Experimental Study On Durability Strengthening Of Concrete By Using Industry Metal Slag Waste Partially Replacement Of Fine Aggregate

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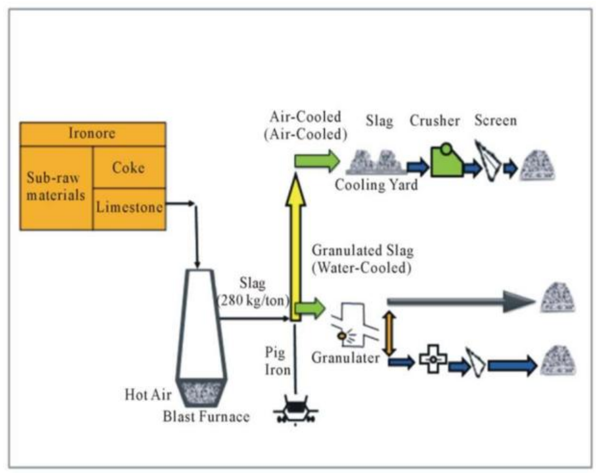
ABSTRACT

This paper present result of an experimental investigation carried out to evaluate effects of replacing aggregates (course& fine) with that of Slag (Crystallized & Granular) which is an industrial waste by product on concrete strength properties by using Taguchi's approach of optimization. Whole study was done in three phases, in the first phase natural coarse aggregate was replaced by crystallized slag coarse aggregate keeping fine aggregate (natural sand) common in all the mixes, in the second phase fine aggregate (natural sand) was replaced by granular slag keeping natural coarse aggregate common in all the mixes and in the third phase both the aggregates were replaced by crystallized & granular aggregates. The study concluded that compressive strength of concrete did not improve almost all the % replacements of normal crushed coarse aggregate with crystallized slag by 5% to 7%. In case of replacements of fine aggregate and both type of aggregates, the strength improvements were notably noticed at 30% to 50% replacement level. It could also be said that full substitution of slag aggregate with normal crushed coarse aggregate improved the flexure and split tensile strength by 6% to 8% at all replacements and in case of replacing fine aggregate & both the aggregates(Fine & coarse) with slag, the strength improvement was at 30% to 50% replacements. It is evident from the investigation that Taguchi approach for optimization helped in indentifying the factors affecting the final outcomes. Based on the overall observations, it could be recommended that Slag could be effectively utilized as coarse & fine aggregates in all concrete applications.

Keywords: Compressive; Flexure and Split Tensile Strength; Slag Aggregate;
Taguchi's Approach.

1. INTRODUCTION

The proper use of waste materials fundamentally affects our economy and environment. Over a period of time waste management has become one of the most complex and challenging problems in India affecting the environment. The rapid growth of industrialization gave birth to numerous kinds of waste byproducts which are environ- mentally hazard and create problems of storage. The construction industry has always been at forefront in consuming these waste products. The consumption of Slag which is waste generated by steel industry, in concrete not only helps in reducing green house gases but also helps in making environmentally friendly material. During the production of iron and steel, fluxes (limestone and/or dolomite) are charged into blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces iron ore into molten iron product. Fluxing agents separate impurities and slag is produced during separation of molten steel. Slag is a nonmetallic inert byproduct primarily consists of silicates, aluminosilicates, and calcium-alumina-silicates. The molten slag which absorbs much of the sulfur from the charge comprises about 20 percent by mass of iron production. The schematic production details of Slag are shown in Figure1.1.



2. LITERATURE REVIEW

Isa Yuksel, Omer Ozkan, Turhan Bilir, (2006)

Worked on mortar made up of ground granulated blast furnace, gypsum, clinker and steel slag sand. The experimental results show the application of steel slag sand may reduce the dosage of cement clinker and increase the content of industrial waste product using steel slag sand.

Juan M. Manso, *et al.*, (2004)

Experimented use of non ground granulated blast furnace slag as fine aggregate in concrete. The study concluded that the ratio of GGBs/sand is governing criteria for the effects on the strength and durability characteristics.

KeunHyeokYang, JinKyuSong, Jae-SamLee,(2010)

Carried out work in laboratory to produce concrete with good properties using oxidizing EAF slag as fine and coarse aggregate. The concrete was tested for durability characteristics like soundness, leaching test, accelerated ageing test etc. The durability of the EAF slag concrete was found to be acceptable, especially in the geographical region for which its use was proposed, where the winter temperature hardly ever falls below 32˚F (0˚C).

Li Yun-feng, Yao Yan, Wang Liang, (2009)

Studied alkali activated mortar sand concrete using light weight aggregates. Test results showed that the compressive strength of alkali activated mortar decreased linearly with the increase of replacement level of light weight fine aggregate regardless of the water binder ratio.

Lun Yunxia, Zhou Mingkai, Cai Xiao, Xu Fang, (2008).

Investigated effects of steel slag powder on the workability and mechanical properties of concrete. Experimental results show that mechanical properties can be improved further due to the synergistic effect and mutual activation when compound mineral admixtures with steel slag powder and blast furnace slag powder mixed in concrete.

L. Zeghichi, (2006)

Used steel slag as fine aggregate for enhancing the volume stability of mortar. Experimental results indicated that powder ratio, content of free lime and rate of linear expansion can express the improvement in volume stability of different treated methods. Autoclave treatment process is found more effective steam treatment process on enhancement of volume stability of steel slag.

Saud AlOtaibi, (2008)

Experimented on substitution of sand by GBF crystallized slag. Tests carried out on cubes of concrete showed the effect of the substituting part of sand by granulated slag (30%, 50%) and the total substitution on the development of compressive strength. Compressive strength test results at 3, 7, 28, 60 days and 5 months of hardening concluded that the total substitution of natural coarse aggregate with crystallized slag affects positively on tensile, flexural and compressive strength of concrete. The partial substitution of natural aggregate with slag aggregates permits a gain of strength at long term but entire substitution of natural aggregates affects negatively the strength (a loss in strength of 38%).

Sean Monkman, Yixin Shao, Caijun Shi, (2009)

Studied use of recycling steel mill as fine aggregate in cement mortars. The replacement of 40% steel mill scale with that of fine aggregate increased compressive strength by 40%, drying shrinkage was lower when using steel mill scale.

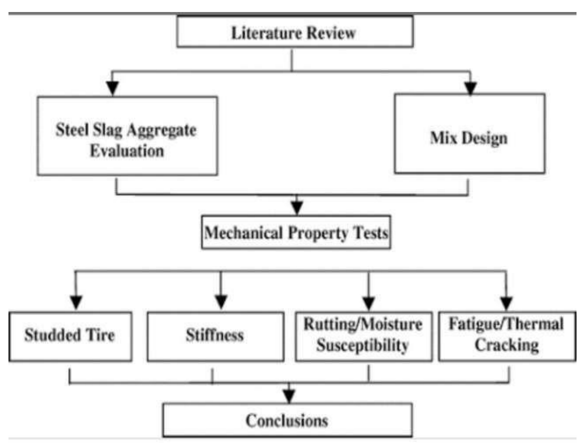
Tarun R Naik, Shiw S Singh, Mathew P Tharaniyil, Robert B Wendfort, (1996)

Investigated the possibility of using a carbonated LF slag as a fine aggregate in concrete. The slag was treated with CO2 to reduce the free lime content while binding gaseous CO2 into solid carbonates. The carbonated LF slag was used as a fine aggregate in zero-slump press-formed compact mortar samples and compare to similar samples containing control river sand. The 28-day strengths of the mortars made with the carbonated slag sand were com-parable to the strengths of the normal river sand mortars. The carbonation of LF slag was found to be suitable for use as a fine aggregate. Significant amounts of carbon sequestration could be realized in a potentially useful form that further utilizes a waste slag material. Carbonated mortars that used LF slag sand offer the largest gains in terms ofCO2uptake.

3. METHODOLOGY

Study Scope

In this study, concrete of M20, M30 & M40 grades were considered for a W/C ratio of 0.55, 0.45 & 0.40 respectively with the targeted slump of 4 ± 1 in. (100 ± 25 mm) for the replacement of 0%, 30%, 50%, 70% & 100% of aggregates (fine & coarse) with that of slag aggregate. These concrete mixes were studied for the properties like compressive, split tensile and flexure strengths.



4. EXPERIMENTAL INVESTIGATION

RawMaterials

In this investigation, slag from the local steel making plant, normal crushed coarse aggregate from Panchgaon Basalt query, natural sand from the local Kanhan river shown in Figure 2 and Portland Pozzolana cement were used. All the chemical & physical properties of the materials are given in the Table 4.1.

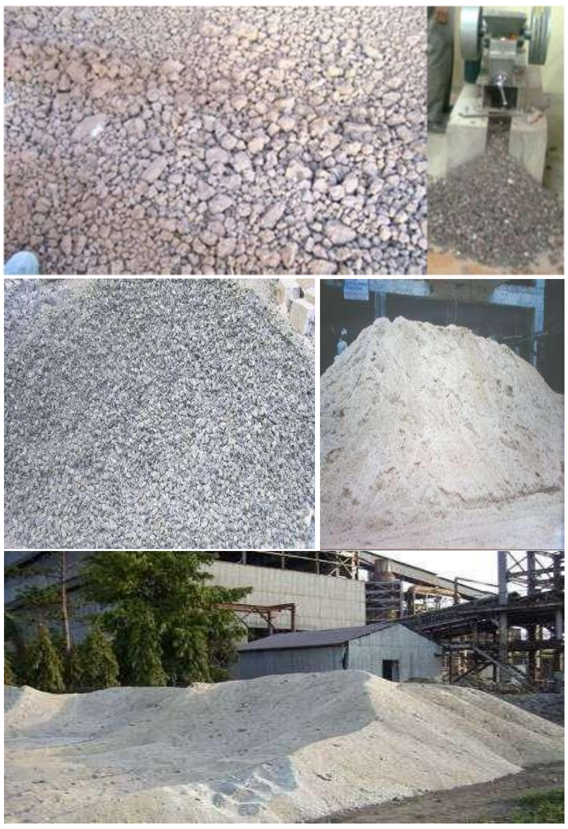


Figure 4.1. View of Slag, normal crushed coarse aggregate & natural sand

Unit: 1000 kg/m^3 = 143.5 lb/ft^3, 1 MPa, 150 psi., 1 m^2/kg = 4.78 ft^2/lb., 1 kg 2.25 lb

5. MIXPROPORTIONS

The mix proportions were made for a control mix of slump 4 ± 1 in. (100 ± 25 mm) for M20, M30 & M40 grade of concrete for w/c ratio of 0.55, 0.45 & 0.40 respectively by using IS-10262-2009 method of mix design shown in Table 2.Table 3 is providing mix proportions details for control mixes (without replacements with slag).

Test Set-Up

The 4 in. cubes (100 mm cubes set of 3) each were cast for compressive (7, 28, 56, 91 & 119 days), split strength(7 & 28 days) and 4 in. (100 mm) beam mould for flexure strength (7 & 28 days). After the cast, all the test specimens were finished with a steel trowel and immediately covered with plastic sheet to minimize the moisture loss. All the cubes were de-mould after 24 hours time and put into the water tank for curing maintaining temperature of 89.6˚F ± 35˚F (27˚C ± 2˚C) as per IS requirements shown in Figure 5.1.

Hardened Concrete Properties

The set of 4 in. cubes (100 mm cubes 3 nos.) were tested for compressive strength at 7, 28, 56, 91 & 119 days. Similarly, 4 in. (100 mm) cubes and 4 × 4 × 20 in. (100 × 100 × 500 mm) beams were tested for split tensile & flexure strength respectively after 7 & 28 days time as per the IS-516-1991, Methods of test of strength of concrete. The test set-up is shown in Figure 5.2.

Taguchi'sApproach

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on "OR-THOGONAL ARRAY" experiment which gives much reduced "variance" for the experiment with "optimum settings" of control parameters. Thus the marriage of De-sign of Experiments with optimization of control parameters to obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results. In this method a process/product optimization is done in various steps of planning, conducting and evaluating results of matrix experiments to determine the best levels of control factors. The primary goal is to keep the variance in the output very low even in the presence of noise inputs. Thus, the processes/products are made ROBUST against all variations.

The performance characteristic was chosen as the optimization criteria.

There are three categories of performance characteristics,

The larger the better S/N = –10log10 [mean of sum squares of measured data]

The smaller the better S/N = –10log10 [mean of sum squares of reciprocal of measured data]

Nominal the better S/N = –10log10 [Square of means/variance]

Where S/N (S/N unit: dB) are performance statistics, de-fined as the signal to noise ratio.

The approach is to select the best combination of the control parameters so that the product or process is the most robust with respect to noise factors. It utilizes orthogonal arrays from design of experiments theory to study a large number of variables with a small number of experiments. An orthogonal array significantly reduces the number of experimental configurations to be studied. Furthermore, the conclusions drawn from small-scale experiments are valid over the entire experimental region spanned by the control factors and their settings.

In this study W/C ratio, replacements of natural coarse aggregate with slag aggregate & replacements of natural fine aggregate with slag aggregate were considered as control factors for optimizing (maximizing) compressive, split & flexure strengths of concrete for M20, M30 & M40grade of concrete shown in Table 5.2.

Factors	Factors Designation	Level 1	Level 2	Level 3
• W/C	A	0.55	0.4	5
• % replacements of natural coarse aggregate with slag aggregate	B	0	50	100
• % replacements of natural fine aggregate with slag aggregate	C	0	50	100

Table 5.1. Replacement proportions of aggregates.

Mix No.	Normal Crushed Coarse Aggregate-%	Slag Aggregate-%	Natural sand-%	Slag sand-%
Control Mix				
1	100	0	100	0
Replacement of Coarse aggregate				
2	70	30	100	0
3	50	50	100	0
4	30	70	100	0
5	0	100	100	0
Replacement of Fine aggregate (Natural Sand)				
2	100	0	70	30
3	100	0	50	50
4	100	0	30	70
5	100	0	0	100

Table 5.2. Mix proportions of control mixes.

Mix Proportions of Control Mixes			
Ingredients (Kg/cum) (1 Kg/cum = 0.143 lb/ft^3)	**M20**	**M30**	**M40**
Cement	348	362	407
Water (W/C ratio, 0.55,0.45 & 0.40)	192	163	163
Mass of normal coarse aggregate	1187	1225	1198
Mass of fine aggregate	725	748	731
Super Plasticizer (PC based)	0.00	2.17	3.26
Total Weight	**2452**	**2500**	**2502**

6. SUMMARY & CONCLUSIONS

The conclusions are drawn as below.

The compressive strength of concrete increased by 4% to 6% for replacements of both coarse & fine aggregates from 30% to 50%. However, in case of coarse aggregate the compressive strength increased by 5% to 7% and decreased in case of fine aggregate by 7% to 10% at 100% replacement over control mixes in M20, M30 & M40 grade of concrete. It could be said that 100% replacement of normal crushed coarse aggregate with slag aggregate, improved the flexure and split tensile strength by about 6% to 8% in all mixes. The improvement in strength was attributed to the rough surface

texture which ensured strong bond ing and adhesion between aggregate particles and cement paste. In case of natural fine aggregate replacement with slag fine aggregate the strength increased was for 50% by 5% to 6% but It is evident from the investigation that Taguchi approach for optimization helped in identifying the factors affecting the final outcomes.

Based on the above summaries and conclusions, it could be recommended that slag due to its chemical composition and its chemical inertness soundness of aggregate & concrete, could be effectively utilized as aggregates (coarse & fine) in all the concrete constructions like plain concrete and reinforced cement concrete including pavement concrete either as partial or full replacements over an observed range of 50 to 100%. Since such slag have compatible performance at par with conventional aggregates, their immediate use in Plain concrete & Reinforced concrete including pavements shall reduce the construction cost significantly.

Future Scope

Based on the experience of work, following future scopes are identified,

- Characterization of slag available from various steel Manufacturing plants could be done for the compare- son of performances of concretes obtained with these slag.
- Collection of data for characterization of such slag wastes generated from all the steel making plants is of extreme importance & could be taken up immediately.
- Study of environmental problems created by such wastes remaining without recycling and proper utilization.
- Development of mathematical model based on various parameters to ascertain its strength characteristics in respect of concrete.

7. MATERIAL INVESTIGATION

The presentation of results obtained from various tests conducted on material used for the concrete. An experimental program was planned to investigate the effect of iron slag on compressive strength, split tensile strength and sulphate resistance of concrete.

Materials:-

The properties of material used for making concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were cement, coarse aggregates, and fine aggregates, in addition to iron slag. The aim of studying of various properties of material is used to check the appearance with codal requirements and to enable an engineer to

reduced at 100% replacements by6 to 8%. The reason for reduction in strength for 100% replacement could be attributed to the presence of coarser particle sizes which could be overcome by addition of finer materials.

design a concrete mix for a particular strength.

Ordinary Portland cement:-

Although all materials that go into concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. The function of cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. It constitutes only about 20 percent of the total volume of concrete mix; it is the active portion of binding medium and is the only scientifically controlled ingredient of concrete. Any variation in its quantity affects the compressive strength of the concrete mix.

Portland cement referred as (Ordinary Portland Cement) is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. The OPC is classified into three grades, namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days. It has been possible to upgrade the qualities of cement by using high quality limestone, modern equipments, maintaining better particle size distribution, finer grinding and better packing. Generally use of high grade cement offers many advantages for making stronger concrete. Although they are little costlier than low grade cement, they offer 10-20% saving in cement consumption and also they offer many hidden benefits.One of the most important benefits is the faster rate of development of strength.

Aggregates:-

Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. To increase the density of resulting mix, the aggregates are frequently used in two or more sizes. The most important function of the fine aggregate is to assist in producing workability and uniformity in mixture. The fine aggregate assist the cement paste to hold the coarse aggregate particles in suspension. This action promotes plasticity in the mixture and prevents the possible segregation of paste and coarse aggregate, particularly when it is necessary to transport the concrete some distance from the mixing plant to placement. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. They should therefore meet certain requirements if the concrete is to be workable, strong, durable and economical. The aggregates must be proper shape, clean, hard, strong and well graded.

SN	Characteristics	Values Obtained Experimentally	Values Specified by IS
1	Specific gravity	3.15	-
2	Standard consistency(%)	33	-
3	Initial setting time	105 (minutes)	30 (minutes)
4	Final setting time	430 (minutes)	600 (minutes)
5	Compressive Strength 3 days 7days 28days	25.2N/mm2 39.9N/mm2 47.8N/mm2	23N/mm2 33N/mm2 43N/mm2

Coarse Aggregates:

The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate.

The coarse aggregates may be of following types:-

1. Crushed graves or stone obtained by crushing of gravel or hard stone.
2. Uncrushed gravel or stone resulting from the natural disintegration of rocks.
3. Partially crushed gravel obtained as product of blending of above two types.

The normal maximum size is gradually 10-20 mm; however particle sizes up to 40 mm or more have been used in Self Compacting Concrete. Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of interlocking of angular particles, while rounded aggregates improved the flow because of lower internal friction. Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition.

Fine Aggregates:

The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. The Fine aggregate may be of following types:

1. Natural sand, i.e. fine aggregate resulting from natural disintegration of rocks.
2. Crushed stone sand, i.e. fine aggregate produced by crushing hard stone.
3. Crushed gravel sand, i.e. fine aggregate produced by crushing natural gravel.

According to size, the fine aggregate may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The sand was sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and conforming to grading zone II. It was coarse sand light brown in colour.

Characteristics	Value
Specific gravity	2.32
Bulk density	1.3
Fineness modulus	2.62
Water absorption	0.88

Water:-

Generally, water that is suitable for drinking is satisfactory for use in concrete. Water from lakes and streams that contain marine life also usually is suitable. When water is obtained from sources mentioned above, no sampling is necessary. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided since the quality of the water could change due to low water or by intermittent tap water is used for casting.

The potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable water was used for making concrete available in Material Testing laboratory. This was free from any detrimental contaminants and was good potable quality.

Iron Slag:-

In this work, the Iron Slag is taken from the JMP Industry located at Jalandhar, Punjab. It is black in colour

Characteristics	Value
Colour	Grey
Size	20mm
Shape	Angular
Specific Gravity	2.78

Test Methods:-

The procedure of methods used for testing cement, coarse aggregates, fine aggregate and concrete are given below:

Specific Gravity

Specific gravity is ratio of the weight of a given volume of a substance to the weight of an equal volume of some reference substance, or equivalently the ratio of the masses of equal volumes of two substances. Specific gravity is not a sign of the quality of the cement, but is required for calculations during concrete mix design. The specific gravity of Portland cement is approximately 3.15.

Specific Gravity of Aggregate

Setting Time:-

To enable the concrete to be laid in position properly the initial setting of cement should not start too quickly. Once the concrete has been laid it should harden rapidly so that the structure could be put to use early. Initial setting of cement is that step in the process of setting, after which if any cracks appear do not reunite. Final setting is that when it has occurred, sufficient strength and hardness is attained. As soon as water joins the cement, it forms gel that causes the paste to stiffen. However, this stiffening does not affect workability until initial set takes place. Thus, setting describes "The strength of the cement paste". Setting may also be understood as "setting refers to a transformation from a fluid to a hard state". During setting, the paste attains some strength. But it is different from hardening, which refers to the increase of strength of a set cement paste. The setting process is associated with temperature changes in the cement paste. Initial set is related to a quick increase in temperature and final set to the highest temperature. Setting time decreases with rise in temperature.

Setting time of cement can be increased by adding some admixture, as sodium carbonate. The setting time of cement is measured using vicat apparatus with different penetrating attachment.

Final setting time of cement

Sieve Analysis for Coarse and Fine Aggregates as per IS: 2386 (Part I) – 1963

The sieve analysis is used for the determination of particle size distribution of fine and coarse aggregates by sieving or screening.

Compressive Strength of Concrete:-

Cube specimens of size 150 mm x 150 mm x 150 mm were taken out form the curing tank at the ages of 7,14 and 28 days and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested. The position of cube when tested was at right angle to that as cast.

The load of4KN as applied gradually without shock till the failure of the specimen occurs and thus the compressive strength was found. The quantities of cement, coarse aggregate (20 mm), fine aggregate, Iron slag and water for each batch i.e. for different percentage of iron slag replacement was weighed separately.

The cement and iron slag were mixed dry to a uniform colour separately

Concrete Mixes:-

Mix design for M30 grade of concrete was carried out using the guidelines prescribed by IS: 10262-1982. Iron slag concrete mixes were obtained by adding Iron slag to basic control mix in percentages varying from 25% to 35% at an increment of 5% by weight of cement. (ISC0, ISC25, ISC30, ISC35).

Batching, Curing and Mixing:-

The concrete ingredients cement, sand and coarse aggregate were weighed according to M30 and are dry mixed on a platform. To this the calculated quantity of iron slag was added and dry mixed thoroughly. The required quantity of water was added to the dry mix and homogenously mixed. The homogeneous concrete mix was placed layer by layer in moulds kept on the vibrating table. The specimens are given the required compaction both manually and through table vibrator. After through compaction the specimens were finished smooth. After 24 hours of casting, the specimen were remolded and transferred to curing tank where in they were immersed in water for the desired period of curing.

8. RESULTS AND DISCUSSION

This chapter deals with the presentation of results obtained from various tests conducted on concrete specimens cast with and without iron slag. The main objective of the research program was to understand the strength of concrete obtained using iron slag as partial replacement for sand. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of iron slag on compressive strength and split tensile strength. The experimental program consists of casting, curing and testing of controlled and iron slag concrete specimen at different ages.

The experimental program included the following:

- Testing of properties of materials used for making concrete.

- Design mix (M30).

- Tests to determine the compressive strength and split tensile strength.

Compressive Strength:-
In most structural applications, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal.
The vertical crack occurs due to lateral tensile strains. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strains.

Test Procedure and Results:-

Test specimens of size 150*150*150 mm were prepared for testing the compressive strength concrete. The concrete mixes with varying percentages (0%, 25%, 30% and 35%) of iron slag as partial replacement of fine aggregate (sand) were cast into cubes and cylinders for subsequent testing.

In this study, to make concrete, cement and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at a temperature of 270C. The specimens so cast were tested after 7, 14 and 28 days of curing measured from the time water is added to the dry mix. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with varying proportions of iron slag replacement at the age of 7, 14 and 28 days are given in table 4, 5 and 6.

Compressive strength of cube for 7days

Mix(%)	Compressive Strength		Average compressive strength after 7days
	Specimen 1	Specimen 2	
0	20.02	20.18	20.10
25	33.45	33.53	33.49
30	42.39	42.43	42.410
35	37.67	37.79	37.73

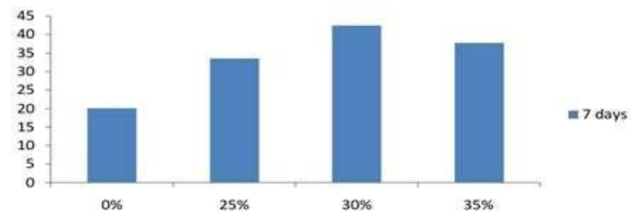


Fig.Graphical Representation of cube for 7 days

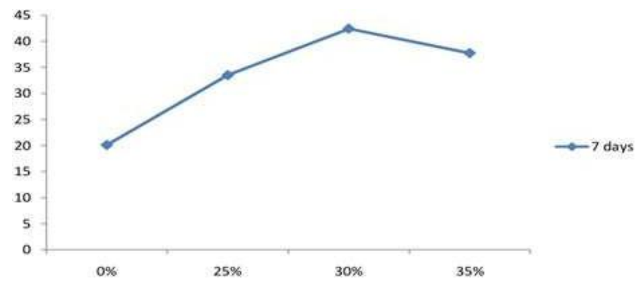


Fig Linear Representation of cube for 7days

Table .Compressive strength of cube for 14days

Mix(%)	Compressive Strength		Average compressive strength after 7days
	Specimen 1	Specimen 2	
0	25.48	25.62	25.55
25	41.32	41.04	41.18
30	49.59	49.73	49.66
35	44.68	44.82	44.75

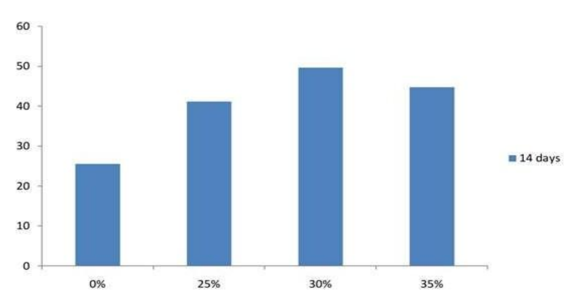


Fig Graphical Representation of cube for 14 days

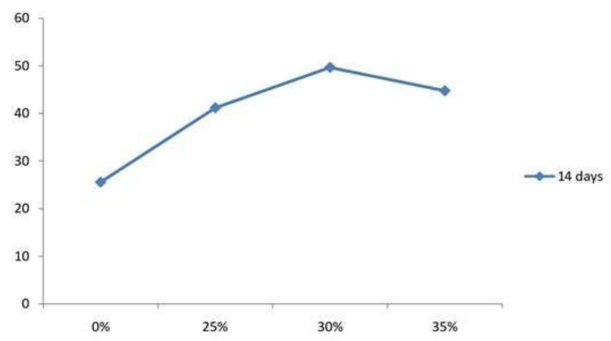


Fig Linear Representation of cube for 14 days

Table .Split Tensile Strength of Cylinder after 28 Days

Mix%	Split Tensile Strength N/mm^2		Average split tensile strength after 28 days
	Specimen 1	Specimen 2	
0	4.60	4.74	4.67
25	4.72	4.98	4.85
30	4.83	4.97	4.90
35	4.79	4.93	4.86

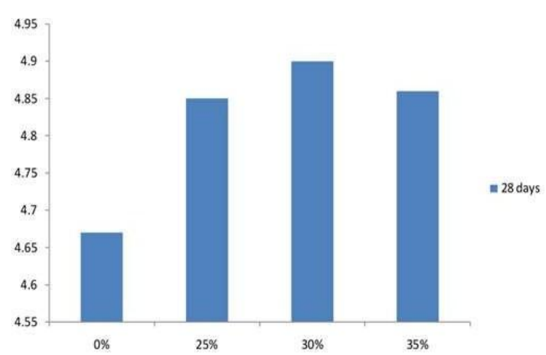


Fig .Graphical Representation of Cylinder for 28 Days

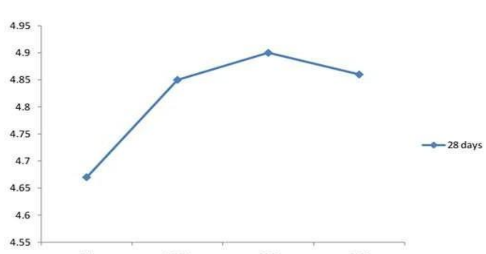


Fig.Linear Representation of Cylinder for 28 Days

9. CONCLUSIONS

The strength characteristics of concrete mixtures have been computed in the present work by replacing 25%, 30% and 35% iron slag with the sand. On the basis of present study, following conclusions are drawn.

Compressive Strength:-

- After adding 25% iron slag in the mix, there is an increase in compressive strength after 7 days, 14 days and 28 days respectively as compare to control mix. After 30% there is decrease in compressive strength. At 30% there is enormous increase in compressive strength of cube. The optimum value of compressive strength comes at 30% replacement.
- The Compressive strength tends to increase with increase percentages of iron slag in the mix.
- The optimum strength of cube is obtained at 30% replacement.

Fig .Compressive Strength of Cube

Split Tensile Strength:-

- After adding 25% iron slag in the mix, there is an increase in split tensile strength after 7 days, 14 days and 28 days respectively as compare to control mix. After 30% there is decrease in compressive strength. At 30% there is enormous increase in split tensile strength of cube. The optimum value of split tensile strength comes at 30% replacement.
- The Compressive strength tends to increase with increase percentages of iron slag in the mix.

- The optimum strength of cube is obtained at 30% replacement.

Fig .Split Tensile Strength of Cylinder

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