American Journal of Earth Science and Engineering
2018; 1(3): 143-149
http://www.aascit.org/journal/ajese

American Association for Science and Technology

Study on Strength and Durability of Recycled Aggregate Using Glass Powder

Deeksha Anand, Akshatha Shetty*

Department of Civil Engineering, A. J Institute of Engineering and Technology Mangaluru, Karnataka, India

Email address

akshathashetty16@gmail.com (A. Shetty)
*Corresponding author

Citation

Deeksha Anand, Akshatha Shetty. Study on Strength and Durability of Recycled Aggregate Using Glass Powder. *American Journal of Earth Science and Engineering.* Vol. 1, No. 3, 2018, pp. 143-149.

Received: January 26, 2018; **Accepted**: February 24, 2018; **Published**: April 27, 2018

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 the novel concept 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). These reactions bring about favourable changes in the structure of the hydrated cement paste and the interfacial transition zones in recycled aggregate concrete. In this paper has also attempted to provide concise information of strength of concrete using eight types of mixes containing waste glass powder and recycled aggregate under sulphate attack.

Keywords: Glass Powder, Recycled Aggregate, Strength

1. Introduction

The application of Portland cement in concrete industry became extensive in practice only after the advent of steel reinforcement. The large-scale production of cement is passing environmental problems on one hand and the unrestricted depletion of natural resources on other hand. The cement industry is responsible for around a 5% of the CO_2 emissions worldwide and considering that concrete is one of the most used materials in construction material next to water [1]. Million tons of waste glass is being generated annually all over the world [2]. Sunny et al. 2013 [3] looked in to the feasibility of waste glass inclusion as partial cement replacement in cementitious systems. Waste arising from construction and demolition constitutes one of the largest waste streams It is now widely accepted that there is a significant potential for reclaiming and recycling demolished debris for use in value added applications to maximize economic and environmental benefits.

The objective of this work is to evaluate the behaviour of RCA with glass powder for strength property. Study also carried out on durability property when exposed to sulfate solution i.e., immersed in $MgSO_4$. The deterioration of concrete was examined by carrying out compressive strength test and split tensile strength test.

1.1. Significance of the Project

In this rapid industrialized world, recycling construction material plays an important role to preserve the natural resources. Continued use of cement and aggregate has started posing serious problems with respect to its availability, cost and environmental impact. To address these situations in this study supplementary cementitious material like waste glass powder and recycled aggregates are used as an economic alternative to the construction materials.

1.2. Objectives

1) To compare the strength and durability characteristics of recycled aggregate concrete made with waste glass powder as a replacement for cement.
2) To find the optimum percentage of recycled aggregate as a replacement for coarse aggregate.
3) To determine the curing period effect on development of strength characteristics for the concrete made with waste glass powder and recycled aggregate with different percentages.
4) Durability studies on concrete containing waste glass powder and recycled aggregate.

2. Methodology Followed

2.1. Materials Used

a) Cement

The cementing action occurs due to the chemical reaction between cement and siliceous soil in the presence of water. Locally available Ordinary Portland Cement (OPC) of grade 43 [Figure 1] is used for the study. Chemical composition of cement is represented below in Figure 2. Cement tests are conducted to obtain its physical characteristics as per IS: 4031–1999 [4].

Figure 1. *View of cement.*

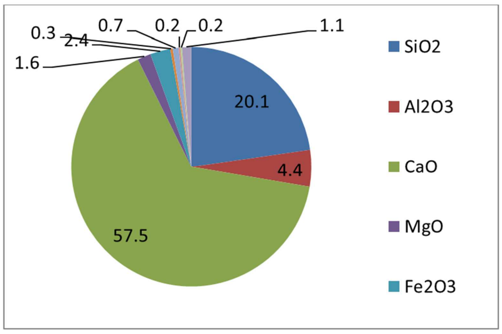

Figure 2. *Chemical composition of cement.*

b) Coarse Aggregate

Coarse aggregates [Figure 3] are the particles of size greater than 4.75 mm. The type of coarse aggregate is of angular type and nominal size of 20 mm obtained locally in the market. Test results were obtained as per IS 383:1970 [5].

Figure 3. *Coarse Aggregate.*

c) Fine Aggregate

In this investigation 4.75mm down size aggregates are used for the study. They are tested as per IS 383:1970 [5]. View of fine aggregate is shown in Figure 4.

Figure 4. *Fine aggregate.*

d) Glass Powder

Glass powder is collected from Enviro Safety Glasses, Mysore. Chemical composition is shown below. View (Figure 5) and Chemical composition of glass powder is shown in Figure 6.

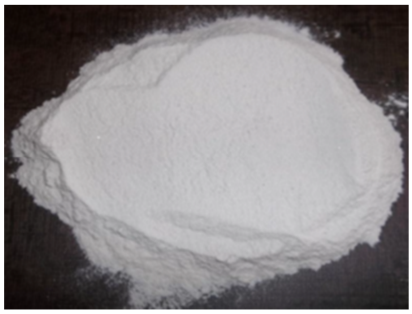

Figure 5. *View of Glass Powder.*

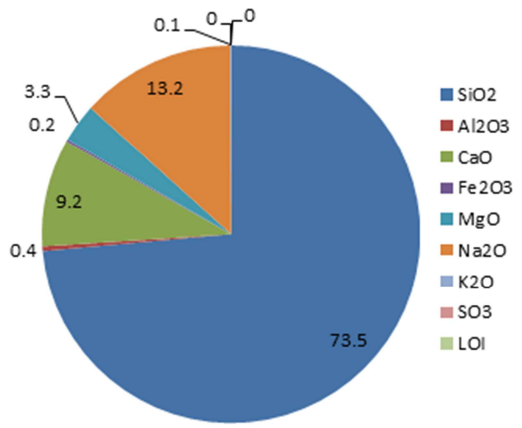

Figure 6. *Chemical composition of Glass Powder.*

e) Water

Water used in concreting plays an important role in mixing, laying, compacting, setting and hardening of concrete. The strength of the concrete directly depends on the quantity and quality of water used in the mix.

f) Recycled coarse aggregate

Recycled coarse aggregate of 20mm downsize are collected from a demolished building in Ujire, Karnataka, India. Figure 7 shows the view of coarse aggregate.

Figure 7. *View of Recycled Coarse aggregates*

2.2. Preparation of Test Specimen

The concrete moulds were prepared with M30 grade of concrete. Mixing of ingredient of concrete is done as per design mix proportion designed based on 10262-2009 [6]. Total eight numbers of mixes were prepared by considering different proportions of materials. Table 1 represents the different types of mixes and Target Slump [Figure 8] values.

Figure 8. *Slump test of concrete.*

Table 1. *Types of mix and its description with slump value.*

Types of mix	Description	Slump (mm)
M1	Conventional Concrete (CC)	60
M2	25% Recycled Aggregate (RA)	62
M3	50% Recycled Aggregate	65
M4	75% Recycled Aggregate	69
M5	20% Glass powder replaced by cement	64
M6	25% RA+ 20% Glass powder	67
M7	50% R A, 20% Glass powder	71
M8	75% R A, 20% Glass powder	75

The steel cube moulds of dimension 150mm X 150mm X 150mm and cylinder moulds of size 150 mm x 300mm were coated with oil on their inner surfaces and were placed on plate. 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, for a slump range of 60 -80mm [Table 1]. Concrete was poured into the moulds in three layers each layer being tamped using a tamping and the top surface was finished using trowel. After 24 hours concrete cubes were de-moulded and the specimens were kept for curing in water for 7, 28 and 56 days.

2.3. Test Procedure

a) Preliminary Tests

Normal consistency test and setting time of cement (IS 4031-1988 [4]), specific gravity test on coarse aggregate, recycled aggregate, fine aggregate, cement and glass powder were conducted. Sieve analysis tests were conducted for coarse, fine and recycled aggregates and compressive strength of mortar cube were carried out.

b) Compression test

Compressive strength of concrete is determined using compression testing machine as per IS 516 – 1959 [7]. The compressive strength of concrete i.e., ultimate strength of concrete is defined as the load which causes failure of the specimen divided by the area of the cross section in uniaxial compression, under a given rate of loading. To avoid large variation in the results of compression test, a great care is taken during the casting of the test specimens and loading as well. The use of 150mm cubes have been made as per IS code of practice IS 456 – 2000 [8]. Compression testing machine is used to test the concrete cubes.

Compression strength is calculated using the formula,

$$Compressive\ Strength\ (N/mm^2) = \frac{Breaking\ load}{Area}$$

At each desired curing periods of 7, 28 and 56 days specimens were taken out of water and kept for surface drying. The cubes were tested in 2T capacity compressive testing machine to get the compressive strength of concrete.

c) Split Tensile Tests

Splitting tensile strength of concrete is determined as per IS: 516 – 1959 [7]. The splitting tensile strength of concrete i.e., ultimate tensile strength of concrete is defined as twice the load which causes failures of the cylindrical specimen divided by the circumferential surface area of the cross section in uniaxial compression, under a given rate of loading [Figure 9]. The use of 150mm x 300mm cylinders have been made as per IS code of practice IS 456-2000 [8].

Split Tensile strength was calculated using the formula,

$$Split\ \ Tensile\ \ Strength\ (N/mm^2) = \frac{2P}{\pi \times D \times L}$$

Figure 9. *Split Tensile Strength test on concrete cylinder.*

d) Durability 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. All the sulphates, i.e., magnesium sulphate ($MgSO_4$) cause maximum damage to concrete. A characteristic whitish appearance is the indication of sulphate attack.

Cube moulds of dimension 150mm x 150mm x 150mm and cylindrical specimen of size 150mm x 300mm specimens were prepared and kept for curing in water for 28 and 56 days. Then the specimen was immersed in a 5% $MgSO_4$ solution for 28 and 56 days. Compressive strength and split tensile strength tests are conducted. View of cube and cylinder specimen after sulphate attack is shown in Figure 10 & 11.

Figure 10. *Cube specimen attack by* $MgSO_4$.

Figure 11. *Cylindrical specimen attack by* $MgSO_4$.

3. Results

3.1. Preliminary Test Results

i) Characteristics test results on coarse aggregate, fine aggregate and cement and glass powders are represented in Table 1, Table 2, Table 3 and Table 4.

Table 2. *Characteristic test results on coarse aggregate.*

Sl. No	Particulars	Test Results
1	Specific Gravity	2.69
2	Type of Aggregate	Angular
3	Grade of Aggregate	Well graded
4	Water Absorption	0.23%

Table 3. *Characteristic test results on fine aggregate.*

Sl. No	Particulars	Test Results
1	Specific Gravity	2.64
2	Zone of Aggregate	II
3	Grade of Aggregate	Well graded
4	Water Absorption	1.2%

Table 4. *Characteristic test results on cement.*

Sl. No.	Particulars	Test Results	IS Requirement
1.	Specific gravity	3.13	IS 2386 (Part III) [9]
2.	Normal Consistency	31%	IS 5513-1969 [10]
3.	Initial setting time	105 minutes	30 minutes
4.	Final setting time	250 minutes	600 minutes
5.	Fineness (retained on 90 micron is sieve)	2.2%	
6.	Compressive strength cement		
	3 days	23.5	≥23 N/mm^2
	7 days	34.0	≥33 N/mm^2
	28 days	45	≥43 N/mm^2

Table 5. *Specific Gravity test result of glass powder.*

Sl. No	Particulars	Test Results
1.	Specific Gravity	2.73

3.2. Test Results

a) Compression Test

Comparison of compressive strength at different curing periods i.e., 7, 28 and 56 days of normal concrete with different replacement levels of cement with glass powder and coarse aggregate with recycled aggregate are shown in Figure 12. Effect of sulphate attack on compressive strength for different mixes is shown in Figure 13 and the Comparison of

Compressive strength against types of mixes in Normal and $MgSO_4$ Solution is shown in Figure 14.

b) Split Tensile Test

Comparison of split tensile strength at different curing periods i.e., 7, 28 and 56 days of normal concrete with different replacement levels of cement with glass powder and coarse aggregate with recycled aggregate are split tensile strength for different mixes is shown in Figure 15 and Effect of sulphate attack on split tensile strength Figure 16 the Comparison of Split tensile strength against types of mixes in Normal and $MgSO_4$ Solution is shown in Figure 17.

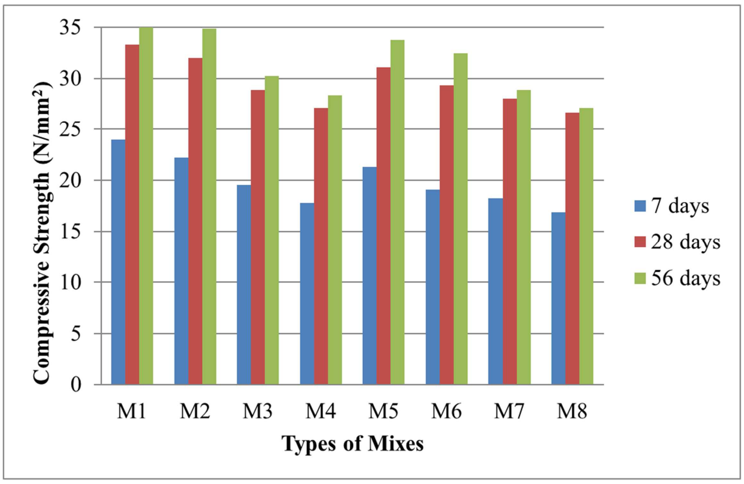

Figure 12. *Compressive Strength of conventional concrete for 7, 28 and 56 days.*

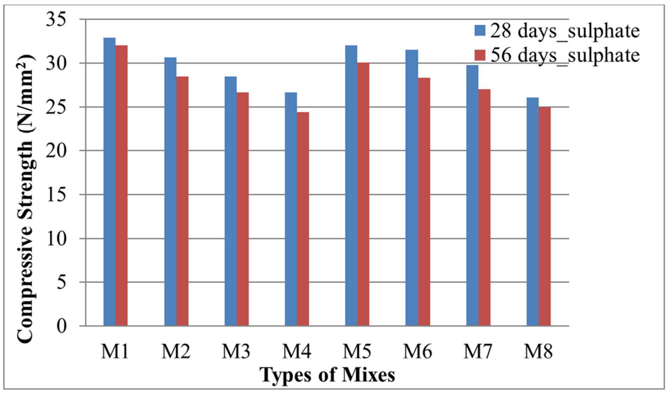

Figure 13. *Compressive strength against types of mixes immersed in $MgSO_4$.*

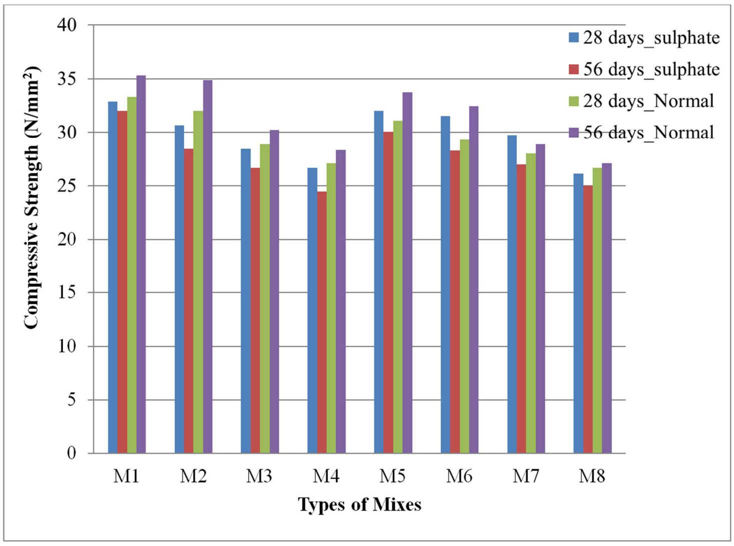

Figure 14. *Comparison of Compressive strength against types of mixes in Normal and immersed $MgSO_4$ Solution.*

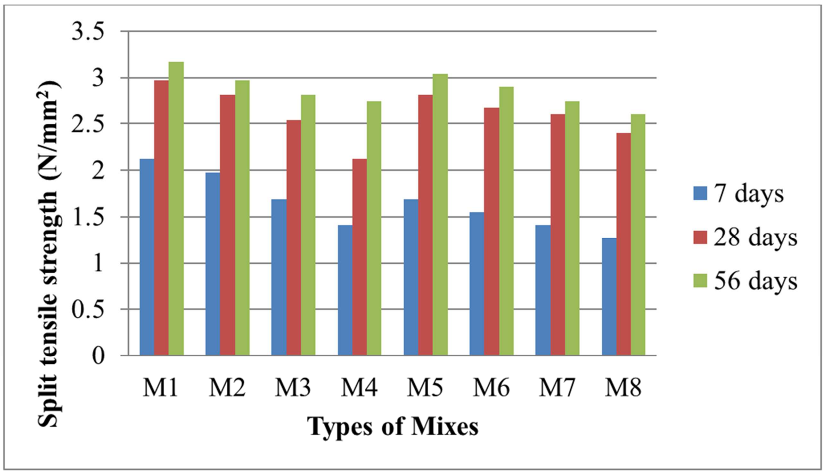

Figure 15. *Split Tensile Strength against % Replacement for 7, 28 and 56 days.*

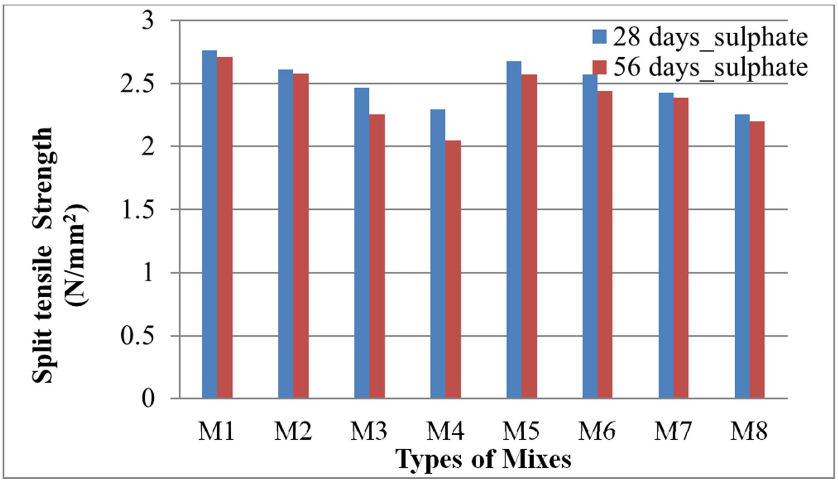

Figure 16. *Split tensile strength against types of mixes immersed in $MgSO_4$.*

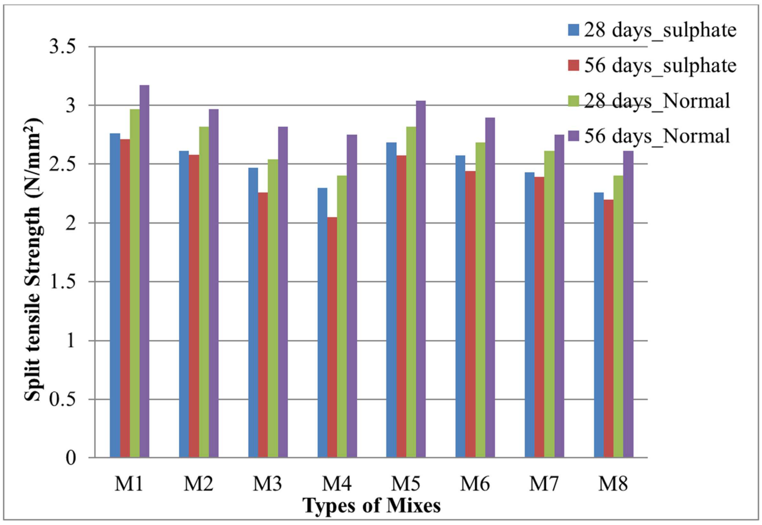

Figure 17. *Comparison of Split tensile strength against types of mixes in Normal and immersed $MgSO_4$ Solution.*

4. Discussions

4.1. Discussion on Preliminary Test Results

Preliminary test results on coarse aggregate, fine aggregate, cement and RCA were found to be within the IS standard limit and suitable for use in concrete works. Furthermore, the well graded aggregate and slump result reveals the better workability conditions.

4.2. Discussion on Conventional Concrete and Fly Ash and Quarry Dust Concrete

Figure 12 and Figure 15 shows the compressive and split tensile strength of different types of mixes for 7, 28 and 56 days for various percentages of recycled aggregate replacing coarse 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.

Figure 14 and Figure 16 shows the compression strength test results for the cubes and cylinders subjected to sulphate attack. The specimens are immersed in 5% $MgSO_4$ solution for about 28days and 56 days. 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.

Figure 14 shows the drop in compressive strength percentage for about 12.3%, 10%, 11%, 13% 10%, 6.5%, 9.9% and 7.7% observed for M1 to M8 mix respectively.

5. Conclusion

In this study it is observed that workability increases as the glass powder content increased since glass powder absorbs lesser water. It is recommended that utilization of waste glass powder in concrete as cement replacement is possible. It is recommended that the utilization of recycled aggregates in concrete as coarse aggregate replacement is possible. Significant increase in the later age strength is achieved through the formation of denser and less permeable microstructure. 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.

Compressive strength of 56days durability attack it is observed that concrete mix M2 i.e., 25% of recycled aggregate and 20% glass powder shows better strength and durability compared to the other mixes this can be effectively used in concrete work.

References

[1] Viviana Letelier, EsterTarela, Giacomo Moriconi (2017). "Mechanical Properties of Concretes with Recycled Aggregates and Waste Brick Powder as Cement Replacement". Procedia Engineering, Vol. 171, pp 627-632.

[2] SadiqulIslam, M. H. Rahman and NayemKazi (2017). "Waste glass powder as partial replacement of cement for sustainable concrete practice". International journal of sustainable built environment, Vo; 6 (1), pp 37-44.

[3] Sunny O. Nwaubani and Konstantinos I. Poutos (2013). "The Influence of Waste Glass Powder Fineness on the Properties of Cement Mortars", Volume 2 (2), pp 14822-14826.

[4] IS 4031-1988: "Methods of Physical Tests for hydraulic cement"- Bureau of Indian Standards, New Delhi, India.

[5] IS 383-1970: “Specification for coarse aggregate and fine aggregate from natural source of concrete”, Bureau of Indian Standards, New Delhi, India.

[6] IS 10262-2009: “Recommended guidelines for concrete mix design”, Bureau of Indian Standards, New Delhi, India.

[7] IS 516-1959: “Methods of tests for strength of concrete”, Bureau of Indian Standards, New Delhi, India.

[8] IS 456-2000, “Plain and Reinforced Concrete-Code of Practice”, Bureau of Indian Standards, New Delhi, India.

[9] IS 2386 (Part III)-1963: “Methods of tests for aggregate for concrete”, Bureau of Indian Standards, New Delhi, India.

[10] IS 5513-1969: “Specification for Vicat apparatus”, Bureau of Indian Standards, New Delhi, India.