Strength and Durability Study on Recycled Aggregate Concrete Using Glass Powder

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Abstract— Waste **glass powder was used as secondary cementitious material towards production of recycled aggregate concrete with improved strength and durability attributes. Experimental investigation of using waste glass powder, as partial replacement for cement, to overcome the drawbacks of recycled aggregate and the resulting concrete showed that waste glass, when milled to micro-scale particle size, is estimated to undergo pozzolanic reactions with cement hydrates, forming secondary calcium silicate hydrate (C–S–H)[1]. These reactions bring about favorable changes in the structure of the hydrated cement paste and the interfacial transition zones in recycled aggregate concrete. Use of milled waste glass, as partial replacement of cement, is estimated to produce significant gains in strength and durability of recycled aggregate concrete. This paper has also attempted to provide concise information of strength of concrete containing waste glass powder and recycled aggregate when subjected to sulphate attack.**

Keywords— **Recycled aggregate (RA), Waste glass powder (g), Ordinary concrete (OC), Compressive Strength, Tensile strength, Durability**

I. INTRODUCTION

Concrete is comprised of Portland cement, fine aggregate, coarse aggregate, water, Pozzolans and air. Glass is produced in many forms, including packaging of container glass, flat glass, and bulb glass, cathode ray tube glass, all of which have a limited life in the form they are produced and need to be reused/recycled in order to avoid environmental problems that would be created if they were to be stockpiled or sent to landfill. Utilization of waste glass is very important for human development because huge amount of glass waste produce by human increases the need of precious land for dumping waste glass, decreasing possible area that can be used for landfills of other waste increasing the need to establish new expansive landfills. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixture(s). Among these, aggregates, i.e. inert granular materials such as sand, crushed stone or gravel form the major part. Traditionally aggregates have been readily available at economic price. However, in recent years the wisdom of our continued wholesale extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection. Recent technology has also improved the recycling process; this study aims to evaluate physical properties of concrete using recycled coarse aggregate. In this research concrete waste is from demolished structure has been collected and coarse aggregate of different % is used for preparing fresh concrete.

II. OBJECTIVES OF THE WORK

The experiment was carried out to overcome the problems created due to huge requirement of the raw material for manufacturing of conventional building material and also to minimize hazards caused by Industrial waste on the environment.
Some other objectives are:

- The development of alternate low-cost and environment suitable building materials from industrial wastes is an economic way.
- Importance must be given to cheap and locally available building materials and hence it is necessary to check & utilize the suitable waste products to replace some of the conventional materials.
- Current demand of cement is far in excess of production and is rapidly increasing.

By keeping the above objectives in mind the aims of present work is to check the suitability and utilization of waste glass powder as a partial replacement of Portland cement in concrete and also utilization of recycled coarse aggregate as a partial replacement of virgin coarse aggregate.

III. MATERIALS AND METHODS

A. Materials

The following are the details of the materials used for concrete cubes.

Cement: In this experiment 43 grade Ordinary Portland Cement (OPC) with brand name JK is used for all concrete mixes. The cement used is fresh and without any lumps. The testing of cement is done as per IS: 8112-1989. The specific gravity of cement is found to be 3.15. The physical properties of cement used are as given in table.

TABLE1

PHYSICAL PROPERTIES OF CEMENT

Sl. No.	Particulars	*Experimental result	As per standard
1	Normal consistency (%)	31	28-35
2	Fineness	220 m^2/kg	Not less than 225 m^2/kg
3	Setting time (minutes)		
3a)	Initial	183	Not less than 30
3b)	Final	289	Not more than 600

Fine aggregate: Natural river sand well graded passing through 4.75mm sieve was used. Specific gravity was found to be 2.65.Fineness modulus was found to be 2.1, water absorption 0.96% and confirming to zone II.

Coarse aggregate: Crushed aggregate is with a maximum size of 20 mm and normal continuous grading. The specific gravity of the coarse aggregates of 2.73 was used. The sieve analysis of fine and coarse aggregates is confirmed to IS10262.

Glass powder

Glass powder is collected from Environ Safety Glasses, Mysore. The specific gravity of glass powder is 2.73 and the size of the particle used is 90µ.

Recycled coarse aggregate

Recycled coarse aggregate of 20mm downsize is collected from a demolished building in Ujre. The specific gravity of recycled coarse aggregate of 2.4 was used with water absorption of 3.4%.

IV. DESIGN MIX FOR M30 GRADE CONCRETE

Grade of concrete : M30
Cement : JK 43 grade
Target Strength : $f_{ck}+1.65(s) = 38.25$ N/mm^2
Cement content : 480 kg/m^3
Water/Cement ratio : 0.4
River sand content : 626 kg/m^3
Coarse aggregate content: 1151kg/m^3

TABLE 2
MIX DESIGN PROPORTIONS

Cement	Fine Agg	Coarse Agg	Water
1	1.3	2.39	0.4

TABLE 3
AMOUNT OF WASTE GLASS POWDER AND RECYCLED AGGREGATE USED IN CONCRETE

Cement (kg/m3)	480			
Fine aggregates (kg/m3)	626			
Coarse aggregates (kg/m3)	1151			
Water (lit/m3)	192			
Replacement of cement by glass powder %	20			
Glass powder (kg/m3)	96			
Replacement of Course aggregate by Recycled aggregate %	0	25	50	75
Recycled aggregate	0	287.75	575.5	863.25

V. CASTING OF CONCRETE CUBES AND CYLINDERS

The test moulds are kept ready before preparing the mix. The bolts of the moulds are tightened carefully because if not kept tight the concrete slurry may come out of the mould when compaction process takes place. Then moulds are cleaned and oiled on all contact surfaces and concrete is filled into moulds in 3 different layers and 25 blows must be given to each layer. The top surface of concrete is struck off level with a trowel. The identification number and date of casting are put on the top surface of the cubes and cylinders. Casted cubes and cylinders are de-molded after 24 hours and kept for curing.

VI. TESTS FOR CONCRETE

A. Test for Compressive strength of concrete cubes:

To calculate the compressive strength of concrete cubes the compression testing machine (CTM) having capacity of 2ton was used. In this test the strength obtained in tone. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed to the nearest “N/mm2”.

Out of many tests applied to the concrete, this is the outmost important which gives an idea about all the characteristics of concrete. For cube test, moulds of size 15 cm x 15cm x 15 cm are used. These specimens are tested by compression testing

machine after 7 days curing and 28 days curing. Load is applied gradually at the rate of 140 kg/cm2 per minute till the specimen fails. Load at failure divided by area of specimen gives the compressive strength of concrete.

Calculations:

Compressive strength = Maximum load/ Area

$= P/A$

B. Test for Split tensile strength of concrete cylinders:

As the concrete is weak in tension, 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. Cracking is a form of tension failure. The usefulness of the split tensile test for assessing the tensile strength of concrete in the laboratory is widely accepted and the usefulness of the above test for control purposes in the field is under investigation. The standard has been prepared with a view to unifying the testing procedure for this type of test for tensile strength of concrete. The load at which splitting of specimen takes place shall then be recorded. The compression testing machine (CTM) having capacity of 2ton was used to determine the split tensile strength of the concrete cylinders.

Calculations:

The split tensile strength of the specimen is calculated from the formula,

$$Tsp = \{2P/(\pi dL)\}$$

Where,

P= maximum load

L= length of the specimen

d= diameter of the specimen.

C. Sulphate attack test

Sulphate attack denotes an increase in the volume of cement paste in concrete due to chemical action between the products of hydration of cement and solution containing sulphates. Of all the sulphates, magnesium sulphate causes maximum damage to concrete. A characteristic whitish appearance is the indication of sulphate attack.

Test procedure as follows:

The steel cube moulds of dimension 150mm X 150mm X 150mm were coated with oil on their inner surfaces and were placed on plate. The amount of cement, sand, coarse aggregates required for required number of cubes were weighed. The materials were first dry mixed then mixed with total amount of water thoroughly to get homogeneous mix. The slump test was conducted to ascertain the workability of the mix, which required a slump of 50 -100mm. Concrete was poured into the moulds in three layers and the top surface was finished using trowel. After 24 hours concrete cubes were de- molded and the specimens were kept for curing in water for 28 and 56 days. Then the specimen was immersed in a 5% MgSo4 solution for 28 and 56 days[11]. Compressive strength and split tensile strength tests are conducted.

VII. RESULT ANALYSIS

TABLE 4
TYPES OF MIXES AND ITS SPECIFICATION

Types of mixes	Mix specification
M1	OC
M2	25% RA
M3	50% RA
M4	75% RA
M5	OC, 20% g
M6	25% RA, 20% g
M7	50% RA, 20% g
M8	75% RA, 20% g

1) Test for Compressive strength of concrete cubes:

TABLE 5

EFFECT ON COMPRESSIVE STRENGTH OF CONCRETE FOR DIFFERENT TYPE OF MIXES

Types of mixes	Compressive Strength(7 days) N/mm^2	Compressive Strength (28 days)N/mm^2	Compressive Strength (56days)N/mm^2
M1	24	33.33	35.33
M2	22.22	32	34.88
M3	19.55	28.88	30.22
M4	17.77	27.11	28.33
M5	21.33	31.11	33.77
M6	19.11	29.33	32.44
M7	18.22	28	28.88
M8	16.88	26.66	27.11

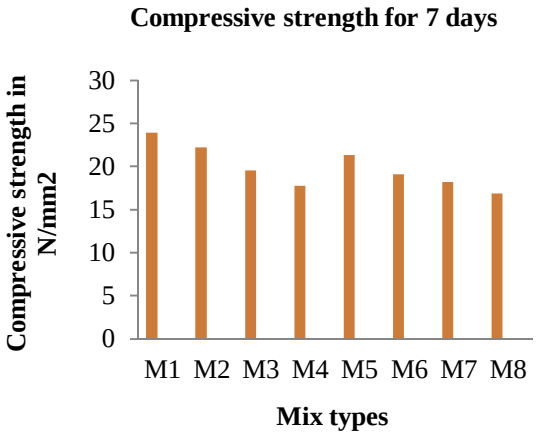

Fig. 1 Compressive strength in N/mm^2 for 7 days

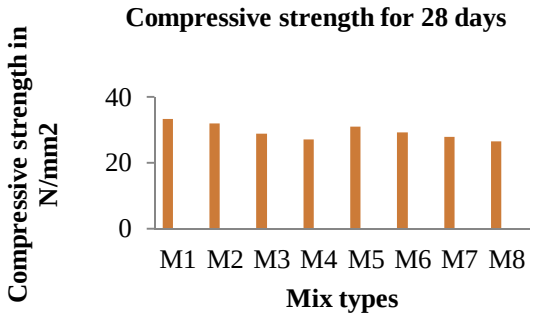

Fig. 2 Compressive strength in N/mm^2 for 28 days.

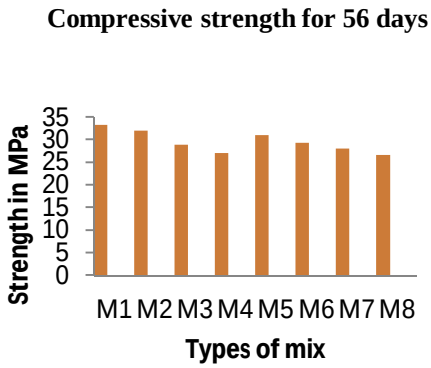

Fig.3 Compressive strength in N/mm^2 for 56 days.

Table 5 and Fig 1, 2 and 3 shows the compressive strength of different types of mixes for 7, 28 and 56 days for various percentages of recycled aggregate replacing virgin aggregates, with and without waste glass powder. The compressive strengths of concrete mixes with waste glass powder used as partial replacement for cement were lower than those of the corresponding concrete mixes without waste glass. But there is improvement in 56 days strength may be due to the pozzolanic activity of waste glass powder.

2) Test for Split tensile strength of concrete cylinders:

TABLE 6
EFFECT ON SPLIT TENSILE STRENGTH OF CONCRETE FOR DIFFERENT TYPE OF MIXES

Types of mixes	Split tensile Strength(7 days) N/mm^2	Split tensile Strength (28 days)N/mm^2	Split tensile Strength (56days)N/mm^2
M1	24	33.33	35.33
M2	22.22	32	34.88
M3	19.55	28.88	30.22
M4	17.77	27.11	28.33
M5	21.33	31.11	33.77
M6	19.11	29.33	32.44
M7	18.22	28	28.88
M8	16.88	26.66	27.11

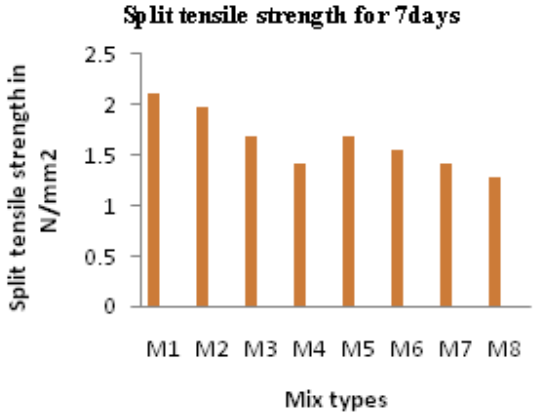

Fig. 4 Split tensile strength in N/mm^2 for 7 days

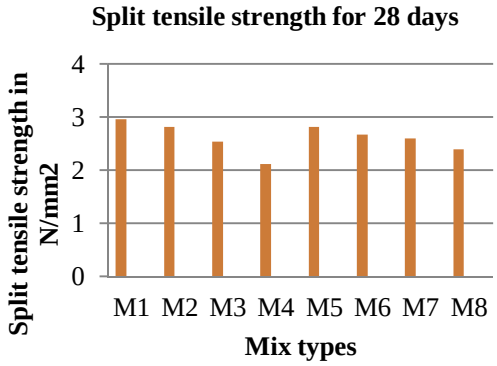

Fig 5 Split tensile strength in N/mm^2 for 28 days

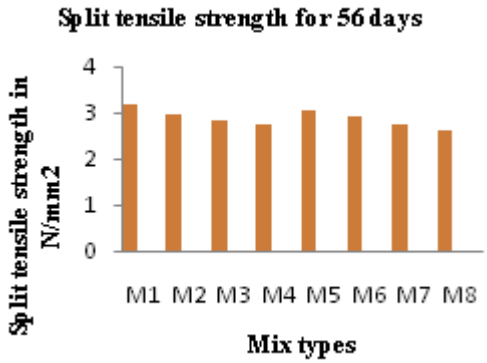

Fig. 6 Split tensile strength in N/mm^2 for 56 days

Table 6 and Graph 4, 5 and 6 shows the split tensile strength of different types of mixes for 7, 28 and 56 days for various percentages of recycled aggregate replacing virgin aggregates, with and without waste glass powder. The split tensile strengths of concrete mixes with waste glass powder used as partial replacement for cement were lower than those of the corresponding concrete mixes without waste glass

powder. But there is improvement in 56 days strength may be due to the pozzolanic activity of waste glass powder

D. Sulphate attack test

1) Test for Compressive strength of concrete cubes:

TABLE 7
EFFECT ON COMPRESSIVE STRENGTH OF CONCRETE FOR DIFFERENT TYPE OF MIXES WHEN IMMERSED IN 5% $MGSO_4$

Types of mixes	Compressive Strength (28 days)N/mm^2	Compressive Strength (56days)N/mm^2
M1	32.88	32
M2	30.66	28.44
M3	28.44	26.66
M4	26.66	24.44
M5	32	31.11
M6	31.55	29.33
M7	29.77	27.11
M8	27.55	25.77

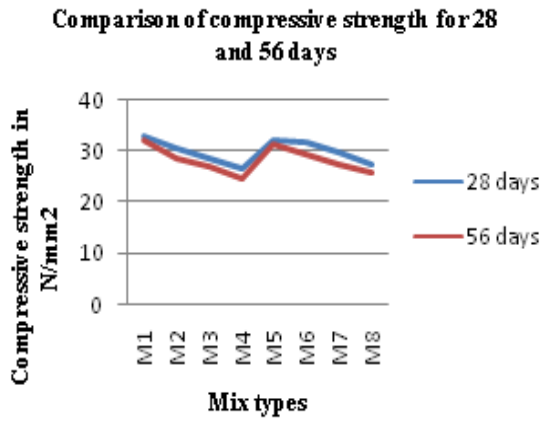

Fig. 7 Comparison of compressive strength when immersed in $MgSo_4$

Table 7 and Fig 7 shows the compression strength test results for the cubes and cylinders subjected to sulphate attack. The specimens are immersed in 5% $MgSo_4$ solution. The strength reduces with increase in percentage of recycled coarse aggregate. Also strength reduces with the introduction of glass powder but percentage of strength reduction is less when compared to specimens without glass powder. This may be due to the filling effect of glass particles, and conversion of CH to C–S–H available in the old mortar/cement paste attached to the surface of recycled aggregate

2) Test for Split tensile strength of concrete cylinders

TABLE 8
EFFECT ON SPLIT TENSILE STRENGTH OF CONCRETE FOR DIFFERENT TYPE OF MIXES WHEN IMMERSED IN 5% $MGSO_4$

Types of mix	Split tensile Strength 28 days (N/mm^2)	Split tensile Strength 56 days (N/mm^2)
M1	2.76	2.71
M2	2.61	2.58
M3	2.47	2.26
M4	2.37	2.05
M5	2.68	2.57
M6	2.57	2.44
M7	2.43	2.39
M8	2.26	2.20

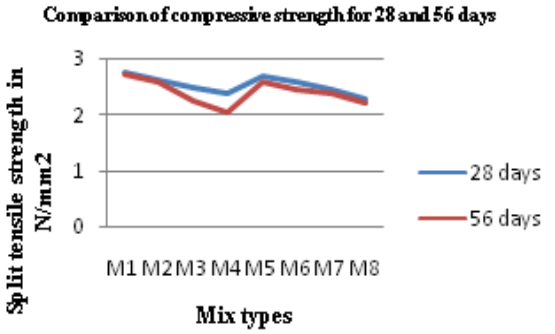

Fig. 8 Comparison of split tensile strength when immersed in $MgSo_4$

Table 8 and Fig 8 shows the split tensile strength test results for the cubes and cylinders subjected to sulphate attack. The specimens are immersed in 5% MgSo4 solution. The strength reduces with increase in percentage of recycled coarse aggregate. Also strength reduces with the introduction of glass powder but percentage of strength reduction is less when compared to specimens without glass powder. This may be due to the filling effect of glass particles, and conversion of CH to C–S–H available in the old mortar/cement paste attached to the surface of recycled aggregate.

VIII. CONCLUSION

The use of milled waste glass as partial replacement for cement is estimated to effectively overcome the limitations of recycled aggregate. When glass is used in fine particle size as partial replacement for cement in concrete, it is estimated to undergo pozzolanic reaction that results in improved microstructure of recycled aggregate concrete. The use of milled waste glass as partial replacement of cement in recycled aggregate concrete results in enhanced durability characteristics. Improvement in 56 days strength provides an indirect measure of the pozzolanic

activity of milled waste glass. Waste glass powder in appropriate proportions could be used to resist Sulphate attack.

IX.SCOPE FOR FURTHER WORK

a) Study on the flexural strength of the concrete beams can be taken up by using proper percentage of glass powder and recycled coarse aggregate.
b) Experiments can be performed for various combinations of water cement ratios to arrive at compressive strength and split tensile strength for different grades of concrete mix.
c) Durability studies such as sorption, chloride permeability, alkali-silica reaction and freeze–thaw resistance tests can be carried out.

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REFERENCE

[1]. Roz-Ud-Din Nassar , Parviz Soroushian- "*Strength and durability of recycled aggregate concrete containing milled glass as partial replacement for cement*", Construction and Building Materials 2012.
[2]. Sudhir p.patil, Ganesh s.ingle, Prashant d.sathe- "*Recycled coarse aggregates*"-International Journal of Advanced Technology in Civil Engineering, ISSN: 2231 –5721, Volume-2, Issue-1**,** 2013.
[3]. Dr. G.Vijayakumar, Ms H. Vishaliny, Dr. D. Govindarajulu- "*Studies on Glass Powder as Partial Replacement of Cement in Concrete Production*"February 2013, vol 3.
[4]. R. Idir, M. Cyr, A. Tagnit-Hamou-" *Use of waste glass as powder and aggregate in cement-based materials*-SBEIDCO" – 1st International Conference on Sustainable Built Environment Infrastructures in Developing Countries ENSET Oran (Algeria)12 Oct 2009.
[5]. R.Vandhiyan, K. Ramkumar and R. Ramya-" *Experimental Study On Replacement Of Cement By Glass Powder*"- International Journal of Engineering Research & Technology (IJERT)- Vol. 2 Issue 5, May – 2013.
[6]. Parviz Soroushain- "*Towards broad use of recycled aggregates*", Innovation in sustainability seed grant December 2012.
[7]. Dhanaraj Mohan Patil, Dr. Keshav K. Sangle- "*Experimental investigation of waste glass powder as partial replacement of cement in concrete*"- International Journal of Advanced Technology in Civil Engineering,- Volume-2, Issue-1, 2013.
[8]. Sunny O. Nwaubani and Konstantinos I. Poutos- "*The Influence of Waste Glass Powder Fineness on the Properties of Cement Mortars*"-Volume 2, Issue 2, February 2013**.**
[9]. M.N.Bajad ,C.D.Modhera and A.K.Desai "*Effect of glass on strength of concrete subjected to sulphate attack*",International journal of civil engineering research and development, volume 1, number 2 may-october 2011, pp. 01-13.
[10]. Bashir alam, Muhammad Ashraf, Khan Shahzada, Salman Afzal and Kaffayatullah Khan "*Sulphate Attack in High-Performance Concrete-A Review*", International Journal of Advanced Structures and Geotechnical Engineering, Vol. 01, No. 01, July 2012.
[11]. M.N.Bajad 1,C.D.Modhera 2 and A.K.Desai-" Effect of glass on strength of concrete subjected to sulphate attack"- International Journal of Civil Engineering Research and Development, Volume 1, Number 2 May-October 2011
[12]. Jabbar Abbas Jabir- "Influence of internal sulphate attack on some of properties for concrete containing recycled aggregate.