Partial Replacement of Coarse and Fine Aggregates using Steel Slag and Waste Glass Powder

MD Rehan[1] Chaitra Nayak[2] Nadeem Dalayat[3] Mallikarjun H.S[4] Niyaz Dafedar[5]
[1,2,3,4]Students [5]Assistant Professor
[1,2,3,4,5]Department of Civil Engineering
[1,2,3,4,5]Secab Institute of Engg and Technology Viajaypura

Abstract— Glass is one of the oldest and the most widely used materials in the world. Glass has a very limited life in the form in which it is used. One option for safe environmental and economic disposal of this waste is to reuse them in building materials. So glass has to be recycled or reused to avoid environmental problems. Also during the past few decades the availability and cost of river sand has become a major concern. The objective of this project work is to study the effects of using waste glass as a partial replacement for fine aggregate and steel slag as a partial replacement of coarse aggregate. Different concrete mixes were prepared by varying the amounts for crushed waste glass. The waste glass was used to replace fine aggregate in the proportions of 0%, 10%, 20%, 30%, 40%,50%. Property like compressive strength have been reviewed in this paper. Another attempt has also been made to replace coarse aggregate with steel slag as there is a growing interest in using waste materials as alternative aggregate materials and significant research is made on the use of many different materials as aggregate substitutes such as coal ash, blast furnace slag and steel slag aggregate. This type of use of a waste material can solve problems of lack of aggregate in various construction sites and reduce environmental problems related to aggregate mining and waste disposal. Different concrete mixes were prepared by varying the amounts for steel slag. The steel slag was replaced as a partial replacement of coarse aggregate in the proportion of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%.and compressive strength of concrete has been reviewed and yet another attempt has been made by replacing both fine aggregate and coarse aggregate by waste glass powder and steel slag respectively, and studying the compressive strength of concrete.

Key words: Coarse and Fine Aggregates, Steel Slag and Waste Glass Powder

I. INTRODUCTION

Concrete is most widely used construction material today. Concrete has attained the status of a major building material in all the branches of modern construction. It is difficult to point out another material of construction which is as variable as concrete. Concrete is the best material of choice where strength, durability, impermeability, fire resistance and absorption resistance are required

Concrete is a blend of cement, sand, coarse aggregate and water. Today global warming and environmental devastation have become manifest harms in recent years, concern about environmental issues, and a changeover from the mass-waste, mass-consumption, and mass production society of the past to a zero-emanation society is now viewed as significant. Normally glass does not harm the environment in any way because it does not give off pollutants, but it can harm humans as well as animals, if not dealt carefully and it is less friendly to environment because it is non-biodegradable. Thus, the development of new technologies has been required. The term glass contains several chemical diversities including soda-lime silicate glass, alkali-silicate glass and borosilicate glass. To date, these types of glasses glass powder have been widely used in cement and aggregate mixture as pozzolana for civil works.

Use of waste materials in place of natural resources is one of the best approaches, the waste can be minimized. Because the quantity of waste getting generating is increasing day by day. In India 0.7% of total urban waste generation consists of glass. Concrete is most widely used man made construction material and its demand is rapidly increasing. Use of river sand as fine aggregate leads to the exploitation of natural resources, lowering of the water table, sinking of bridge pier and erosion of river bed. So it is better to replace the sand by other substituent. The using of waste glass waste in concrete creates a problem due to the formation of ASR(alkali silica reaction). The silica in the glass reacts with the alkalis in the cement and form a gel like structure (ASR gel). The formation of ASR leads to the formation of severe cracks and further damage of the concrete. This can be avoided by reducing the size of glass aggregate, which shows no alkali reaction

Also, steel slag could be used as a partial replacement for coarse aggregate. Good environmental conditions by effective utilization of these by-products will occur which will otherwise remain as a waste material. Steel slag aggregates are already being used as aggregates in asphalt paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity. The feasibility of the usage steel slag as substitutes for conventional concrete are investigated. The test results of workability levels and strength are also same when compared to the conventional concrete 1) The improvement of the concrete mixture properties by addition of steel slag in concrete is observed. The waste material can be replaced by natural aggregates in concrete. 2) The strength of plain concrete and CFSTs with partial replacement of natural aggregates by waste materials in concrete strength is same. 3) The investigation of property of concrete by replacing fine and coarse aggregate by steel slag shows that the strength increased and workability decreased. Also concrete density is decreased. 4) The steel slag when used as a replacement for coarse aggregate increases the strength and workability.

II. MATERIAL USED

Waste Glass: In order to make concrete industry sustainable, the use of waste materials in place of natural resources is one of the best approaches. An enormous quantity of waste glass is generated all around the world. In India, 0.7% of total urban waste generated comprises of glass. UK produces over three million tons of waste glass annually. It has been estimated that several million tons of waste glasses are generated annually worldwide. The key sources of waste glasses are waste containers, window glasses, windscreen, medicinal bottles, liquor bottles, tube lights, bulbs, electronic equipments, etc. Only a part of this waste glass can be recycled. A majority of the waste glass remains unutilized.

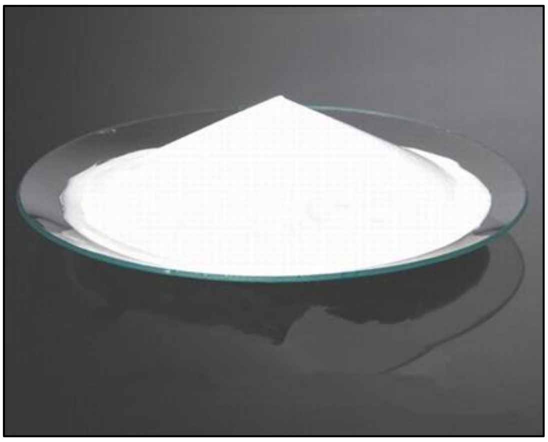


Fig. 1: Crushed Waste Glass

Steel Slag: Steel slag is an industrial byproduct obtained from the steel manufacturing industry. It is produced in large quantities during the steel-making operations which utilize Electric Arc Furnaces (EAF). Steel slag can be used in the construction industry as aggregates in concrete by replacing natural aggregates. Natural aggregates are becoming increasingly scarce and their production and shipment is becoming more difficult. Steel slag is currently used as aggregate in hot mix asphalt surface applications, but there is a need for additional work to determine the feasibility of utilizing this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. Steel slag is a byproduct of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces

Fig. 2: Steel Slag

The chemical composition of slag is usually expressed in terms of simple oxides calculated from elemental analysis determined by x-ray fluorescence. Table 4.1 lists the range of compounds present in steel slag from a typical base oxygen furnace. Virtually all steel slag's fall within these chemical ranges but not all steel slag's are suitable as aggregates. Of more importance is the mineralogical form of the slag, which is highly dependent on the rate of slag cooling in the steel-making process.

Concrete is a mixture of cement, water and aggregates with or without admixtures. It is a composite material composed of granular materials like aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues them together. Concrete is unique among major construction materials because it is designed specifically for particular civil engineering projects. Thus the concept of replacement of coarse aggregate with steel slag seems to be promising.

Constituent	Composition (%)
CaO	40-52
SiO2	10-19
FeO	10-40
MnO	5-8
MgO	5-10
Al2O3	1-3
P2O5	0.5-1
S	<0.1

Table 1: Steel Slag Chemical Composition

A. Fine Aggregate (FA):

The aggregate which is passing through 4.75 mm sieve is known as fine Aggregate. Locally available river sand which is free from organic impurities is used. Sand passing through 4.75 mm sieve and retained on 150 micron IS sieve is used in this investigation.

B. Coarse Aggregates:

Coarse Aggregate is the important constituents in concrete. They give body to the Concrete, reduce shrinkage and effect economy; one of the most important factors for producing workable concrete is good gradation of coarse aggregate. Coarse aggregate used in this experiment was locally available crushed aggregate passing through 20mm IS sieve. The aggregates used where conforming to IS-383-1970. Crushed aggregate tends to improve the strength because of inter locking of angular particles, while rounded aggregate improves the flow because of lower internal friction. Elongated aggregate are not preferable.

C. Cement:

Cement in general can be defined as a material which possesses very good adhesive and cohesive properties which make it possible to bond with other material to form compact mass. It is possible to upgrade the qualities of cement by using high quality limestone, modern equipment, and closer on line of control of constituents, maintaining better particle size distribution, finer grading and better packing. ACC OPC 43 grade cements are used.

D. Water:

Portable drinking water having pH value of 7 and conforming to IS 456-2000 IS used for concreting as well as curing of specimens.

E. Chemical Admixture:

Super plastisizer are used.It is a powerful water reducing agent in concrete agent in concrete. It increases the workability of concrete.

F. Mineral Admixture: No

III. OBJECTIVES

- To study cube compressive strength for 7 and 28 days of curing.
- To study the strength development of concrete by percentage replacement of steel slag and glass powder as coarse and fine aggregate.
- To find the optimum dosage of steel slag.
- To find the optimum dosage of glass powder.
- To find the optimum dosage of both glass and steel slag combinedly in concrete.

IV. METHODOLOGY

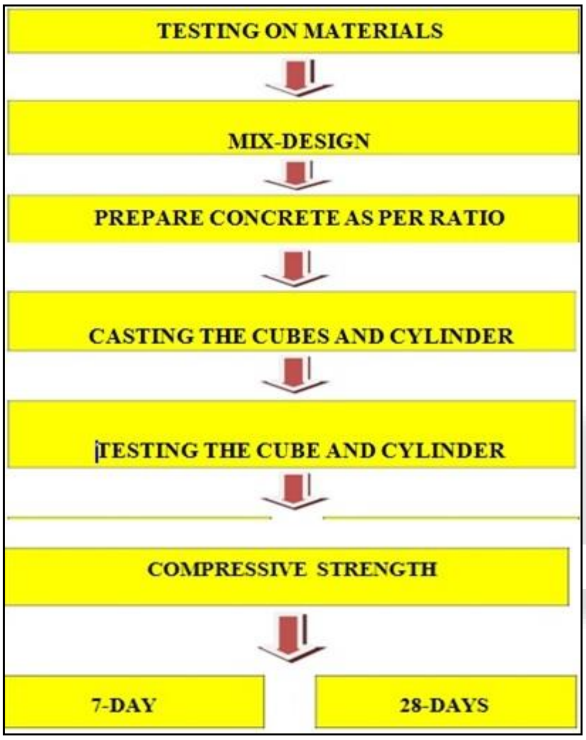


Fig. 3: Flow diagram for Methodology

Based on above objectives of present study, following methodology is set for present work.

1) Mix design of M_{40} grade of concrete using IS 10262:2009.
2) IS383:1970- Specification of CA and FA.
3) IS 456:2000 – code of CA and FA

The following tasks are to be carried out in order to achieve the research objectives:

1) Collecting the required information and documents related to the waste glass and steel slag
2) Collecting the waste glass and crushing by manually or by Los Angeles abrasion machine.
3) Sieving through standard IS sieves. The maximum nominal size of waste glass is 2.36mm.
4) The experimental investigation includes casting and testing of cubes, The cubes are tested for compressive strength at 7 and 28 days of curing.

V. TESTS ON MATERIALS AND ITS PROPERTIES

Cement: Cement in general can be defined as a material which possesses very good adhesive and cohesive properties which make it possible to bond with other material to form compact mass. It is possible to upgrade the qualities of cement by using high quality limestone, modern equipment, and closer on line of control of constituents, maintaining better particle size distribution, finer grading and better packing.

Generally use of high grade cement offer many advantages for making strong concrete. Although they are little costlier than low grade cement, they offer 10-20% saving of cement consumption and also they offer many other hidden benefits. One of the important benefits is the faster rate of development of strength.

A. Cement Test Result

Brand Name: ACC (OPC 43 GRADE)

- Normal Consistency 34%
- Specific gravity 3.15
- Initial setting time 35mints
- Final setting time 320mints

1) Fine Aggregates:

The aggregate which is passing through 4.75 mm sieve is known as fine Aggregate. Locally available river sand which is free from organic impurities is used. Sand passing through 4.75 mm sieve and retained on 150 micron IS sieve is used in this investigation.

The sample shall be brought to an air dry condition before weighing and strivings this may be achieved by drying at room temperature or by heating at a temperature of 100C to 110C. The air dry sample shall be weighted and sieved successively on the appropriate sieves starting with largest. Care shall be taken to ensure that the sieves are clean before use. The test were conducted as per IS 383-1975 and result of sieve analysis and physical properties of fine aggregate are shown below

Fine aggregates Test Results Are,

- Fineness modulus 2.6
- Specific gravity 2.73

2) Coarse Aggregate:

Coarse Aggregate is the important constituents in concrete. They give body to the Concrete, reduce shrinkage and effect economy; one of the most important factors for producing workable concrete is good gradation of coarse aggregate. Coarse aggregate used in this experiment was locally available crushed aggregate passing through 20mm IS sieve. The aggregates used where conforming to IS-383-1970. Crushed aggregate tends to improve the strength because of inter locking of angular particles, while rounded aggregate improves the flow because of lower internal friction. Elongated aggregate are not preferable.

Coarse aggregates Test Results Are,

- Aggregates type Crushed
- Specific gravity 2.74
- Fineness modulus 7.20
- Water absorption 1.00%
- Density 1865.24 kg/m^3

Steel Slag

- Test Results are,
- Specific gravity : 3.14
- Water absorption : 0.01%
- Density : 2003.54kg/m^3

VI. CASTING AND TESTING

The moulds of size 150mm x 150mm x 150mm are used for casting of cubes. The moulds are cleaned but the corners are pasted with oil. One coat of cutting oil is applied on all internal surfaces.

The moulds are filled in three layers and the height of each layer is about 1/3rd height of mould, each layer is compacted by giving 25 blows with a tamping rod over the entire cross section uniformly for members. After filling and compacting the moulds, the top surface are made smooth and kept for a period of 24 hours. Then the mould is removed and the cubes, cylinders and prism are kept for desired period of curing. The water should be clean and free from impurities. The water should be changed for every three days to obtained good results

Then after completing the curing period all the specimen should be removed and kept for drying for one day, because it should be completely dried to obtained good results. The surface of the specimens should be cleaned and the test is carried out under the compression testing machine and universal testing testing machine.

VII. TESTS FOR COMPRESSIVE STRENGTH, RESULTS AND DISCUSSION

The compressive strength of concrete is one of the most important properties of concrete is most structural application concrete is implied primarily to resist compressive stress.

In this investigation, conventional concrete cubes and concrete cubes with percentage of Waste Glass were used for testing the compressive strength. The cubes are tested in a compressive testing machine of capacity 3000KN. The load has been applied at the cube in such a way that the two opposite sides of the cube are compressed. The load at which the control specimens ultimately fail is noted. The average of 3 cubes is taken as compressive strength.

Compressive strength is calculated by dividing load by area of specimen

$$Fc = P/A$$

Where,

Fc = Cube compression strength in N/mm^2

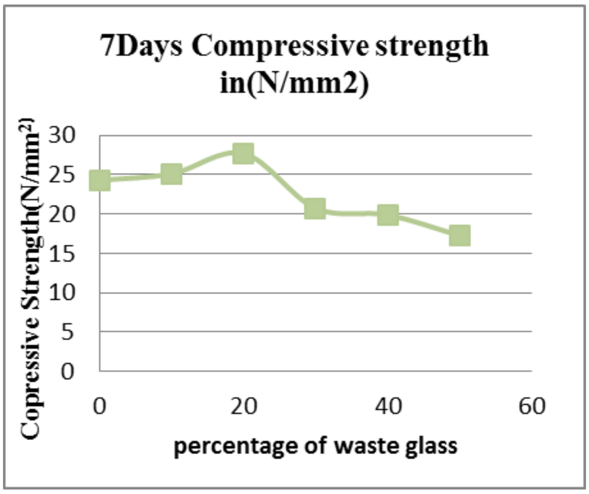
P = Cube compressive load causing failure in K N.

A = Cross sectional area of cube (mm^{2})

Number of cube tested for different proportion with conventional concrete and Concrete with percentage of Waste Glass powder and Steel slag are shown in table below.

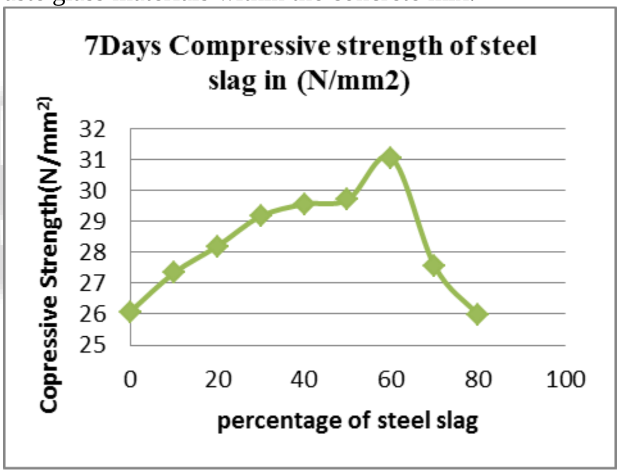
SN	% of Glass Replacement	Avg. Failure Load(KN)	Area(mm^2)	Compressive Strength(N/mm^2)
1	00	544.80	22500	24.31
2	10	565.26	22500	25.11
3	20	623.36	22500	27.70
4	30	466.56	22500	20.73
5	40	447.47	22500	19.88
6	50	383.33	22500	17.26

Table 2: Compressive Strength of cubes for Glass replacement (7Days)



Graph 1: Seven days compressive strength of Glass powder

Graph 1 shows the effect of fine waste glass content into the concrete mix on the 7-days compressive strength of the hardened concrete for 0.45 water-cement ratio. The output results interpretation was achieved on the bases: the waste glass content. It was observed that the hardened concrete 7-days compressive strength is fairly improved at of 20% waste glass powder content. Other than that, the concrete strength was adversely affected by using waste glass materials within the concrete mix.



Graph 2: Seven days compressive strength of Glass powder

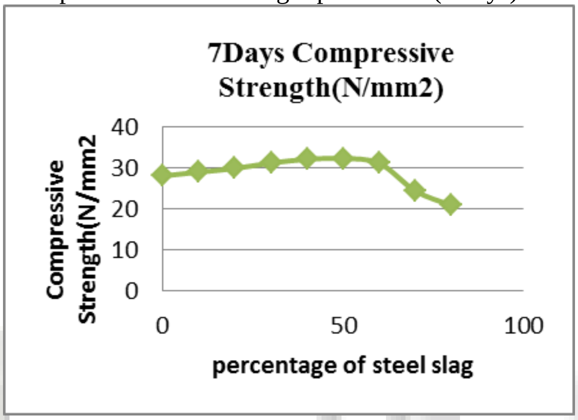
Graph 2 shows the effect of steel slag content into the concrete mix on the 7-days compressive strength of the hardened concrete for 0.45 water-cement ratio. The output results interpretation was achieved on the basis of the steel slag content. It was observed that the hardened concrete 7-days compressive strength is maximum at 60%(optimum) of steel slag content. Other than that, the concrete strength was negatively affected by using steel slag within the mix.

SN	% of Steel Slag	Avg. Failure Load(KN)	Area (mm$^{2)}$	Comp. Strength(N/mm^2)
1	0	586.75	22500	26.08
2	10	615.05	22500	27.33
3	20	634.50	22500	28.20
4	30	656.50	22500	29.17
5	40	665.00	22500	29.56
6	50	668.50	22500	29.71
7	60	699.50	22500	31.08
8	70	620.50	22500	27.54
9	80	584.50	22500	25.97

Table 3: Compressive Strength of cubes for steel slag replacement (7Days)

SN	% of Steel Slag	Avg. Failure Load(KN)	Area (mm^{2})	Comp. Strength(N/mm^2)
1	0	631.00	22500	28.04
2	10	652.00	22500	28.97
3	20	672.33	22500	29.88
4	30	702.00	22500	31.20
5	40	720.33	22500	32.10
6	50	726.33	22500	32.31
7	60	700.00	22500	32.11
8	70	547.66	22500	24.35
9	80	467.33	22500	20.80

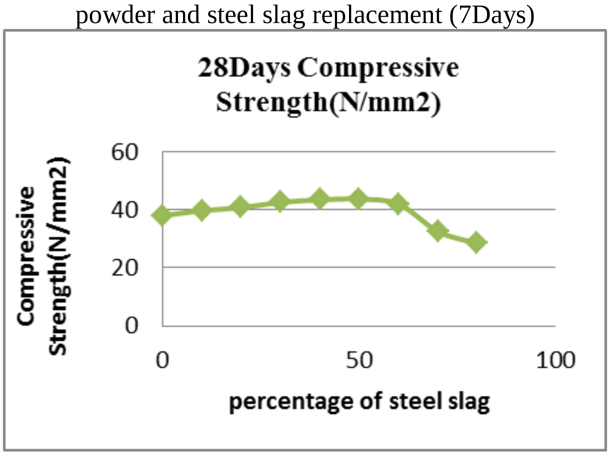
Table 4: Compressive Strength of cubes for combined glass powder and steel slag replacement (7Days)



Graph 3: Compressive Strength of cubes for combined glass powder and steel slag replacement(7Days)

SN	% of Steel Slag	Avg. Failure Load(KN)	Area (mm^{2})	Comp. Strength(N/mm^2)
1	0	856.66	22500	38.03
2	10	895.00	22500	39.78
3	20	918.00	22500	40.80
4	30	959.33	22500	42.63
5	40	988.66	22500	43.49
6	50	983.33	22500	43.70
7	60	945.33	22500	42.01
8	70	732.33	22500	32.56
9	80	640.00	22500	28.44

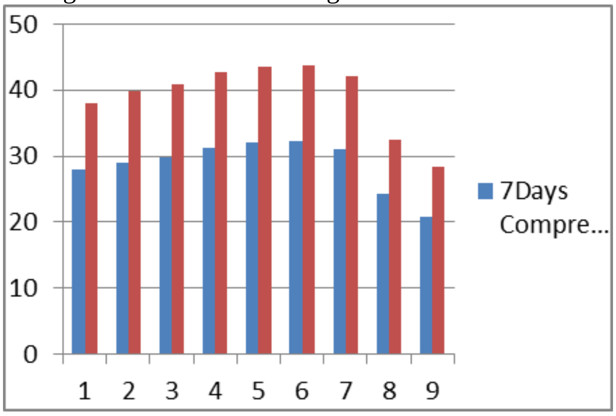
Table 4: Compressive Strength of cubes for combined glass powder and steel slag replacement (7Days)



Graph 4: Compressive Strength of cubes for combined glass powder and steel slag replacement (28Days)

Above Graph 3 & 4 Shows that the optimum percentage of replacement of steel slag in concrete at 7 and 28-days compressive strength is 50% with 20% replacement of glass powder.

Hence. Optimum % of both combined replacement is 20% glass with 50% Steel Slag.



Graph 5, 7 & 28 -Days concrete Compressive Strength vs. Replacement of Coarse and fine aggregates by Steel slag and Waste glass Powder

The test was conducted on(54+45) different samples, and the final output results are listed in Table 8.1 to 8.4, From the testing results, it can be concluded that the use of waste glass content in the concrete mix increase the Compressive strength of the mix with 20% waste glass powder. For concrete mixes containing 10%, 20%,30% 40% and 50% of waste glass powder there is increase in Compressive strength of 13.94% as compared with normal mix.

The primary objective of this present project is to study the effect of waste glass and steel slag content on the properties of concrete mixes when added as a partial replacement of fine and coarse aggregates respectively. This objective was achieved through identifying the effects of adding waste glass powder and steel slag on the fresh properties of concrete mixes, Studying the influence on the hardened concrete properties, Determining the optimum waste glass and steel slag content to be included within the concrete mix as a partial replacement, Focusing on the concrete mixes with optimal waste glass and steel slag contents by testing their compressive strength

These targets were reached by conducting a standard series of compressive strength tests. The output results obtained from this laboratory program showed reliable data points and further research horizons.

VIII. CONCLUSIONS

- This report summarizes the behavior of concrete involving replacement of fine aggregate at 10%, 20%, 30%, 40% and 50% by waste glass powder.
- 20% optimum replacement of fine aggregate showed 13.94% increase in compressive strength as compared with normal concrete mix with curing of 7 days.
- The concrete mixes containing 30%, 40% & 50% of waste glass powder, there was reduction in compressive strength.
- The concrete mixes containing 10%, 20%, 30%… up to 80% of steel slag, there was increase in compressive strength of concrete by 27.84% with 60% optimum

replacement as compared with normal concrete mix for 7 days curing.

- The concrete mixes containing more than 60% of steel slag as coarse aggregates shows there was reduction in compressive strength.
- For combined replacement of waste glass powder and steel slag, while keeping the waste glass powder 20% constant throughout and varying in % of steel slag as a coarse aggregates partial replacement and found optimum results at 50%
- Use of waste materials in concrete can prove to be economical as it is non-useful and free of cost.
- Environmental effects from wastes and maximum amount of sand mining can be reduced by using alternatives.

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