalcium silicate ($3CaO \cdot SiO_2$), tricalcium aluminates ($3CaO \cdot Al2O_3$), and dicalcium silicate ($2CaO \cdot SiO_2$), in varying proportions together with small amounts of magnesium and iron compounds. Gypsum is often added to slow down the hardening process.

3.3 Water

The water has two roles in concrete mixture First the chemical composition with cement and to perform cement hydration and second is to make the concrete composition fluent and workable. The water which is used to make the concrete is drinking water. The impurity of water can have undesirable effect on concrete strength.

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together fills voids within it and allows it to flow more freely. Less water in the cement paste will yield a stronger, more durable concrete and more water will give a free-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles and other components of the concrete to form a solid mass.

3.4 Aggregates

Since aggregate usually occupies about 75% of the total volume of concrete, its properties have a definite influence on behavior of hardened concrete. Not only does the strength of the aggregate affect the strength of the concrete, its properties also greatly affects durability (resistance to deterioration under freeze-thaw cycles).

Since aggregate is less expensive than cement it is logical to try to use the largest percentage feasible. Hence aggregates are usually graded by size and a proper mix has specified percentages of both fine and coarse aggregates. Fine aggregate provides the fineness and cohesion of concrete. It is important that the fine aggregate should not contain clay or any chemical pollution. Also, fine aggregate has the role of space filling between coarse aggregates.

Coarse aggregate includes fine gravel, gravel and coarse gravel In fact coarse aggregate comprises the strongest part of the concrete. It also has reverse effect on the concrete fineness.

The coarse aggregate, the higher is the density and the lower is the fineness. Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are used mainly for this purpose.

3.5 Waste Glass

Theoretically, glass is a fully recyclable material and it can be recycled without any loss of quality. There are many examples of successful recycling of waste glass as a cullet in glass production, as raw material for the production of abrasives, in sand-blasting as a pozzolanic additive, in road beds, pavement and parking lots as raw materials to produce glass pellets or beads used in reflective paint for highways, to produce fiberglass, and as fractionators for lighting matches and firing ammunition.

Waste glass can also be produced from empty glass bottles and pots and come in several distinct colors containing common liquids and other substances. This waste glass is usually crushed into small pieces that resemble the sizes of gravels and sands. Therefore - as an alternative - there is a potential to partially replace the concrete mix aggregate with waste glass due to the lack of natural resources in Gaza Strip.

In its original form, glass comes as a balanced combination from three main raw natural materials: sand, silica, and limestone, in addition to a certain percentage of recycled waste glass utilized in the manufacturing process.

The glass recycling process produces a crushed glass product called "cullet" which is often mixed with virgin glass materials to produce new end products. These materials were primarily originated from pure and clear glass windows. The whole quantity was cleaned out of the dirt materials and impurities and then crushed in crushing machines into different particles sizes.

3.6 Waste glass powder (WGP)

The waste glass used for this project was collected from the points in Karur District. Waste Glass is converted into fine aggregate as shown in flowchart Fig. (**1**) And also the procedure for making Waste Glass concrete is shown in flowchart Fig. (**2**)

3.7 Oxide content for waste glass powder.

Table-2 Oxide content for waste glass powder.

Oxide	Content (%)
Sio_2	72
Na_2O	14
CaO	9
Al_2O_3	2
MgO	2.2
K_2O	0.5

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Fe_2O_3	0.2
Cr, S and Co	0.1

Waste glass is a major component of the solid waste stream in many countries and is generally used in landfills. As an alternative, however waste glass could be used as a concrete aggregate either as a direct replacement for normal concrete aggregates (low value) or as an exposed decorative aggregate in architectural concrete products (high value). Expansive alkali silica reactions (ASR) can occur between glass particles and cement paste particularly in moist conditions and high alkali cements.

This reaction can occur whenever an aggregate contains reactive silica. However, it is now well known that by controlling cement alkali level and moisture. Research has shown that the waste glass can be effectively used in concrete either as aggregate or as pozzolana. Waste glass when ground to a very fine powder shows pozzolanic properties. Therefore the glass powder shows pozzolanic properties. Therefore glass powder can partially replaces cement and contribute to strength development.

Finely ground glass has the appropriate chemical composition including Sio_2 to react with alkalis in cement (Pozzolanic Reaction) and form cementitious products that helps to contribute the strength development. Alkali silica reaction (ASR) of glass aggregate concrete can be minimized by the use of the suppressants including pulverized fuel ash (PFA) and metakaolin (MK).

3.8 Research Significance

Recycling of waste glass possesses major problems for municipalities everywhere and this problem can be greatly eliminated by re-using waste glass as cement replacement in concrete. Moreover, there is a limit on the availability of natural aggregate and minerals used for making cement and it is necessary to reduce energy consumption and emission of carbon dioxide resulting from construction processes and solution of this problem are sought thought usages of waste glass as partial replacement of Portland cement.

Replacing cement by pozzolanic material like waste glass powder in concrete not only increases the strength and introduces economy but also enhances the durability. Chlorides and sulphates of sodium, magnesium and calcium are present in alkaline soils and water.

Sulphates react chemically with product of hydration causes expansion and chloride deposited in the concrete that tends to make the concrete more porous .Therefore, the action of chlorides and sulphates in concrete containing waste glass powder needs to be investigated.

3.9 Concrete Mix Design

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economical as possible. The Bureau of Indian Standards recommended a set of procedure for design of concrete mix mainly based on the work done in national laboratories.

Design Stipulations

Characteristic strength required in the field at 28 days	= 25MPa
Maximum size of aggregate	= 20 mm(Angular)
Degree of workability	= 0.90 compacting

factor

Degree of quality control = Good

Test data for materials

Specific gravity of cement =3.15

Specific gravity of coarse aggregate =2.83

Specific gravity of fine aggregate =2.68

Water absorption of coarse aggregate =0.5%

Target mean strength

$\bar{f}_{ck} = f_{ck} + tS$

$\bar{f}_{ck}$ = Target mean strength at 28 days

f_{ck} = characteristic compressive strength at 28 days

t = statistical value (from table 2 of Appendix)

S = Standard deviation (from table 1 of Appendix)

$20 + 1.65 \times 4 = 26.6$ MPa

Water Cement Ratio

Adopt W/C ratio as 0.5 (IS 10262 - 2009)

Water and Sand content

For 20 mm size aggregate water content per cubic meter = 186 kg (IS 10262 - 2009)

Sand content as percentage of total aggregate by absolute volume = 35% (IS 10262 - 2009)

Hence required water content = 191.6 l/m^3

Determination of cement content

W/C ratio = 0.5

Water = 191.6 l

Cement = 191.6/0.5 = 383 kg/m^3

Determination of coarse and fine aggregates content

$V = [W+C/S+(1/P)(f_a/S_{fa})]$

$C_a = (1\text{-}P/P)\times f_a\times(S_{ca}/S_{fa})$

Hence f_a = 546 kg/m^3

C_a = 1188 kg/m^3

Hence mix proportion is given in table 3.5

Table 3- Mix Design Ratio

CEMENT (kg)	FINE AGGREGATE (kg)	COARSE AGGREGATE (kg)	WATER (lr)
383	546	1188	191.6
1	1.5	3.1	0.51

4. RESULTS AND DISCUSSIONS

The main aim of this chapter is to obtain the fresh concrete workability and the hardened concrete compressive strength as the essentials for the analyses following the methodology targeting to highlight the usefulness of considering waste glass materials as a main component within the concrete mix. Proper treatment of uncertainties within the data analysis process required understanding the sources of errors for determining the final output results. It is worthy to mention that for the sake of simplicity, some of the variables that may actually influence the hardened concrete compressive strength such as:

various combinations of both coarse and fine waste glass within the concrete mix, the effect of different admixtures on concrete mixes containing waste glass and the effect of waste glass material type and properties on the engineering properties of concrete, etc. are not considered within the scope of this research study, since those excluded variables may act as sources of errors for the resulting predictions and recommendations.

- For determination of compressive strength in OPC for different replacement have been casted and curing is being processed

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- Concrete mix design has been designed based on the Bureau of Indian standards
- The testing of materials for ordinary Portland cement, river sand and Glass Waste Powder has been conducted and results are tabulated

4.2 Specific Gravity Test

It is defined as the ratio of the mass of void in a given volume of sample to the mass of an equal volume of water at the same temperature. If the volume of aggregates includes the voids, the resulting specific gravity is called as "apparent specific gravity", it refers the volume of aggregate includes impermeable voids.

The specific gravity most frequently and easily determines and it is based on the saturated dry condition of the aggregate because the water absorbed aggregate in the pores of the aggregate does not take part in the chemical reaction of the cement.

Therefore it is considered as a part of the aggregate. The specific gravity is required for the calculation of the yield of concrete or the required quantity of aggregate for the given volume of concrete.

This test is done to determine the specific gravity of fine- grained soil by density bottle method as per IS: 2720 (Part III/Sec 1) – 1980. Specific gravity is the ratio of the weight of a given volume of solids to the weight of an equivalent volume of water

Table 4- Specific Gravity of Materials

S.NO	PROPERTIES	VALUE
1.	OPC	3.15
2.	COARSE AGGREGATE	2.83
3.	RIVER SAND	2.60
4.	GLASS WASTE POWDER	2.68

4.3 Water Absorption of Aggregate

Some of the aggregates are porous and absorptive. Porosity and absorption of aggregate will affects the water / cement ratio and hence the workability of concrete.

The water absorption of aggregate is determined by measuring the increase in weight of an oven dried sample when immersed in water for 24 hours. The ratio of increase in weight of the dry sample expressed as percentage is known as absorption of aggregate.

Fig 3 -Water absorption of coarse aggregate

4.4 Consistency Test

When water is mixed with cement to form a paste, reaction starts. The action of changing of the cement paste from fluid state is called setting time.

For the initial setting time test, a needle of 1 mm square section is to be fitted to the moving rod while for the final setting time test, the needle with annular attachment is to be used.

4.4.1 Initial and Final setting time test

- The mould and the non-porous plate are washed, cleaned and dried.
- 400 g of the given sample of cement is kept on the non-porous plate.

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- The volume of water equal to 0.85 times the percentage of water required for standard consistency is added very carefully to the dry cement and mixed thoroughly to form a neat cement paste. The mixing is completed within 3 to 5 minutes from the moment of adding water. At the instant of adding water to the cement, the time taken is noted by using a stop watch.
- The Vicat mould is placed on the non-porous plate and is filled with the prepared cement paste and the surface of the pate is made smooth in level with the mould by using a trowel.
- By shaking the mould slightly air if any is expelled from the sample.
- The non-porous plate and the mould are placed under the needle.
- The needle is gently lowered to touch the surface of the plate and then the indicator adjusted to show zero reading.
- The needle is released quickly allowing it to penetrate in to the paste.
- When the needle comes to rest, the reading on the index scale is noted.
- The moving rod is raised clear off the cement paste and is wiped clean. The procedure to releasing the needle is repeated at every 30 seconds until the reading on the index scale showed 5 ±0.5 mm from the bottom of the mould.
- Then the time is noted down. The time that elapsed between the moment when water is first added to the cement and the moment section failed to pierce the test block to a depth to 5±0.5 mm from the bottom of the mould is the initial setting time for the cement under the test.

Result

Initial setting time = 35 minutes

Final setting time=510 minutes

Fig 4- Initial setting time test

Fig5- Vicat's apparatus

4.5 Workability Test

Workability is the property of concrete which determines the amount of useful internal work

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necessary to produce full compaction. Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work.

4.5.1 Slump cone test

- The internal surface of the mould is cleaned thoroughly and freed from any old set concrete before commencing the test.
- The mould is placed on a smooth horizontal rigid and non – absorbent surface.

Sieve size (mm)	Percentage of Passing (%)
4.75	97
2.36	80
1.18	49
0.6	30
0.3	15
0.15	5
0.075	2

- The mould is then filled in four layers each approximately one – fourth of the height of the mould.
- Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section.
- After the top layer has been rodded the concrete is struck off level with a trowel and a tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction.
- This allows the concrete to subside. This subsidence is referred to as SLUMP of concrete. The slump values for different mixes have been given in the table 6

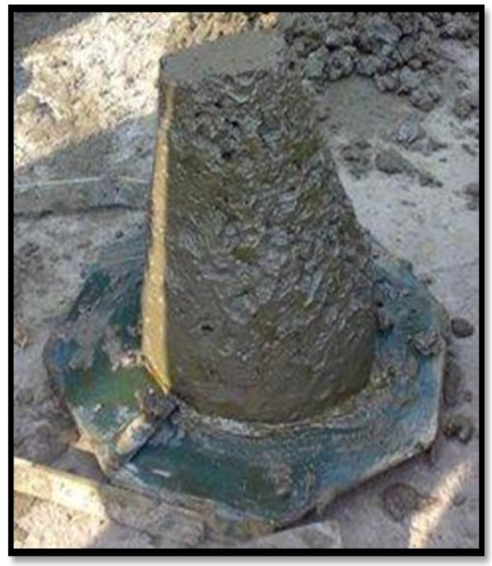

Fig 6- Slump test

Table 5- Slump values for different mixes

S.No	Ratio		Slump Value for OPC mixes(mm)
	RS (%)	GWP (%)	
1	100	0	23
2	90	10	25
3	80	20	27
4	70	30	31
5	60	40	31
6	50	50	35
7	0	100	36

4.6 Sieve Analysis

Table 6-Sieve Analysis for Coarse

Table 7- Sieve analysis for fine aggregate

4.7 Durability Test

Compression test is the most common test conducted on hardened concrete. The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications, concrete is used primarily to resist compressive stress.

In those cases where strength in tension or in shear is of primary importance, the compressive strength is frequently used as a measure of these properties. Compressive strength is also used as a qualitative measure for other properties of hardened concrete. In practical, the compressive strength increases as the specimen size decreases.

At least three cubes of size 150mm x 150mm x 150mm were casted for each age usually 7, 14 & 28 days. The specimens were kept in moisture for one day and then subjected to water curing for the rest of the days. Specimens were tested in saturated condition. After curing, the specimens were tested for compressive strength using a calibrated compression testing machine of 2000kN capacity.

- Cube moulds of 15 cm × 15 cm × 15 cm were used. Concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours, these moulds are removed and test specimens are put in water for curing.
- The specimen is removed from water after specified curing time and excess water from the surface is wiped out.
- The bearing surface of the testing machine is cleaned.
- The specimen is placed in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
- The specimen is aligned centrally on the base plate of the machine.
- The load is applied gradually without shock and continuously till the specimen fails.
- The maximum load is recorded.
- Compressive strength = (Load in N / Area in mm^2)

Fig 7- Mixing of concrete

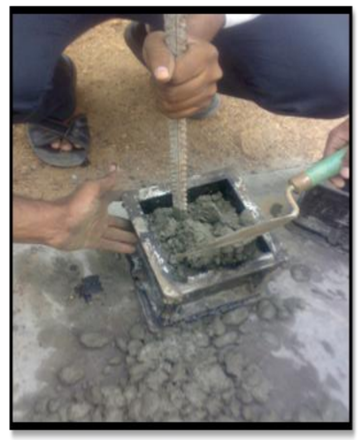

Fig 8- Compaction of concrete

Compressive strength test results of conventional concrete and Glass Waste Powder for 7, 14, 21 and 28 days are shown in Tables and bar charts

4.8 Waste glass contents in concrete mixes

The main goal of this research is to introduce the waste glass materials into the concrete mix for economic and environmental benefits but with the improvement of the concrete compressive strength, or at least without losing the expected level of standard concrete mixes.

From the above mentioned output results and the corresponding illustrative figures, analyses using regression techniques and differentiation

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methods were performed focusing on the concrete mix samples with a water-cement ratio of 0.4 (w/c). Table: 7 summarize the testing outcomes for the 7-days category for coarse waste glass while Table: 8 summarize the testing outcomes for the 28-days category for coarse waste glass respectively.

5. CONCLUSION

The output results obtained from this laboratory program showed reliable data points and promising further research horizons.

Conclusion

From the tests conducted on waste glass replaced in fine aggregate for concrete as presented in various sections, the following conclusions are made are

- The water requirement decreases as the waste glass content increases. The compressive strength of cubes of the concrete for all mix increases up to 20 % replacement of waste glass but decreases as the age of curing increases due to alkali silica reaction.
- 100% replacement of waste glass in concrete showed better results than that of conventional concrete at 28 days curing but later it started to decrease its strength because of its alkali silica reactions.
- The optimum replacement level in fine aggregate with waste glass is **8% to 25%**
- Waste glass is available in significant quantities as a waste and can be utilized for making concrete. This will go a long way to reduce the quantity of waste in our environment.

6. REFERENCES

[1] Job Thomas, “Utilization of quarry powder as a substitute for theriver sand in concrete”, *J. Struct. Eng.*, vol.32, no.5, pp. 401-407,January 2006.

[2] C. Meyer, and S. Baxter, “Use of recycled glass and fly ashfor precast concrete,” *NYSERDA Rep.*, vol.1, pp. 98-18, October1998.

[3] Y. Shao, T. Lefort, S. Moras, and D. Rodriguez, “Studies on concrete containing ground waste glass,” *Cem. Concr. Res.*, vol. 30,no. 1, pp. 91-100, June 2000.

[4] A.Shayan, and A. Xu, “Value - Added Utilization of waste glass inConcrete,” *Cem. Concr. Res.*, vol. 34, no.1, pp. 81-89, May 2004.

[5] W. Jin, C. Meyer, and S. Baxter, “Glascrete - Concrete with glassaggregate,” *ACI. Mater. J.*, vol. 2, pp. 208-213, May 2000.

[6] C. Polley, S.M. Cramer, and R.V. Crug, “Potential for using wasteglass in Portland Cement Concrete,” *J. Mater. Civil Eng.*, vol. 10,no. 4, pp

[7] AL-Rubaie, M., Fouad, "Properties of Concrete Building Units Containing Crushed Waste Glass", M.Sc. Thesis, The University of Technology, 2007.