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RESEARCH ARTICLE

Study of Partial Replacement of Fine Aggregate by Iron Slag.

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Abstract

The environment problems are very common in India due to generation of industrial byproducts. Due to industrialization enormous byproducts are produced and to utilize these byproducts is the main challenge faced in India. Iron slag is one of the industrial byproduct from the iron and steel making industries. Considering the specificity of physical and chemical properties of metallurgical slag and a series of possibilities for their use in other industrial branches and in the field of civil constructions. This study shows the possibilities of using iron slag as partial replacement of fine aggregate (sand) by iron slag. Iron slag was used to replace 25% to 30% of sand by weight at increment of 5% for both cube and cylinder. The strength of concrete increases rapidly with increase the iron slag content and the optimum value of compressive strength is obtained at 30% replacement. After 30% replacement the strength decreases. Similarly in the case of split tensile strength, the strength increases with the increase in iron slag content and the optimum value of split tensile strength is obtained at 30%. The uniform load conditions for compressive strength and split tensile strength are 4KN and 2KN respectively. In this study, the compressive strength of the iron slag concrete was studied. The results confirm that the use of iron slag overcome the pollution problems in the environment. The results shows that the iron slag added to the concrete had greater strength than the plain concrete.

Introduction:-

As slag is an industrial by- product, its productive use grant an chance to relocate the utilization of limited natural resources on a large scale. Iron slag is a byproduct obtained in the manufacture of pig iron in the blast furnace and is produced by the blend of down to earth constituents of iron ore with limestone flux. Iron and steel slag can be differentiating by the cooling processing when removed from the furnace in the industry. Mostly, the slag consists of magnesium, aluminum silicates calcium and manganese in various arrangements. Even though the chemical composition of slag same but the physical properties of the slag vary with the varying method of cooling. The slags can be used as cement major constituents as they have greater pozzolanic properties.

The history of the use of iron and steel slag dates back a long way. European Slag Association (2006) has reported about the earliest reports on the use of slag, where in it is mentioned that Aristotle used slag as a medicament as early as 350 B.C. In the past, the application of steel slag was not noticeable because enormous volumes of blast furnace slag were available. Through awareness of environmental considerations and more recently the concept of sustainable development, extensive research and development has transformed slag into modern industrial product which is effective and beneficial.

The American Society of Testing and Materials (ASTM) (1999) define blast furnace slag as “the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition at the same time with iron in a blast furnace." Slag was considered to be essential in the production of iron, but once it served its purpose in refining the metal, it was strictly a nuisance with little or no use. The usefulness of slag was realized with the first ore smelting process. The use of slag became a common practice in Europe at the turn of the 19th century, where the incentive to make all possible use of industrial by-products was strong and storage space for by-products was lacking. Shortly after, many markets for slag opened in Europe, the United States, and elsewhere in the world.

Material And Design Methodolgy:-

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 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.

Table 1:- Properties of OPC 43 grade.

S.No	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 7 days 28 days	 25.2 N/mm2 37.9 N/mm2 47.8 N/mm2	 23 N/mm2(minimum) 33 N/mm2(minimum) 43 N/mm2(minimum)

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.

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.

Table 2:- Properties of Coarse Aggregates.

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

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.

Table 3:- Properties of fine aggregate

Characteristics	Value
Specific gravity	2.32
Bulk density(kg/m3)	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 as shown in Figure 1.

Figure1:**-** Concrete mix with iron slag.

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.

Figure 2:- 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 attachments.

Figure 3:- 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.

Figure 4:- Compressive strength of cube.

Split Tensile Strength of Concrete:-

The split tensile strength of concrete is determined by casting cylinders of size 100 mm X 200 mm. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 7, 14 and 28 days of moist curing and tested after surface water dipped down from specimens. This test was performed on compression Testing Machine (CTM). The uniform applied loading of 2KN is given to sample in compression testing machine (CTM). 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. Fine aggregate was mixed to this mixture in dry form. The coarse aggregates were mixed to get uniform distribution throughout the batch. Water added to the mix. Firstly, 50 to 70% of water was added to the mix and then mixed thoroughly for 3 to 4 minutes in mixer. Then the concrete was filled into the cylindrical moulds and then get vibrated to ensure proper compaction. The surface of the concrete was finished level with the top of the mould using trowel.

The magnitude of tensile stress (T) acting uniformly to the line of action of applied loading is given by formula

$T = 0.637P/dl$

Where,

T = Split Tensile Strength in MPa

P = Applied load,

D = Diameter of Concrete cylinder sample in mm.

L =Length of Concrete cylinder sample in mm.

The finished specimens were left to harden in air for 24 hours. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank, filled with potable water in the laboratory.

Figure 5:- Split tensile strength of cylinder.

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 demoulded and transferred to curing tank where in they were immersed in water for the desired period of curing.

Mix Design (M30):-

Test data for materials

(i) Specific gravity of cement	3.15
(ii) Specific gravity of coarse aggregates	2.78
(iii) Specific gravity of fine aggregates	2.32
(iv) Zone of fine aggregates	II
(v) Water absorption of coarse aggregates	0.43%
(vi) Water absorption of fine aggregates	0.88%

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.

Table 4:- Compressive strength of cube for 7days.

Mix(%)	Compressive Strength(N/mm2)		Average Compressive Strength after 7 days
	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

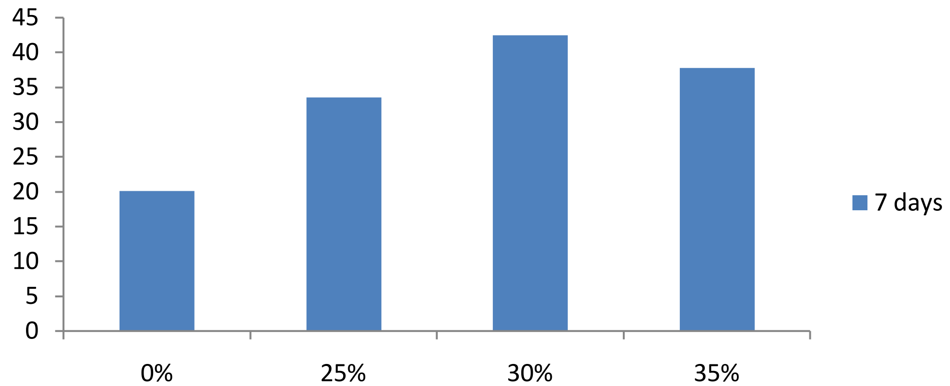

Figure 6:- Graphical Representation of cube for 7 days.

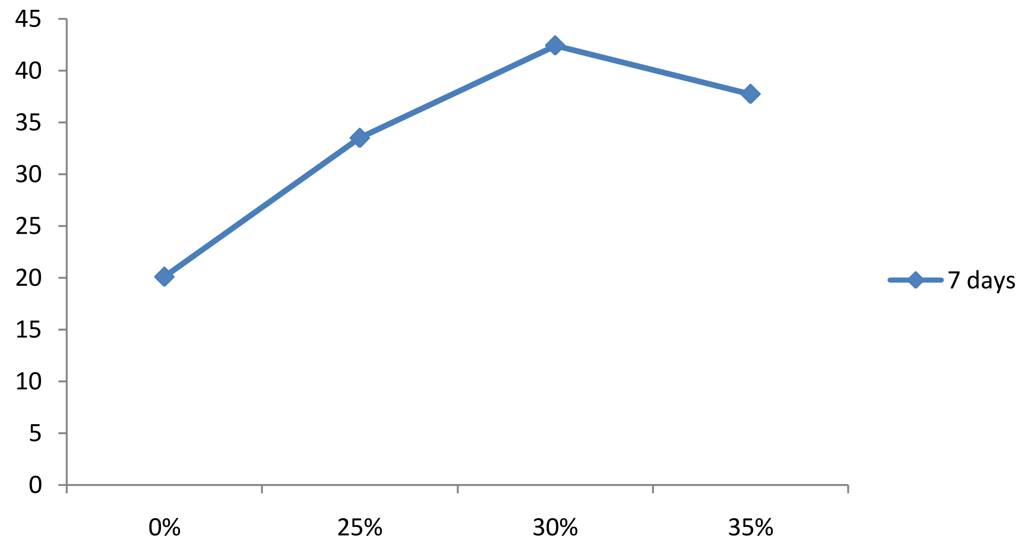

Figure 7:- Linear Representation of cube for 7 days.

Table 5:- Compressive strength of cube for 14 days.

Mix(%)	Compressive Strength(N/mm2)		Average Compressive Strength after 14 days
	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

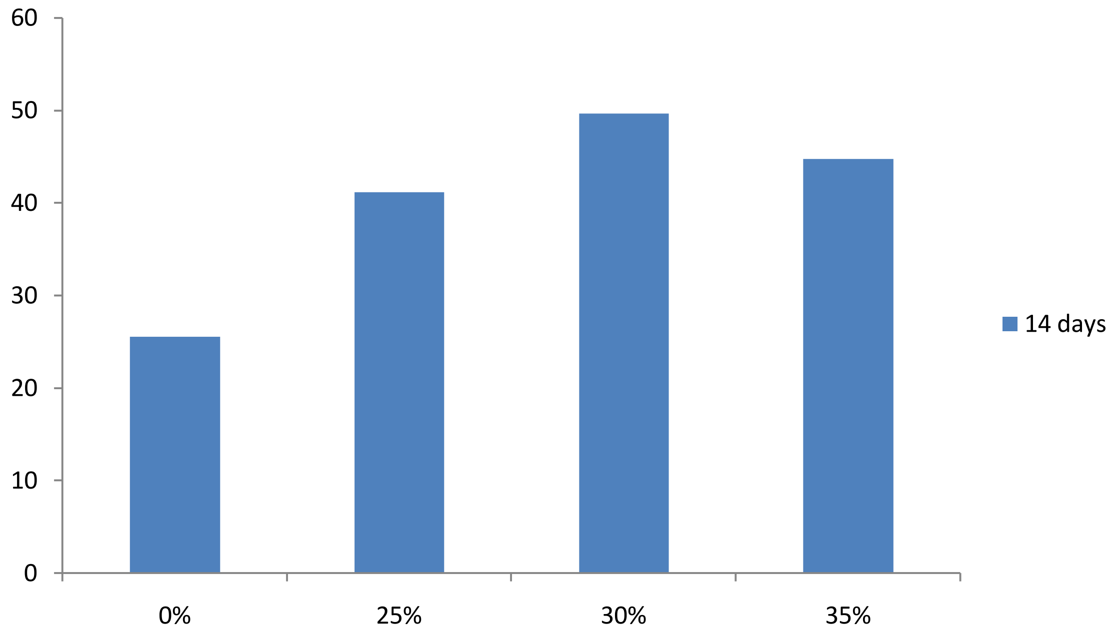

Figure 8:- Graphical Representation of cube for 14 days.

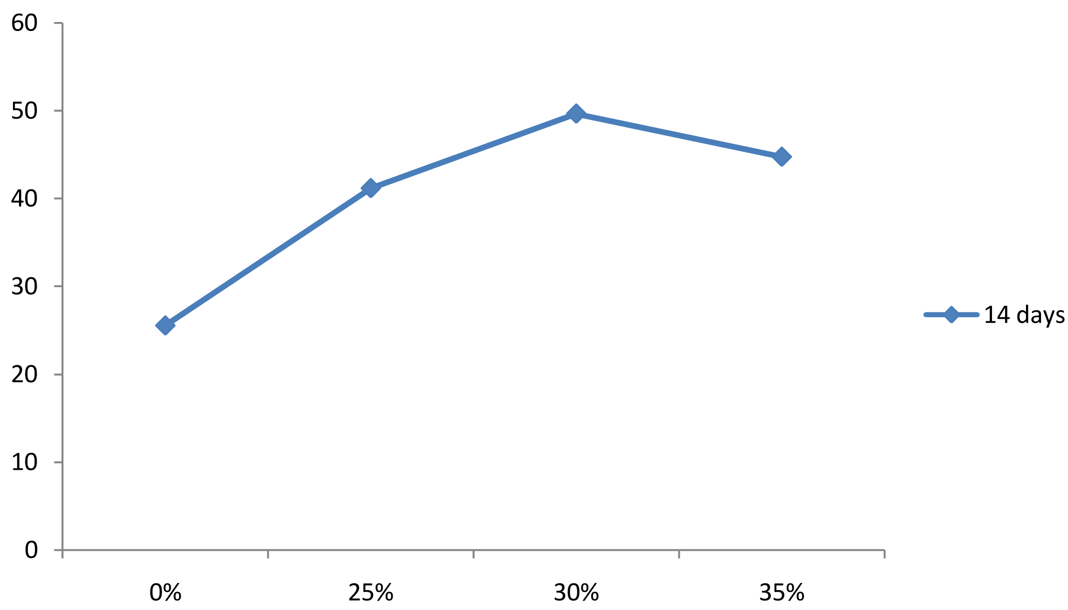

Figure 9:- Linear Representation of cube for 14 days.

Table 6:- Compressive strength of cube for 28 days.

Mix(%)	Compressive Strength(N/mm2)		Average Compressive Strength after 28 days
	Specimen 1	Specimen 2	
0	32.22	32.38	32.30
25	48.54	48.66	48.60
30	55.12	55.36	55.24
35	47.18	47.30	47.24

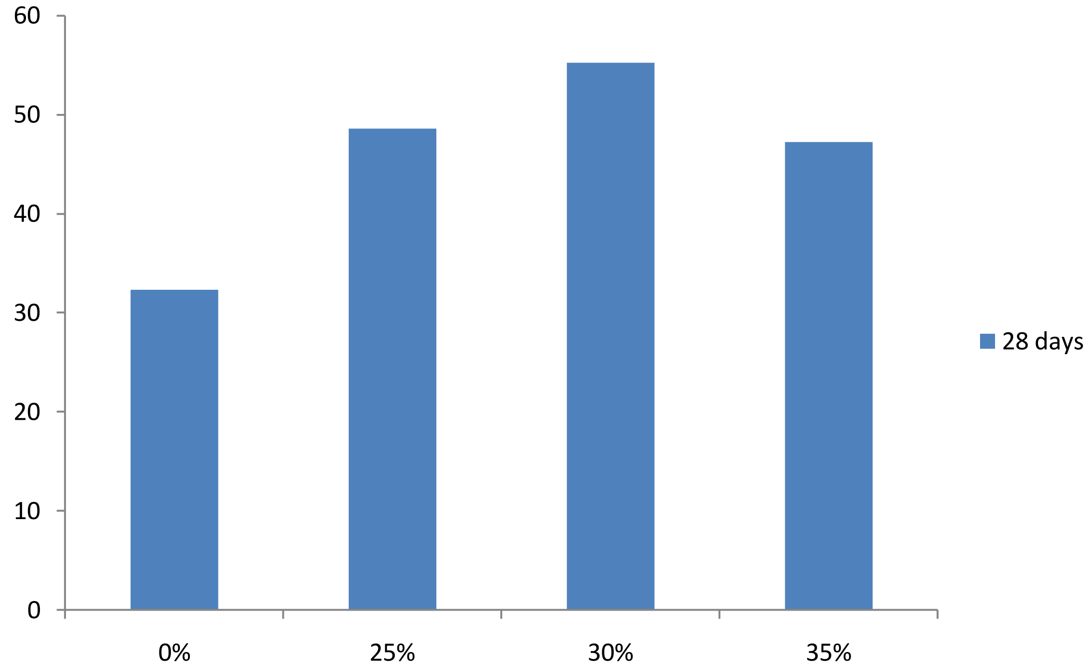

Figure 10:- Graphical Representation of cube for 28 days.

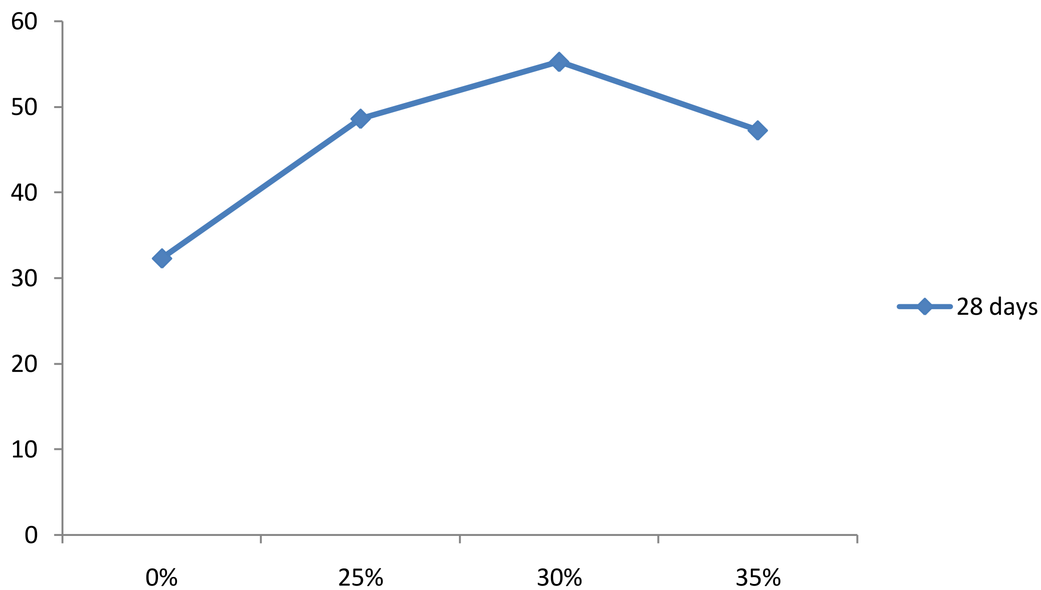

Figure 11:- Linear Representation of cube for 28 days.

Figure 12:- Compressive strength test in progress.

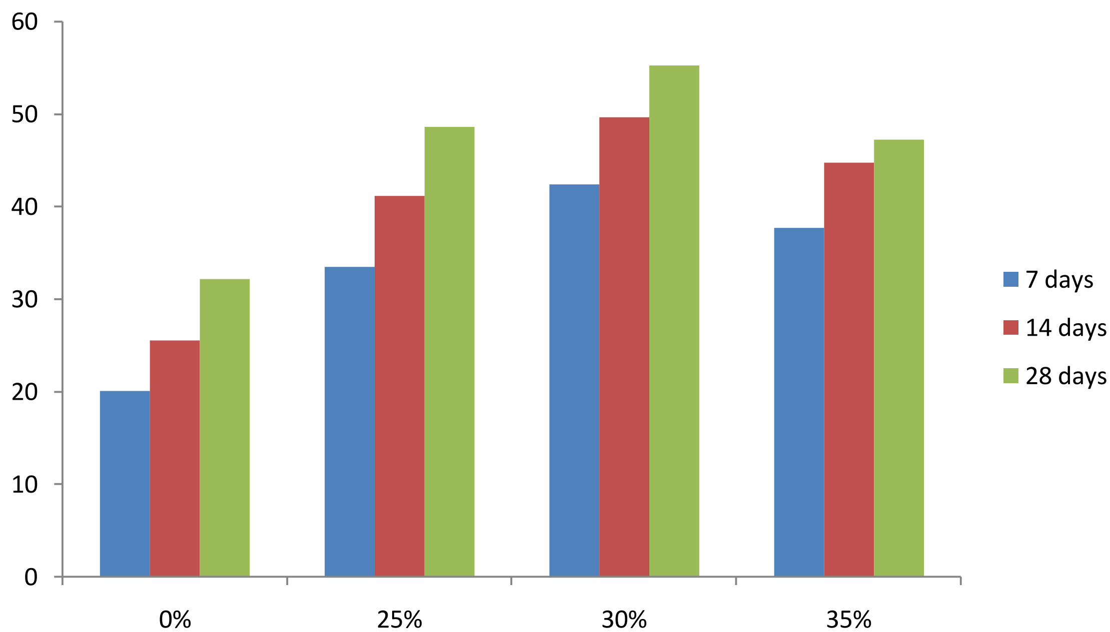

Figure 13:- Comparison of cubes according to days.

The compressive strength increases as compared to control mix as the percentage of iron slag is increased. 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%.

Split Tensile Strength Test:-

Split tensile strength studies were carried out at the age of 7, 14 and 28 days. The split tensile results follow the pattern similar to compressive strength i.e. increase in the value with increase in percentage of iron slag replacement. However, the percentage increase in split tensile strength is smaller as compared to compressive strength. The split tensile strength increases with the percentage increase of iron slag as compared to control mix.

The split tensile strength increases as compared to control mix as the percentage of iron slag is increased. 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 split tensile strength. At 30% there is enormous increase in split tensile strength of cube. The optimum value of split tensile comes at 30%.

Table 7:- Split tensile strength of cylinder for 7 days.

Mix(%)	Split Tensile Strength(N/mm2)		Average Split Tensile Strength after 7 days
	Specimen 1	Specimen 2	
0	2.44	2.52	2.48
25	2.84	2.92	2.88
30	3.44	3.36	3.40
35	2.91	2.95	2.93

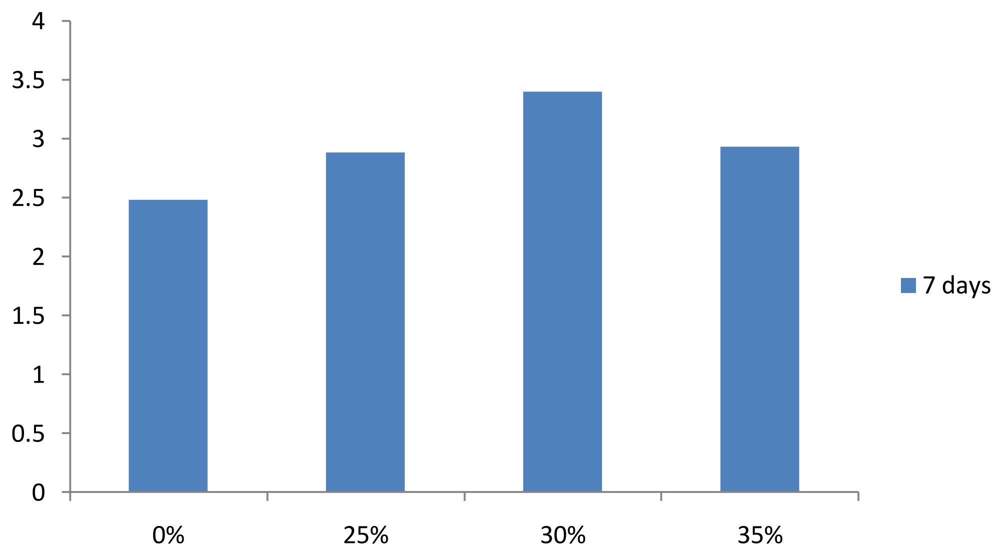

Figure 14:- Graphical Representation of cylinder for 7 days.

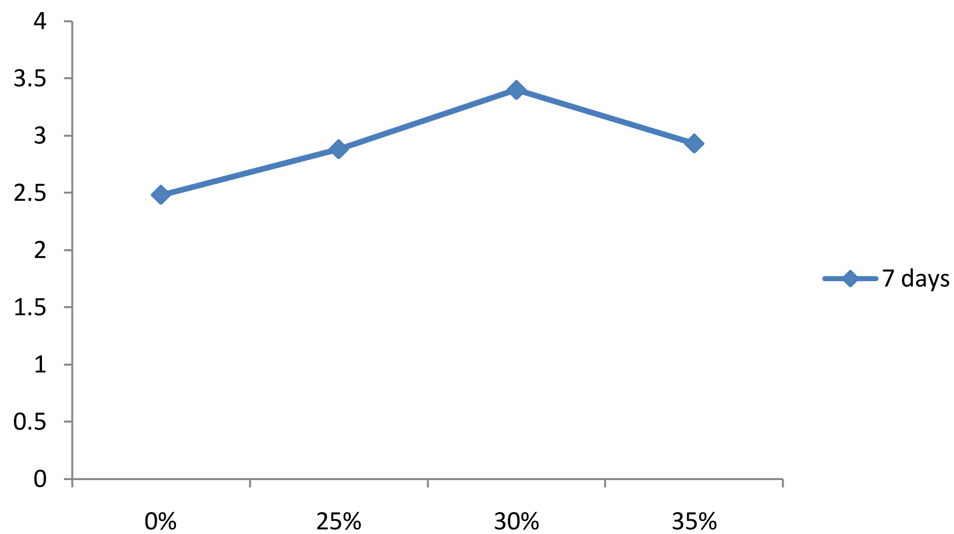

Figure 15:- Linear Representation of cylinder for 7 days.

Table 8:- Split tensile strength of cylinder for 14 days.

Mix(%)	Split Tensile Strength(N/mm2)		Average Split Tensile Strength after 14 days
	Specimen 1	Specimen 2	
0	3.17	3.25	3.21
25	3.51	3.57	3.54
30	3.89	3.99	3.94
35	3.71	3.83	3.77

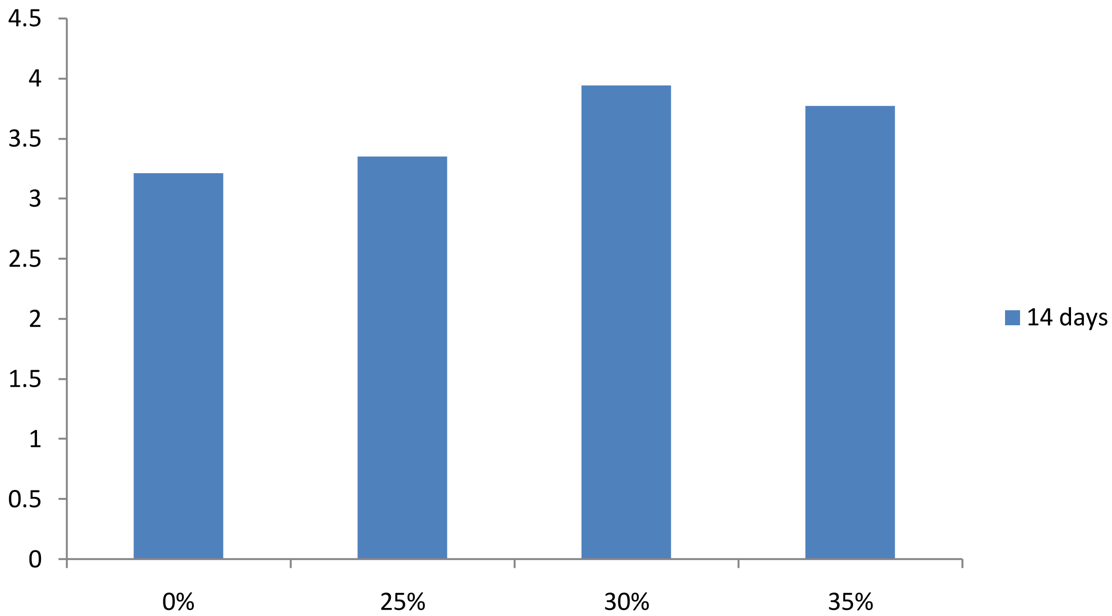

Figure 16:- Graphical Representation of cylinder for 14 days.

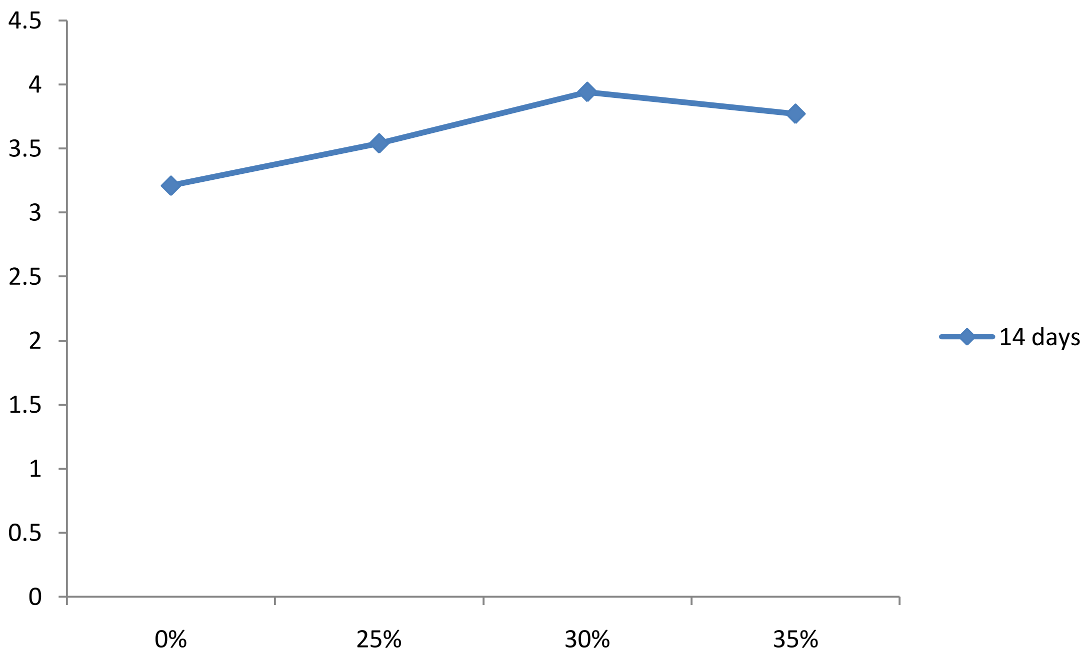

Figure 17:- Linear Representation of cylinder for 14 days.

Table 9:- Split tensile strength of cylinder for 28 days.

Mix(%)	Split Tensile Strength(N/mm2)		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

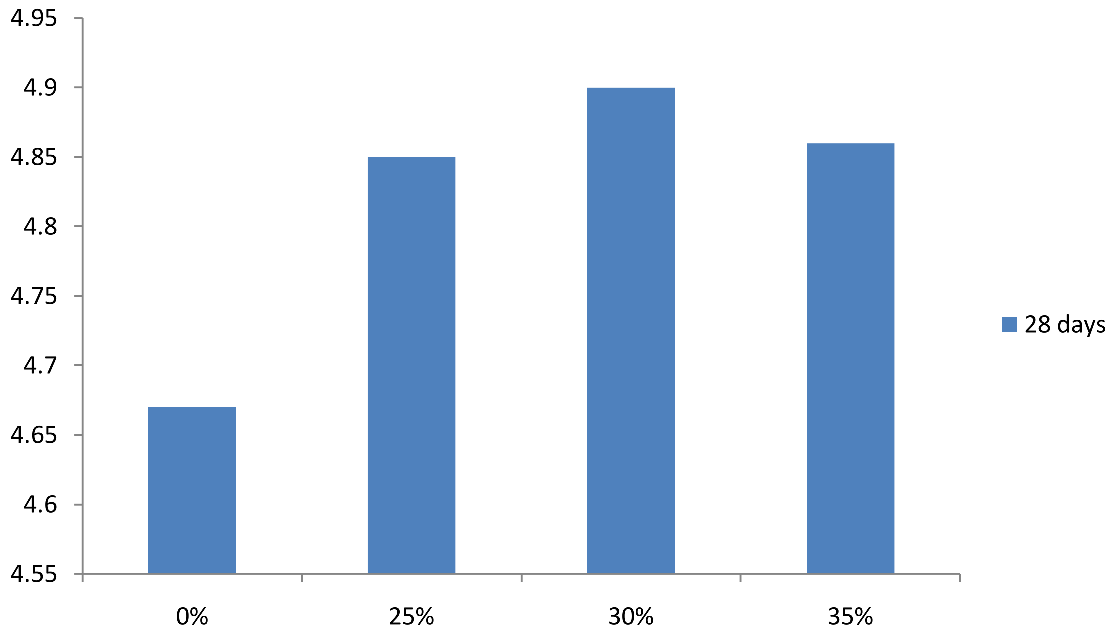

Figure 18:- Graphical Representation of cylinder for 28 days.

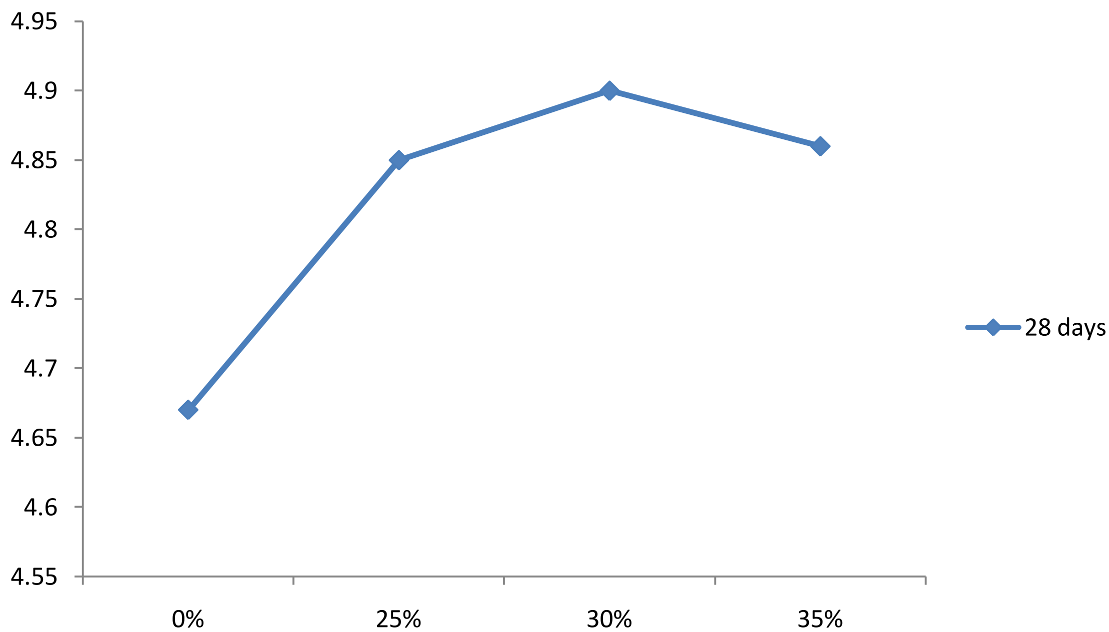

Figure 19:- Linear representation of cylinder for 28 days.

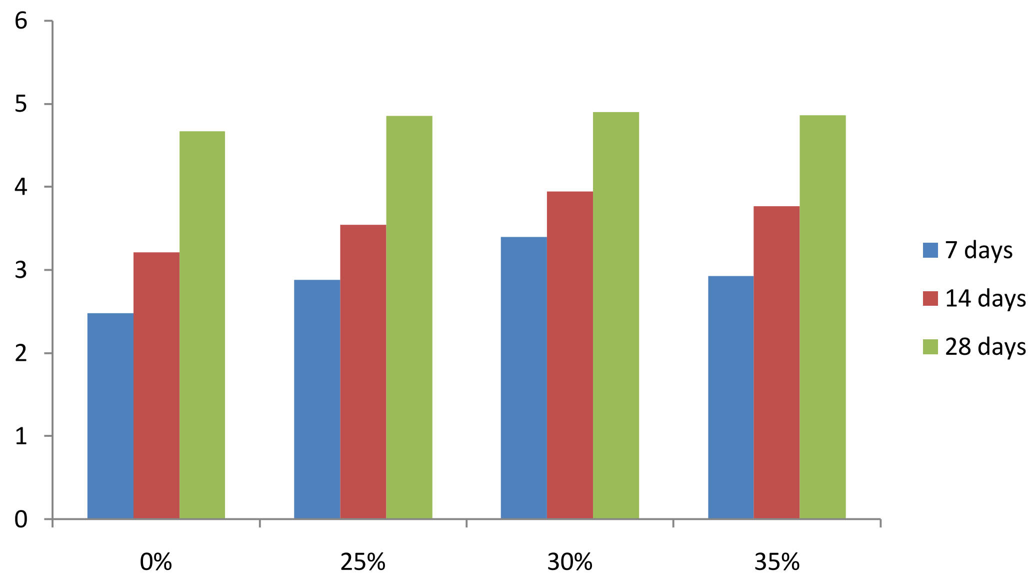

Figure 20:- Comparison of cylinder according to days.

Figure 21:- Split tensile strength test in progress.

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.

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.

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