IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 05, Issue 05 (May. 2015), ||V3|| PP 64-73

Experimental Investigation Of Coarse Aggregate With Steel Slag In Concrete

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Abstract: Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of green house gases, such as CO2, to the atmosphere. Among the greenhouse gases, CO2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. Glass is used in many forms in day-to-day life. It has limited life span and after use it is either stock piled or sent to landfills. Since glass is non-biodegradable, landfills do not provide an environment friendly solution. Hence, there is strong need to utilize waste glasses. Many efforts have been made to use waste glass in concrete industry as a replacement of coarse aggregate, fine aggregate and cement. Its performance as a coarse aggregate replacement has been found to be non-satisfactory because of strength regression and expansion due to alkali-silica reaction. The research shows that there is strength loss due to fine aggregate substitution also. Efforts have been made in the concrete industry to use waste glass as partial replacement of coarse or fine aggregates and cement. In this study, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete. This work examines the possibility of using Glass powder as a partial replacement of cement for new concrete. Glass powder was partially replaced as 10%, 20%, 30% and 40% and tested for its compressive, Tensile and flexural strength up to 28 days of age and were compared with those of conventional concrete; from the results obtained, it is found that glass powder can be used as cement replacement material up to particle size less than 75μm to prevent alkali silica reaction.

Keywords: *Experimental , Investigation, Coarse Aggregate, Steel Slag, Concrete*

I. INTRODUCTION

Slag is a partially vitreous by product of the process of smelting ore. Slag is usually a mixture of metal oxides and silicon dioxides. One of the most beneficial uses for furnace slag is in concrete. Because of its chemical and physical properties, it is a very reactive aggregate. Concrete containing slag can have very high strength and can be very durable. So Slag is can be used in concrete. When it is used in concrete, it acts as filler and as a strengthening material. The furnace slag also combines with calcium oxide and iron oxide. Both of these actions result in a denser, stronger and less permeable material. In this slag concrete we have replaced coarse aggregate up to 50, 60 and 70 percent by furnace slag. Slag has been used as an addition to concrete up to 70 percent by weight of coarse aggregate. It increases the water demand in a concrete mix; however, dosage rates of less than 5 percent will not typically require a water reducer. High replacement rates will require the use of a high range water reducer. The waste material was substituted for replacement of coarse aggregates and for the preparation of concrete blocks. In this project, we have followed Indian standard methods and arrived at the mix design for M35 grade concrete. The preliminary studies were conducted by mixing the slag with the cement concrete cubes of standard sizes.

II. MATERIAL COLLECTIONS

2.1 Cement

Ordinary Portland cement, 53Grade conforming to IS: 269 – 1976.Ordinary Portland cement, 53Gradewas used for casting all the Specimens. Different types of cement have different water requirements to produce pastes of standard consistence. Different types of cement also will produce concrete have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the particular cement used. It is also important to ensure compatibility of the chemical and mineral admixtures with cement.

2.2 Fine Aggregate

Locally available river sand conforming to Grading zone I of IS: 383 –1970.Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens.

2.3 Course Aggregate

Locally available crushed blue granite stones conforming to graded aggregate of nominal size 20 mm as per IS: 383 – 1970.Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability.

2.4 Slag

Obtained from JSW Steel Ltd., Mecheri conforming to ASTM C 989 as coarse aggregate form. Slag is a partially vitreous by product of the process of smelting ore. Slag is usually a mixture of metal oxides and silicon dioxides. Slag are named based on the furnaces from which they are generated. Slag, the by-product of steel and iron producing processes, has been used in civil engineering for more than 100 years. Rapidly water-cooled Furnace Slag, due to its relative high amorphous silica content which has pozzolanic activities, is to be employed in the production of blended cement. Even there are some research works about the properties of concrete, in which air-cooled and ground granulated FS is used as aggregate. The conclusions of these studies indicate that there is a great likelihood to use FS instead of natural aggregate in concrete. Steel slag has higher strength characteristics than normal aggregate, which result in more strength differences between slag aggregate concrete and natural aggregate concrete, in high strength concrete series. Slag is a waste metallic material which might have long term delayed reactions, further experiments would be necessary to evaluate the durability of concrete made by steel slag aggregates. The following size of slag available from JSW Steel Ltd,0-4mm,4-12mm,12-20mm,20-40mm and above 40mmCrushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability Slag is one of the artificial lime stone and silica, commonly used as coarse aggregate in HPC. Slag is a partially vitreous by product of the process of smelting ore. Slag is usually a mixture of metal oxides and silicon dioxides. One of the most beneficial uses for furnace slag is in concrete.

III. PROPERTIES OF MATERIAL

3.1 Physical Properties Of Cement

Physical Properties Of Cement given in Table.3.1

Table 3.1: Physical Properties Of Cement

S.NO	PROPERTY OF EMENT	VALUE
1	Fines of cement	7.5%
2	Grade of cement	53 Grade(OPC)
3	Specific gravity of cement	3.15
4	Initial setting time	30min
5	Final setting time	60min
6	Normal consistency	35%

3.2 Propertiy Of Fine Aggregate

Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens. Properties Of Fine Agreggate given in Table.3.2

Table.3. 2 Properties Of Fine Agreggate

S.NO	PROPERTIES	VALUE
1	Specific Gravity	2.65
2	Fineness Modulus	2.25
3	Water absorption	1.5%

3.3 Propertiy Of Course Aggregate

Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability. Properties Of Course Aggregate given in Table 3.3

Table.3. 3 Properties Of Course Aggregate

S.NO	PROPERTIY	VALUES
1	Specific Gravity	2.68
2	Size Of Aggregates	20mm
3	Fineness Modulus	5.96
4	Water absorption	2.0%
5	Impact Test	15.2%

3.4 Slag

Slag is one of the artificial lime stone and silica, commonly used as coarse aggregate in HPC. Slag is a partially vitreous by product of the process of smelting ore. Slag is usually a mixture of metal oxides and silicon dioxides. One of the most beneficial uses for furnace slag is in concrete.Physical Properties Of Slag given in Table.3. 4

Table.3. 4 Physical Properties Of Slag

S.NO	COMPOSITION	VALUE
1	Specific gravity	3.12
2	Specific surface area of about	1050-1375 kg/m^3
3	Unit Weight	1600 - 1920, kg/m^3
4	Absorption	up to 3%

3.4.1 Physical Properties Of Slag

The particle size, color, oversize, specific gravity, etc. are explained briefly:-

1) **Particle Size**: - Slag particles are granular shape, spherical size is 1/100 the diameter of Portland cement particle and average particle diameter lies between 0.1 to 0.2 micron range.
2) **Colour**: - The color of Slag depends on silica content, In contrast to the stony grey of concrete made with Portland cement, the near white color of furnace slag cement permits architects to achieve the lighter color finish.
3) **Specific Gravity**: - The specific gravity of slag produced from high quality silica and high grade ferrosilicon alloys typically ranges between 3.0 and 3.6.

3.4.2 Chemical Properties Of Slag

Table 3.5 Chemical Properties Of Slag

Chemical parameter	Slag (%)
SiO_2	10-19
Al_2O_3	1-3
Fe_2O_3	10-40
CaO	40-52
MgO	5-10
MnO	5 - 8
Metallic Fe	0.5 - 10

3.5 Water

Casting and curing of specimens were done with the potable water that is available in the college premises.

3.6 Constituent Materials Used

Materials that are used for making concrete for this study will be tested before casting the specimens. The preliminary tests will be conducted for the following materials.

- Cement
- Fine aggregate
- Coarse aggregate
- Water
- Slag

3.6.1 Cement

Cement used in construction is characterized as hydraulic or non-hydraulic. Hydraulic cements (e.g., Portland cement) harden because of hydration, chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (e.g., lime and gypsum plaster) must be kept dry in order to retain their strength. The most important use of cement is the production of mortar and concrete. The bonding of natural or artificial aggregates to form a strong building material that is durable in the face of normal environmental effects.

3.6.2 Aggregates

"Fine aggregate" is defined as material that will pass a No. 4 sieve and will, for the most part, be retained on a No. 200 sieve. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.Coarse aggregate is a material that will pass the 3-inch screen and will be retained on the No. 4 sieve. As with fine aggregate, for increased workability and economy as reflected by the use of less cement, the coarse aggregate should have a rounded shape. Even though the definition seems to limit the size of coarse aggregate, other considerations must be accounted for the concrete.

3.6.3 Coarse Aggregates

Broken granite stone/gravel and its size is 4.75mm gauge plus i.e., retained on 4.75mm IS sieve.

3.6.4 Slag

Slag in stone/gravel form is added to coarse aggregate in concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. Addition of furnace a slag so reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions and those of humid continental roadways and runways (because of the use of deicing salts) and saltwater bridges.

IV. MIX DESIGN

4.1 Definition

Mix design is the process of selecting suitable ingredient if concrete and determines their relative proportions with the object of certain minimum strength and durability as economically as possible.

4.2 Objective Of Mix Design

The objective of concrete mix design as follows.

- The first objective is to achieve the stipulated minimum strength.
- The second objective is to make the concrete in the most economical Manner. Cost wise all concrete's depends primarily on two factors, namely cost of material and cost of labour. Labor cost, by way of formwork, batching, mixing, transporting and curing is namely same for good concrete.

V. TESTING PROCEDURE

5.1 Compressive Strength Test

Compressive strength is often measured on a universal testing machine; these range from very small table-top systems to ones with over 53 MN capacity.[1] Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.(Figure.5.1)

- Representative samples of concrete shall be taken and used for casting cubes 15 cm x 15 cm x 15 cm

- The concrete shall be filled into the moulds in layers approximately 5 cm deep. It would be distributed evenly and compacted either by vibration or by hand tamping. After the top layer has been compacted, the surface of concrete shall be finished level with the top of the mould using a trowel; and covered with a glass plate to prevent evaporation.
- The specimen shall be stored at site for 24+ ½ h under damp matting or sack. After that, the samples shall be stored in clean water at $27+2^0$C; until the time of test. The ends of all cylindrical specimens that are not plane within 0.05 mm shall be capped.
- Specimen shall be tested immediately on removal from water and while they are still in wet condition.
- The bearing surface of the testing specimen shall be wiped clean and any loose material removed from the surface. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load cube as cast, that is, not to the top and bottom.
- Align the axis of the specimen with the steel platen, do not use any packing.
- The load shall be applied slowly without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen to the increased load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and any unusual features noted at the time of failure brought out in the report.

Figure.5.1 Compression Test

When a specimen of material is loaded in such a way that it extends it is said to be in tension. On the other hand if the material compresses and shortens it is said to be in compression. On an atomic level, the molecules or atoms are forced apart when in tension whereas in compression they are forced together. Since atoms in solids always try to find an equilibrium position, and distance between other atoms, forces arise throughout the entire material which oppose both tension or compression. The "strain" is the relative change in length under applied stress; positive strain characterises an object under tension load which tends to lengthen it, and a compressive stress that shortens an object gives negative strain. Tension tends to pull small sideways deflections back into alignment, while compression tends to amplify such deflection into buckling. Compressive strength is measured on materials, components, and structures. By definition, the ultimate compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (usually cylindrical) is shortened as well as spread laterally. In the study of strength of materials, the compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structuresAt the time of testing, each specimen must keep in compressive testing machine. The maximum load at the breakage of concrete block will be noted. From the noted values, the compressive strength may calculated by using below formula.

Compressive Strength = Load / Area

Size of the test specimen=150mm x 150mm x 150mm

5.2 Split Tensile Test

The size of cylinders 300 mm length and 150 mm diameter are placed in the machine such that load is applied on the opposite side of the cubes are casted. Align carefully and load is applied, till the specimen breaks. The formula used for calculation.(Figure.5.2)

Split tensile strength = 2P/ πdl

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure.

Figure. 5.2 Split Tensile Test

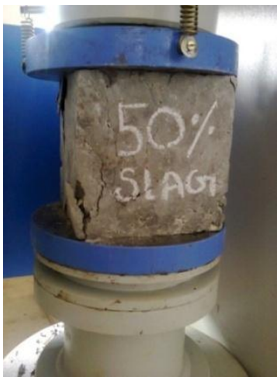


Figure. 5.3 Flexural Strength Test

5.3 Flexural Strength Test

During the testing, the beam specimens of size 700mmx150mmx150mm were used. Specimens were dried in open air after 7 days of curing and subjected to flexural strength test under flexural testing assembly. Apply the load at a rate that constantly increases the maximum stress until rupture occurs.(Figure.5.3). The fracture indicates in the tension surface within the middle third of span length. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength,[a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. The flexural strength would be the same as the tensile strength if the material were homogeneous. In fact, most materials have small or large defects in them which act to concentrate the stresses locally, effectively causing a localized weakness. When a material is bent only the extreme fibers are at the largest stress so, if those fibers are free from defects, the flexural strength will be controlled by the strength of those intact 'fibers'. However, if the same material was subjected to only tensile forces then all the fibers in the material are at the same stress and failure will initiate when the weakest fiber reaches its limiting tensile stress.

VI. TEST RESULT

6.1 Ratio For Special Concrete (Extra Ingredients)

RATIO –I

Furnace slag – 50% by replacement of coarse aggregate

RATIO - II

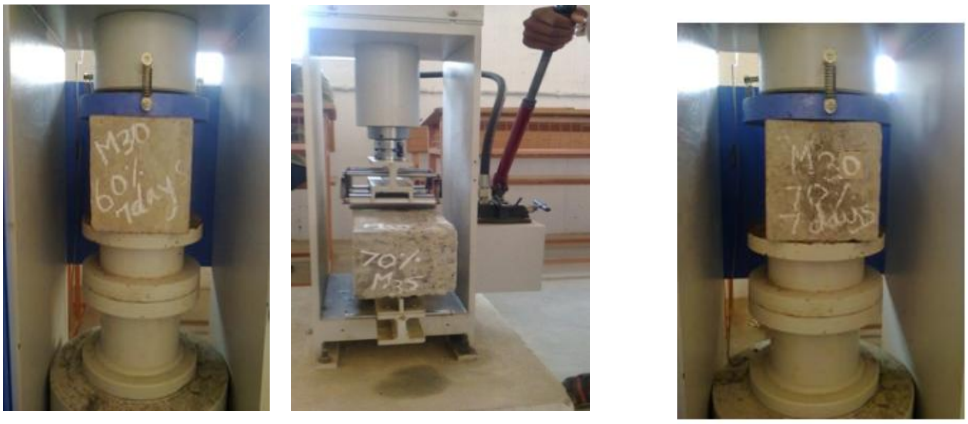
Furnace slag – 60% by replacement of coarse aggregate

RATIO – III:

Furnace slag – 70% by replacement of coarse aggregate

Above all ingredients are added by weight of cement

- Compressive Strength Of Cube For 7 Days,14 days and 28 days are given in Table 6.1,Table.6.2,Table 6.3 and Figure.6.1
- Split Tensile Test For Cylinder 7 Days,14 days and 28 days are given in Table 6.4,Table.6.5 ,Table 6.6 and Figure.6.1
- Flexural Strength Of Beam For 7 Days,14 days and 28 days are given in Table 6.7,Table.6.8,Table 6.9 and Figure.6.1



(A) **B)** **(C)**

Figure.6.1 Compression Testing Of Specimen

A - Compression testing of specimen 50% of slag
B - Compression testing of specimen 60% of slag
C - Compression testing of specimen 70% of slag

Table.6.1 Compressive Strength Of Cube – 7 days

Control Mix	Compressive Strength in N/mm² 7 Days			
	CC (0%)	50%	60%	70%
M30	24.78	26.89	27.5	26.45

Table 6.2 Compressive Strength Of Cube – 14 days

Control Mix	Compressive Strength in N/mm² 14 Days			
	CC (0%)	50%	60%	70%
M30	24.8	25.6	26.7	25.9

Table.6.3 Compressive Strength Of Cube – 28 days

Control Mix	Compressive Strength in N/mm² 28 Days			
	CC (0%)	50%	60%	70%
M30	33.55	35.33	36.44	34.45

Table.6.4 Split Tensile Test For Cylinder– 7

Control Mix	Split tensile Strength in N/mm² 7 Days			
	CC (0%)	50%	60%	70%
M30	2.45	2.83	3.40	3.18

Table.6.5 Split Tensile Test For Cylinder – 14 days

Control Mix	Split tensile Strength in N/mm² 14 Days			
	CC (0%)	50%	60%	70%
M30	3.20	3.65	4.08	3.92

Table.6.6 Split Tensile Test For Cylinder– 28 days

Control Mix	Split tensile Strength in N/mm² 28 Days			
	CC (0%)	50%	60%	70%
M30	3.75	3.89	4.17	4.03

Table.6.7 Flexural Strength Of Beam – 7 days

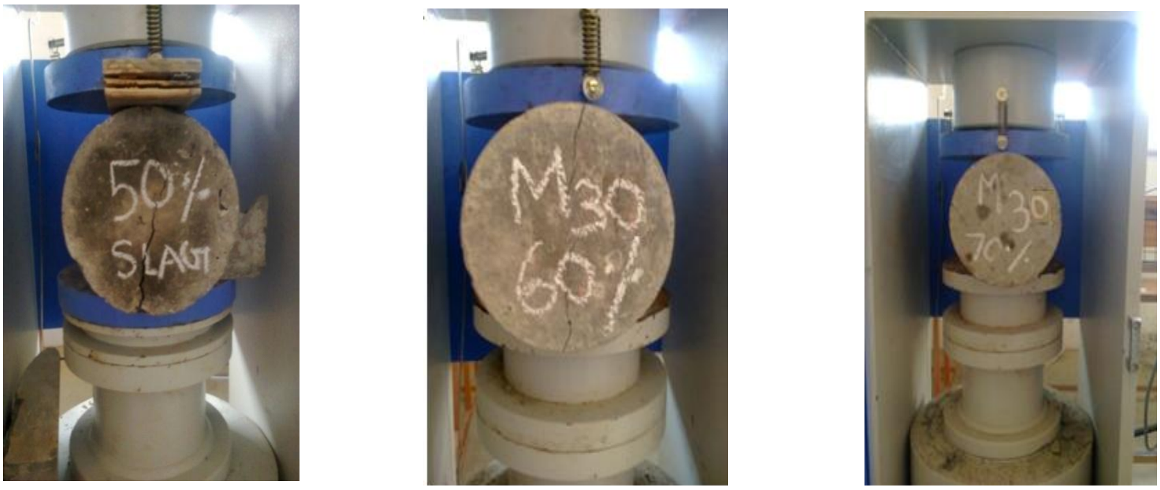
Control Mix	Flexural Strength In N/mm^2 7 Days			
	CC (0%)	50%	60%	70%
M30	4.46	5.39	6.95	6.0

Table.6.8 Flexural Strength Of Beam– 14

Control Mix	Flexural Strength In N/mm^2 14 Days			
	CC (0%)	50%	60%	70%
M30	6.8	7.12	7.65	7.36

Table.6.9 Flexural Strength Of Beam – 28 days

Control Mix	Flexural Strength In N/mm^2 28 Days			
	CC (0%)	50%	60%	70%
M30	7.5	7.36	7.88	7.57



(A) **(B)** **(C)**

Figure.6.2 Split tensile testing of specimen

A -Split tensile testing of specimen 50% of slag
B - Split tensile testing of specimen 60% of slag
C - Split tensile testing of specimen 70% of slag

(A) **(B)** **(C)**

Figure 6.3 Flexural testing of specimen

A - Flexural testing of specimen 50% of slag
B - Flexural testing of specimen 60% of slag
C - Flexural testing of specimen 70% of slag

VII. COST ANALYSIS

7.1 Cost

An amount that has to be paid or given up in order to get something. In business, cost is usually a monetary valuation of effort, material, resources, time and utilities consumed. The original value of an asset for tax purpose, adjusted for stock splits, dividends and return of capital distributions.

7.2 Cost Analysis

The accumulation, examination and manipulation of cost data for comparisons and projections. A process by which business decisions are analyzed. Cost analysis is related to, but distinct from cost effectiveness analysis. Cost analysis is often used by governments and other organizations, such as private sector business, to appraise the desirability of a given policy.

7.3 Cost Optimization

Finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factor and minimizing undesired ones. In comparison, maximization means trying to attain the highest of maximum result or outcome without regard to cost or expense.

VIII. COST DETAILS

Conventional Concrete

Table. 8.1 Conventional Concrete

INCREDIENTS	QUANTITY (Cft)	RATE (Rs)
Cement	6.92	3028
Fine aggregate	12.26	368
Coarse aggregate	28.88	578

Replacement Of Slag

Table 8.2 Replacement Of Slag or 60%

INCREDIENTS	QUANTITY (Cft)	RATE (Rs)
Cement	6.92	3028
Fine aggregate	12.26	368
Coarse aggregate (40%)	**12.48**	**250**
Slag (60%)	**16.4**	**104**

IX. CONCLUSION

The conclusions drawn from these experimental investigations are as follows.

- The Strength of concrete containing furnace slag of 60 % was high compared with that of the conventional mix.
- The coefficient of permeability was found to be negligible in all the samples of concrete mixes containing furnace slag whereas the coefficient of permeability was more in concrete mixes without furnace slag.
- The presence of furnace slag in concrete mixes acts as pore fillers and causes reduction in the pores, resulting fine and discontinuous pore structures and thereby increases the impermeability of concrete.
- Coarse aggregate replacement level of 60 % slag in concrete mixes was found to be the optimum level to obtain higher value of the strength and durability at the age of 28 days.
- By cost analysis it is found that by 60 % replacement of slag, cost is reduced up to 39 % on coarse aggregate. Therefore slag replacement on coarse aggregate up to 60 % is resulted to optimum.

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