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WASTE GLASS POWDER AS PARTIAL REPLACEMENT OF FINE AGGREGATE FOR SUSTAINABLE CONCRETE

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ABSTRACT: Concrete industry is one of the largest consumers of natural resources due to which sustainability of concrete industry is under threat. Natural river sand is mostly used as fine aggregate in concrete. The sand from river basin are excavated, collected and transported to construction site. The use of river sand as fine aggregate leads to exploitation of natural resources, lowering of water table, sinking of bridge piers and erosion of river bed. If fine aggregate is replace by waste glass by specific percentage and specific size range, it will decrease the need of river sand content and thereby eliminate the ill effect of river dredging and make concrete construction industry sustainable. Waste glass generated from construction sites can be pulverized into sand size and used as partial replacement of sand in concrete. This project mainly focuses on the utilization of waste glass powder in reinforced concrete and study of influence of waste glass powder in strength enhancement. As the chemical composition of natural sand and waste glass powder is similar, the partial replacement of sand by waste glass powder in concrete is possible. Most probably the silica content of both sand and glass power is similar. In thispaper, waste glass powder is used as partial replacement of sand in M20 grade concrete. Concrete Cubes are casted with 0%(conventional mix), 10%, 20%, 30% and 40% replacement of sand by glass powder for testing of compressive strength. Cubes are tested at 7 days,14 days and 28 days of curing period for compressive strength test. The test results obtained for glass powder concrete mixer are compared with that of conventional mix 0%.

KEY WORDS: Concrete, Self compacting concrete, self curing.

1. INTRODUCTION

Concrete is usually a mixture of cement, coarse aggregate, fine aggregate and water. Concrete is widely used material in the world. Based on the global usage, it is placed in second position after water. Natural sand from river is one of the major constituent of concrete used as fine aggregate. Concrete is most popular engineering material in the field of civil engineering. It is an artificial compound generally made by mixing of binding material, fine aggregates, coarse aggregate, and water. Freshly mixed concrete before set is known as wet or green concrete whereas after setting hardened concrete. The moulded concrete mix after sufficient curing becomes hard like stone due to chemical actions between the water and binding materials. The increased demand for the usage of the huge quantity of concrete leads to increase in cost of the binding materials (cement) and depletion of natural sources of fine aggregate(sand) which in turn increase

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cost of concrete. This prompted civil engineers to explore and investigate use of alternative materials as partial or complete replacement of ingredients of concrete to minimize the cost of construction. Various studies and research has been carried out to explore alternative materials that can be used as fine aggregate instead of sand in concrete. Use of waste materials like fly ash, glass powder, red mud, etc. as partial replacement of sand has been researched and positive results were obtained.

1.1NATURAL DEMAND OF SAND: Natural sand is the major constituent of concrete in construction. With increasing population, the need of infrastructures for various purposes also increases. The popularity of use of concrete in constructions has increased the demand of concrete. As a result the demand of natural sand used as fine aggregate is also increasing along with the increase in development activities. Natural sand is generally extracted from river basins. Over-exploitation of natural river sand to meet the increasing demands of construction has been a challenge to the environment. This demand is increasing enormously every year with increasing demands for infrastructural advancements. To meet these demands, the natural river sand has been over exploited resulting in scarcity of sand along with the hiking in price of sand. The increase in price of scarce sand has become a problem for contractors and engineers at present context. The collection of 14 crore truckloads of sand every year from river beds, stream beds and pits creates tremendous environmental problems, such as meandering of water courses, denudation of river banks and interference with the natural flow patterns of rivers and streams. The dredging of natural sands has already affected the environment and ecology of many regions of the country. Hence, search for alternative materials for replacement of sand has been carried out. Various alternatives like GGBS, foundry sand, glass powder, quarry dust, etc. as partial replacement of sand has been researched and positive results has been obtained.

1.2GLASS: Glass is one of the oldest and the most widely used materials in the world. It is prepared by melting a mixture of materials such as silica, soda ash and $CaCO_3$ at high temperatures followed by cooling where solidification occurs without crystallization. The various forms in which it is produced includes packaging or container glass (bottles, jars), flat glass (windows, windscreens), bulb glass, cathode ray tube glass (TV screens, monitors) etc., All these glasses has very little life. Hence glass has to be recycled in order to avoid environmental problems. The waste glass like mixed colour glass which cannot be recycled is generally sent for landfills. Land-filling has become a problem and a waste in itself. In the few decades concrete has become one of the largest quantities produced in the world. Reusing waste glass in the production of concrete will convert a waste or a burden to a source. If we recycle the glass and use it, it will again become a waste after serving its purpose for a relatively short period of time. Rather if we use waste glass in concrete, it provides a long term solution. Glass is a 100% recyclable material and can be fully used after recycling.

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Important glass making chemistry: the basic reaction Na_2CO_3+$SiO_2$$Na_2SiO_3$ +CO_2 Na_2SiO_3+xSiO_2 (Na_2O)·(SiO_2)(x+1)

The making of glass involves three basic types of ingredients: formers, fluxes, and stabilizers. The glass former is the key component in the structure of a glassy material. The former used in most glasses is silica (SiO_2). Pure silica is difficult to melt because of its extremely high melting point (1,723 ^{0}C, or 3,133 ^{0}F), but fluxes can be added to lower the melting temperature. Other glass formers with much lower melting points (400 ^{0}C–600 ^{0}C, or 752–1,112 ^{0}F) are boric oxide (B_2O_3) and phosphorus pent oxide (P_2O_5).These are easily melted, but because their glass products dissolve in water, they have limited usefulness. Most silica glasses contain an added flux, so that the silica can be melted at a much lower temperature (800 ^{o}C–900 ^{o}C, or 1,472–1,652 ^{o}F). Standard fluxes include soda (Na_2O), potash (K_2O), and lithium oxide (Li_2O). Frequently the flux is added as a carbonate substance (e.g., Na_2CO_3), the CO_2 being driven off during heating. Glasses containing only silica and a flux, however, have poor durability and are often water-soluble. To make glasses stronger and more durable, stabilizers are added. The most common stabilizer is lime (CaO), but others are magnesia (MgO), barium oxide (BaO), and litharge (PbO). The most common glass, made in largest amounts by both ancient and modern glassmakers, is based on silica as the glass former, soda as the flux, and lime as the stabilizer. It is the glass used to make windows, bottles, jars, and light bulb.

1.2.1CONCEPT OF WASTE GLASS POWDER

The search for new material and new technology, especially in the construction industry is in view of growing awareness on protection of environment and conservation of natural resources. Together with this, the problem of waste disposal has become a major concern for planners and engineers in the developing countries. With the enormous increase in the quantity of waste materials from industries, the continuing shortage of dumping sites, sharp increase in the transportation and disposal cost and above all the stringent antipollution and environment regulations enforced in a number of countries, the waste disposal problem is assuming serious and at times even alarming proportions. It is therefore no wonder that the concept of recycling the waste material and using it again in some form or the other has gathered momentum.Glass is a non-crystalline amorphous solid that is often transparent and has widespread practical, technological, and decorative usage. Use of glass for various purposes like window panes, container for storing food items, brewery industry as beer bottles, etc. has become very popular at modern days .The glass used for these purposes is usually soda lime glass which is one type of silicate glass with high silica content. Along with the increase in demand and use of glass products, the quantity of waste glass is also increasing which has led to problems of environmental pollution and waste glass disposal .As glass is a non-degradable waste, the disposal of these waste create a problem in the environment .Though attempts have been made to reuse and recycle the waste glass containers, the waste glass production has created a problem in developing countries like India.

1.2.2 WASTE GLASS: Waste glass is one of the types of solid waste generated from various domestic, commercial and industrial sectors. Waste glasses are non-degradable wastes which have high potential of being reused and recycled .Waste glass includes containers for storing food items, bottles for storing soft drinks or hard drinks in industries, broken window panes of vehicles, sheet glass cuttings, glass cutting pieces from various building construction sites, waste glasses from various commercial sectors. In context of India, due to unavailability of proper technology, most of the waste glasses are not reused or recycled rather they are transported to sanitary landfills for disposal. Therefore, waste glass has become one of the challenges for pollution control due to its non-degradable nature.

1.2.3SOURCES OF WASTE GLASSES: Waste glasses like sheet glasses used for window panes, container bottles used for storing cool drinks and other items, bottles from brewery industry, glass panes used for architectural purposes are the major sources of waste glass. Use of glass products for various domestic purposes, industrial purposes and also for various construction sectors produces a large amount of waste glasses. Out of all waste glasses generated, only some part of waste glasses are reused and recycled, others are sent to landfills for disposal. In India, about 0.7 percent of the solid wastes generated are waste glass products which are creating problem because of their non-degradable nature. The main sources of waste glass can be divided into following categories as follows:

1. Domestic solid waste 2. Commercial solid wastes 3. Industrial solid wastes

1.2.4 IMPACT OF WASTE GLASS ON ENVIRONMENT: Waste glass disposal in sanitary landfills increase the amount of waste to be disposed of in the environment .As waste glass is non-degradable, the amount of waste to be disposed in landfills goes on increasing with time and a time may come when there will be no more space left for disposal if proper reuse, recycle of waste glass is not carried out. Every metric ton (1,000 kg) of waste glass recycled into new items saves 315 kilograms (694 lbs.) of carbon dioxide from being released into the atmosphere during the creation of new glass. Therefore, waste glass if not reused and recycled can create negative impact on environment as lots of resources and energy is wasted for production of new glass thereby resulting in the emission of various greenhouse gases polluting the atmosphere.

1.2.5 UTILIZATION OF WASTE GLASS: Waste glass like beer bottles and containers can be reused for repeated number of times thereby reducing the amount of waste glass produced. Waste glass recycling to produce glass products from waste glass is another method of utilizing waste glass thereby creating a possibility for greener environment. Reuse and recycling of waste glass is the best utilization of waste glass which finally assists in minimizing the waste production and cost for disposal.

1.2.6 WASTE GLASS IN CONSTRUCTION INDUSTRY: Waste glass powder obtained by crushing waste glass sheets and bottles can be used as partial replacement of natural sand in concrete and mortars. The waste glasses are crushed to sand size and then used as fine aggregate in concrete. Concrete using waste glass powder as fine aggregate showed improved properties compared to conventional concrete. Hence, use of waste glass powder in construction industry can make construction economical by minimizing the use of scarce and expensive natural sand and also minimize the problems of waste glass disposal thereby creating greener and economical Construction. The over exploitation of natural sand from river can be minimized preserving natural resources for future generation. Waste glass can also be used as replacement of coarse aggregate for architectural purposes and in fine powder form, waste glasses can be used as replacement of cement in concrete.

1.2.7 PROCESS OF OBTAINING GLASS POWDER

Glass powder used as partial replacement of sand. In this project, glass powder is obtained from waste glass bottle and broken glass pieces. The process of obtaining the glass powder used in our project includes the following steps as follows.

1.2.8COLLECTION OF WASTE GLASS: Waste glass bottle and broken glass pieces are collected from cold drink shop at waste plants. These waste glasses are usually sent to landfills for disposal Around

40 kg of waste glass pieces is collected and brought to Srinivasa Institute of Engineering and Technology. Waste glasses collected especially includes Soda-Lime Glass which is a type of silicate glasses.

Fig 1: Collected Waste Glass Bottles From Shops

1.2.9CRUSHING OF WASTE BOTTLE GLASS POWDER: Waste glasses are crushed to sand size by using Los Angeles Abrasion Testing Machine. The waste glass pieces are placed inside the machine along with steel balls and then the machine is rotated for 500 rotations to obtain crushed glass pieces. Waste glasses are pulverized into small sizes and are sieved to get required size of glass powder. The crushed glass powder obtained from Abrasion machine is then sieved through 2.36 mm sieve size to obtain fine glass powder of sand size .Then, the sieved glass powder is collected for its use as partial replacement of sand in concrete.

Fig 2: Glass Powder Passed From 1.18mm Sieve

1.2.10 BENEFITS OF USE OF WASTE GLASS POWDER IN CONCRETE

The advantages of use of waste glass powder as partial replacement of fine aggregate in concrete are as follows:

- Elimination of waste glass disposal problems resulting in green and clean environment.
- Reduction in cost of concrete production

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by replacing expensive natural sand.

- Minimizes the ill effects of river dredging of sand like erosion of river bed, sinking of bridge piers, denudation of river banks, changes in the original path of rivers and streams.
- Controls over exploitation of natural river sand thereby preserving natural resources for future generation.

2. MATERIAL PROPERTIES AND MIX DESIGN

PHYSICAL PROPERTIES	RESULTS OBTAINED
Specific Gravity	2.64
Fineness Modulus	2.45
Water Absorption	1%
Elongation Index	11.8%
Flakiness Index	5.4%

COLLECTION OF RAW MATERIALS:

- All the required materials are collected and delivered to laboratory.
- OPC used in our project is UltraTech Cement of 53 Grade, it is collected from Amalapuram.
- F.A is collected from Ravulapalem.
- C.A used is of 20-10mm size, it is collected from Amalapuram. Glass Bottles are collected from Bar Shops

Table No 1: Physical Properties Of Cement

PHYSICAL PROPERTIES	RESULTS OBTAINED
Specific Gravity	3.13
Normal Consistency	33%
Initial Setting Time	35min
Final Setting Time	385min
Fineness of Cement	5%

Table No 2: Physical Properties Of Fine Aggregate & Glass Powder

Physical Propertis	Results Obtained Fine Aggregate	Results Obtained Glass Powder
Specific Gravity	2.60	2.65
Fineness Modulus	2.51	2.59
Bulking Of Sand	31.57	-

Table No 3: Physical Properties Of Coarse Aggregate

M-20 MIX DESIGN AS PER IS-10262:2009

DESIGN STIPULATIONS

1. Grade of Concrete: M20
2. Type of Cement :
3. Nominal Size of Aggregate: 20mm
4. Workability : 25 – 50mm (slump)
5. Exposure Condition: Mild
6. Method of Concrete Placing: Normal
7. Degree of Supervision: Good
8. Specific Gravity of Cement: 3.13
9. Specific Gravity of Coarse Aggregate : 2.64
10. Specific Gravity of Fine Aggregate: 2.60
11. Sieve Analysis :
12. Water Absorption
    - Fine Aggregate : Nil
    - Coarse Aggregate : 0.1%
13. Free Moisture Content
    - Fine Aggregate : Nil
    - Coarse Aggregate : Nil

1. TARGET MEAN STRENGTH FOR MIX PROPORTIONING:

$f`_{ck} = f_{ck} + 1.65 \times S$(From table 1 of IS:

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10262- 2009,

= 20 + 1.65 × 4Standard deviation = 4 N/mm^2)

= 26.66 N/mm2

$f`_{ck}$ = target mean compressive strength at 28 days f_{ck} = characteristic compressive strength at28 days

2. **SELECTION OF WATER – CEMENT RATIO:**

From table 5 of IS 456, Water-cement ratio = 0.55

Based on experience, adopt w/c ratio = 0.50

3. **SELECTION OF WATER CONTENT:**

From table 2, maximum water content for 20mm aggregate = 186 lit. (for 25 to 50mm slump)

4. **CALCULATION OF CEMENT CONTENT :**

W/C ratio = 0.5

Cement content = 186/0.5= 372Kg/m3

From table 5 of IS 456,

Minimum cement content for 'mild' exposure condition = 300 Kg/m3 Above calculate cement content value is > 300 Kg/m3

Hence ok

5.**PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT:**

From table 3of IS 10262 - 2009, volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (zone II) for W/C of 0.5 = 0.62

Therefore, volume of C.A = 0.62 Volume of F.A = 1-0.62 = 0.38

6. **MIX CALCULATION:**

Volume of concrete = 1 m^3 Specific gravity = ϒmaterial/ϒwater

(ϒ= weight/volume)

Specific gravity = (weight/ volume)× (1/ϒw) Volume = (weight/specific gravity) × (1/ 1000)

Volume of cement = (mass of cement / specific gravity of cement) × (1/1000)= (372/3.13) × (1/1000) = 0.118 m^3

Volume of water = (mass of water/specific gravity of water) × (1/1000)= (186/1) × (1/1000) = 0.186 m^3

Volume of all in aggregate = [a-(b+c)]= [1 – (0.118+0.186)] = 0696 m^3

Mass of coarse aggregate = d × volume of C.A ×specific gravity × 1000= 0.696 × 0.62 × 2.64 ×1000 = 1139.21

Mass of F.A = d× volume of F.A × specific gravity × 1000= 0.696 × 0.38 × 2.6 × 1000 = 687.64

Corrections for water content has not be done as the value of water absorption is negligible.

7.MIX PROPORTIONS (1m³ OF CONCRETE):

Water : Cement : Fine aggregate : Coarse aggregate 186 : 372 : 687.64 :1139.21

0.5 : 1 : 1.84 : 3.06

Cement = 372 Kg/m3 Water = 186 lit Fine aggregate = 687.64 Kg/m3 Coarse aggregate = 1139.21 Kg/m3 Water cement ratio = 0.5

3.RESULTS

3.1COMPRESSIVE TEST

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

Compressive test was conducted on 150 × 150× 150 cubes. Concrete specimens were removed from curing tank and wiped clean. In the machine, the cube is placed with the cast faces at the right angles to that of compressive faces. Then they are placed under UTM and then load

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is applied at a constant rate of 149Kg/cm2 minute up to failure and the ultimate load is noted. The compressive tests were carried out at 7, 14 and 28 days .For strength computation; the average of three specimens was reported as the cube compressive strength

Fig 3 Compressive Strength Test

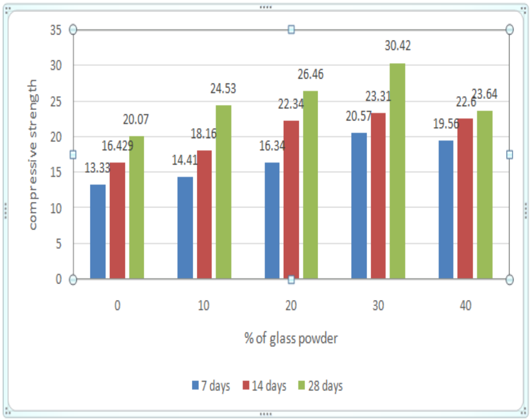

Fig 4: Graph Shows Compressive Strength Results

3.2SPLIT TENSILE STRENGTH TEST: The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Moreover, the concrete is very weak in tension due to its brittle nature. Hence, it is not expected to resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength. Therefore, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Furthermore, splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The procedure based on the ASTM C496 (Standard Test Method of Cylindrical Concrete Specimen) which similar to other codes like IS 5816 1999

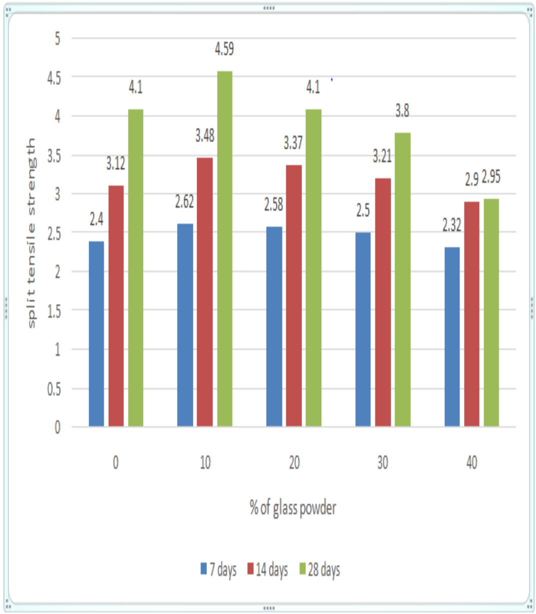

Fig 5: Graph Shows Tensile Strength Results

3.3 FLEXURAL STRENGTH TEST: Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending.The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or psi.The flexural test on concrete can be conducted using either three-point load test (ASTM C78) or centre point load test (ASTM C293).It should be noticed that, the modulus of rupture value obtained by centre point load test arrangement is smaller than three-point load test configuration by around 15 percent.Moreover, it is observed that low modulus of rupture is achieved when larger size concrete specimen is considered.Furthermore, modulus of rupture is about 10 to 15 percent of compressive strength of concrete.

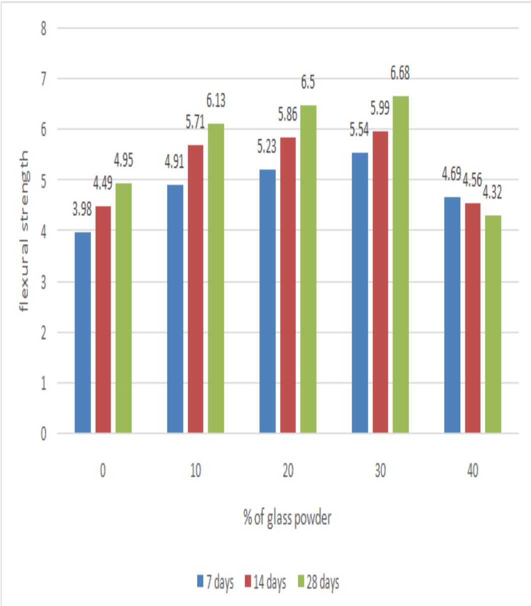

Fig 6: Graph Shows Flexural Strength Results

4. CONCLUSION

- ✓ It is possible to replace scarce and expensive natural sand by waste glass powder.
- ✓ The glass powder concrete is more workable, strong and durable compared to normal sand concrete.
- ✓ Utilization of waste glass as partial replacement of sand can turn this waste into valuable resource.
- ✓ Utilization of waste glass in concrete will eradicate the disposal of waste glass, thereby paving way for greener concrete.
- ✓ Utilization of waste glass in concrete can turn out to be economical as it is no useful waste and is free of cost.
- ✓ Waste glass in concrete can minimize over-exploitation of natural resources like natural sand thereby making concrete construction industry sustainable.

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