Utilization of waste glass as replacement of aggregate in concrete: An experimental study

Sawan Singh[1] & Varinder[2]
[1]Assistant Professor Sant Baba Bhag Singh University.
[2]M.Tech Student Sant Baba Bhag Singh University

Received: September 02, 2018 Accepted: October 26, 2018

ABSTRACT *Climate change is the most important problems of today's world. So "Go Green" is the convenient slogan of this era. As glass powder is waste material, also nonbiodegradable in nature and also having disposal issues. Recycling of waste glass needs a lot of landfill sites but in bigger cities land is very expensive and landfilling sites also cause soil pollution. Waste glass in powdered form is a good material for recycling, and it been used in different sectors. In the field of construction industry, waste glass can be reused for producing concrete. In this paper, partial replacement of fine aggregates with waste glass powders was done to reduce the problem of land fillings and fly ash was also added to reduce alkaline silicate reaction, which is seen in concrete when we add waste powdered glass in concrete for making concrete as green material. Tests were performed on fresh and hardened concrete & results shows that there is a maximum increase in compressive strength of concrete at a replacement of waste glass with fine aggregate up-to at 20%.*

Keywords: *Waste glass powder, Alkali-aggregate reaction, compressive strength*

Introduction

The glass is one of the ancient material manufactured by human, which is known as a material used as construction material in windows, in doors, or in some others building like mall institutional buildings. Glass is used for making of containers, for storage of goods and also for kitchen utensils. All these items have certain lifespan after that they need to be disposed off, in spite of disposing-off waste glass can be converted into desired shape and can be used in production of concrete. The process of use of waste glass is concrete can also be considered as recycling and it has benefits on environment and also reducing landfilling sites so also solves the issue of dumping grounds and further checks land pollution. As India is a developing country so industries are producing a huge amount of glass and simultaneously this is further getting converted to waste glass. Recycling of this waste glass by converting it into construction material as an aggregate is a good idea of saving the environment and can also be economically good. As replacing of fine aggregates with waste glass power will cut the cost of the production of concrete. It has been seen in past researches that waste glass is being used as both CA and FA. Shayan et al (2003) used waste glass as a partial replacement as of sand and concluded that if waste glass powder is used as 30% it used to give maximum compressive strength. Additionally, they also concluded that there was reduction of alkali-aggregate reaction. Further Bum park et al (2004) investigated the properties of fresh as well as hardened concrete by replacing waster glass with coarse aggregates. And it was concluded that replacement of 30% is giving best results. Regarding properties of fresh concrete, the value of slump got increased with addition of glass power as waste glass absorbs less amount of water as compare to natural CA. Her-Yungwang (2008) conducted a study using LED waste glass powder used as a replacement with sand as 0%, 20%, 40%, 60%, and 80%. It was observed that at 20% replacement slump of 150 mm was obtained with is very much adequate for regular RCC constructions. Also with replacement of 20% maximum compressive strength is also obtained. Also, velocity of 4100 meter per second was found when ultrasonic pulse velocity test was performed which shows a good quality concrete. Castro et al (2012): The durability of concrete made by waste glass aggregate was not suitable as compared to durability concrete made with natural aggregates. Some tests were performed such as, absorption of water by capillarity and immersion, the resistance to carbonation, penetration of chloride and shrinkage test which were used to prove the above result. Then 0%, 5%, 10% and 20% of glass aggregate has been used instead of natural aggregate. The experiment proves that the grain size affects a lot on workability of concrete. Also, Abdullah et al (2014) did the investigation on characteristics of concrete with waste glass powder as used as replacement of fine aggregate. He replaced sand with waste glass powder with a percentage of 0%,5 %, 15%, and 20%. There was increase of compressive, splitting tensile and flexural strength of concrete by 5.28 %, 18.38%, and 8.92% respectively at 28 days for 20% replacement. Along with that water, absorption decreased to 14.86%.

Research methodology

Various steps of experimental work:

1. Testing of materials used in concrete
2. Design mix of concrete
3. Tests on fresh concrete
4. Casting of the concrete sample (cubes, beam, and cylinder)
5. Testing for dry samples of concrete
6. Preparation of waste glass to be used as fine aggregate
7. Proportion of waste glasses in fine aggregate
8. Design Mix for M 25

Stipulation for proportioning

- Grade of concrete = M 25
- Cement type = OPC 43 grade
- Max. Size of CA = 20 mm
- Max water/cement ratio = 0.45
- Workability = 100 mm slump
- Exposure condition = severe
- Type of aggregates = crushed
- Maximum cement content = 450 kg/m3

Data required for design mix, obtained from testing

- Specific gravity of cement = 3.150
- The specific gravity of CA = 2.67
- The specific gravity of FA = 2.67
- Water absorption for CA = 0.5
- Water absorption for FA = 1.11
- FA = confirming zone II

Mix proportion

- Cement = 437.50 Kg = 1
- Water = 197.50 Kg = 0.45
- FA = 673.39 Kg = 1.54
- CA = 1053.15 Kg = 2.40
- 20mm = 526.45 Kg
- Ratio of mix = 0.5: 1: 1.54: 2.40

Materials used for casting

Cement: Ordinary Portland cement (OPC) of 43 grades was used for casting of cubes and cylinder. The cement was confirmed as per IS 4031. The specific gravity of OPC was 3.15. The initial and final setting time was 30 min and 600 min respectively.

Coarse aggregate: Crushed stones, basalt stone are used for making of concrete. 10mm and 20 mm aggregates were used. Well graded, all of aggregates are used for casting. The material has to satisfy IS 383. The specific gravity of 10 mm and 20 mm was found 2.67 and 2.67 respectively. Water absorption was 0.74%.

Fine aggregates: Riverbed sand was used. It was confirming zone II. As per IS: 383-1970 provision it was in the range of zone II. The specific gravity of FA was 2.6 and water absorption was 1.5%.

Water: Drinking water was used for the casting of concrete and curing of concrete. Water should fulfill all requirements as per IS 456-2000.

Waste glass: It is a hard material, which is brittle substance and almost transparent or translucent. it is composed by melting sand with soda, lime and cooling fast(rapidly). It is utilized to make many materials for construction like doors, windows and in propose of decollation. It is used also to make other material as drinking containers, tube light, etc.

4.2 Calculation of material

For each percentage of waste glass at 0%, 2.5%, 5%, and 7.5%, we need minimum 3 cubes, 3 beam, and 3 cylinders at 7 days, 14 days and 28 days, for each test to find the compressive, flexural and tensile strength of concrete test.

Table 1: Number needed each % and day

% days	7 days	14 days	28 days
0	3	3	3
2.5	3	3	3
5	3	3	3
7.5	3	3	3

Table 2: Calculation of quantities

Title	Volume(m3)	Density(kg/m3)	Number	Weight(kg)
Cube	$.15x.15x.15=3.375x10^{-3}$	2445	108	889
Beam	$.1x.1x.5=5x10^{-3}$	2445	108	1317
Cylinder	$\frac{\pi}{4}x.15x.15x.3=5.3x10^{-3}$	2445	108	1396

Total quantities = 889.38+1317.6+1396= 3603kg
Total quantities by design mix =2360kg
So the ratio of this two = 3603.656kg/2360.89kg = 1.526
Quantities of ingredients required:

- Cement =437.00 Kg x 1.526 = 666kg
- Water =197.00 Kg x 1.526 = 300kg
- Fine aggregate =673.29 Kg x 1.526 = 1027 kg
- Course aggregate =1053.1 Kg x 1.526 = 1607kg

Equipments used:

- Cube Mould
- Impact machine Test
- Slump cone Test
- Beam mold
- Load compaction
- Los Angeles Machine test
- Compressive machine test
- Cylindrical mold

EXPERIMENTAL WORK

Trail mix

For the trail mix, we need three cubes, three beams and three cylinders which we can test after 7 days of curing so that we can see if we got 60 % of our target mean strength of design mix.

Mixing of concrete ingredients

For cubes, beams and cylinders of three each, we need 24.71 kg of cube, 36.65 kg of beam and 38.75 kg of cylinder material, so we take 46.85 kg of coarse aggregate and 29.95 kg of FA, we mix first these two and add 21.45kg of cement and mix again, after adding 8.75kg of water in three parts for mixing.

Figure 1: Mixing of ingredients before & after addition of water

After mixing properly, concrete was designed for slump of 100 mm but we obtain 97 mm which is acceptable & cubes were filled in the mould in three layers & vibrator was used for compaction. This testing slump, filling the mould and mixing concrete from the time of adding water can take only less than 30 minutes.

Figure 2: Testing slump and filling mould in 3 layers

Testing of hardened concrete and results obtained

As per IS 516, the cube test and beam test with the rate of loading of 5.2KN/second and 0.1KN/second respectively and IS Code 5816-1999, give the procedure for testing of a cylinder with the rate of loading of 2.1KN/second.

Table3: Compressive Strength results of trail mix(KN)

Name	1st sample	2nd sample	3rd sample
Cube	567.8	532	533
Beam	21.4	21.1	21.3
Cylinder	209	201.4	205.3

Calculation of strength

For cube= 1632.8/(3*150*150)= 24.2N but target mean strength of our design mix of M-25 is 33.25N, so 24.2N is 72.75% of 33.25N, this is greater than 60% which we need, so we can reduce some quantities of cement.

Calculations for materials required for mix.

For each batch, I mixed six cubes first and three more afterward, similarly for the beam and the cylinder. For different days (7, 14 and 28) in which I took three readings for more accuracy. This table is showing each different quantities of materials which we need for mixing.

Table 4: Quantities of used materials

Names	Materials/%	0%	5%	10%	20%	Total in Kg
9 cubes	Cement	15.44	13.65	13.65	13.65	56.45
	Water	6.60	6.60	6.60	6.60	26.40
	C.A	35.5	35.5	35.5	35.5	142
	F.A	22.7	21.55	20.45	18.13	82.83
	Glass	0	1.14	2.25	4.56	7.95

	fly ash	0	3.39	3.39	3.39	10.17
9 beams	Cement	22.83	20.1	20.1	20.1	83.13
	Water	9.81	9.81	9.81	9.81	39.24
	C.A	52.39	52.39	52.39	52.39	209.56
	F.A	33.49	31.81	30.19	26.74	122.23
	Glass	0	1.68	3.3	6.75	11.73
	fly ash	0	5.01	5.01	5.01	15.03
9 cylinders	Cement	24.18	21.2	21.2	21.2	87.78
	Water	10.36	10.36	10.36	10.36	41.44
	C.A	55.44	55.44	55.44	55.44	221.76
	F.A	35.44	33.67	31.84	28.35	172.4
	Glass	0	1.77	3.6	7.09	12.46
	fly ash	0	5.31	5.31	5.31	15.93

We mix first fine aggregate and coarse aggregate, secondly we added to cement in the aggregate mix and again mix, we take waste glass powder and mix it with the whole mix, after that we add water in three batches each batch we make a mix, then we test the slump and fill mould in three layers, using vibrating machine for compaction. At the time of adding water till finishing filling the entire mold the time should not exceed 30 min because the settlement of cement is 30 min after adding water to the ingredient.

Curing of concrete: Each sample was cured in the mold for 24 hours and then emerged in water some sample for 7 days, others for 14 days and the rest for 28 days. Use of proper water and should be changed after 7 days. Before testing, we cure it for 30 min at room temperature.

Testing of hardened samples of concrete: We follow procedures as shown in IS codes 516-1959 for the testing cube and beam with the rate of loading 5.1 KN/second for the cube and 0.1 KN/seconds for the beam. For a testing cylinder, we follow IS code 5816 with the rate of loading 2.1KN/seconds.

Figure 3: Testing of samples of hardened concrete (cubes)

Figure 4: Testing of cylinders of hardened concrete

Figure 5: Testing of samples of hardened concrete (beams)

RESULTS AND ANALYSIS

Slump test

Table 5: The value of slump test (mm)

Percentage / round	1st round	2nd round	3rd round
control mix	110	105	110
05 % of replacement	90	85	80
10 % of replacement	70	80	60
20 % 0f replacement	60	65	50

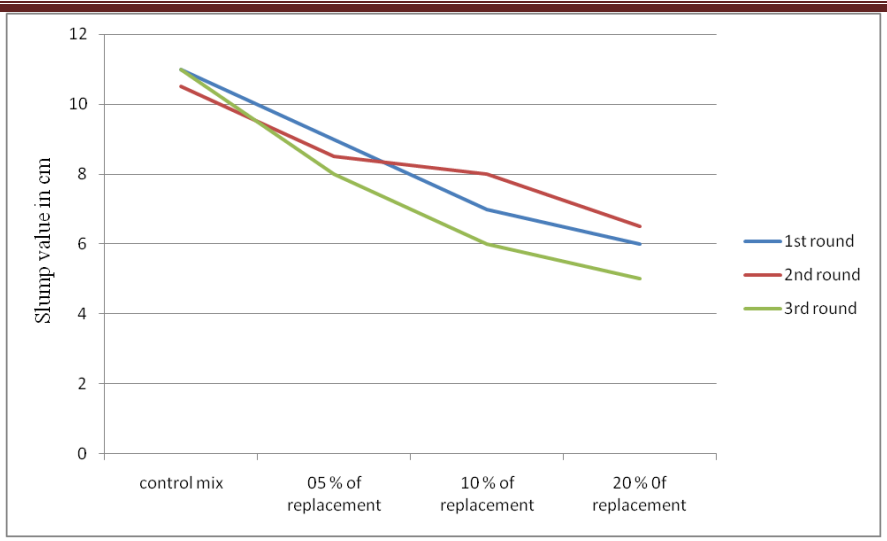

Figure 5: Workability of fresh concrete

6.2 Compressive strength

Table 5: Compressive strength results (N/mm²)

Percentage	7 days	14 days	28 days
0%	26.29	27.91	34.08
5%	24.28	25.05	31.88
10%	25.11	26.11	32.08
20%	25.84	27.21	34.35

As the Waste Glasses is one of the best materials of compressive strength properties it will increase the strength of concrete by increasing the percentage of glass aggregates and this is will be caused by glasses aggregates which used as a powder and this will not be beyond to the result of main control mix.

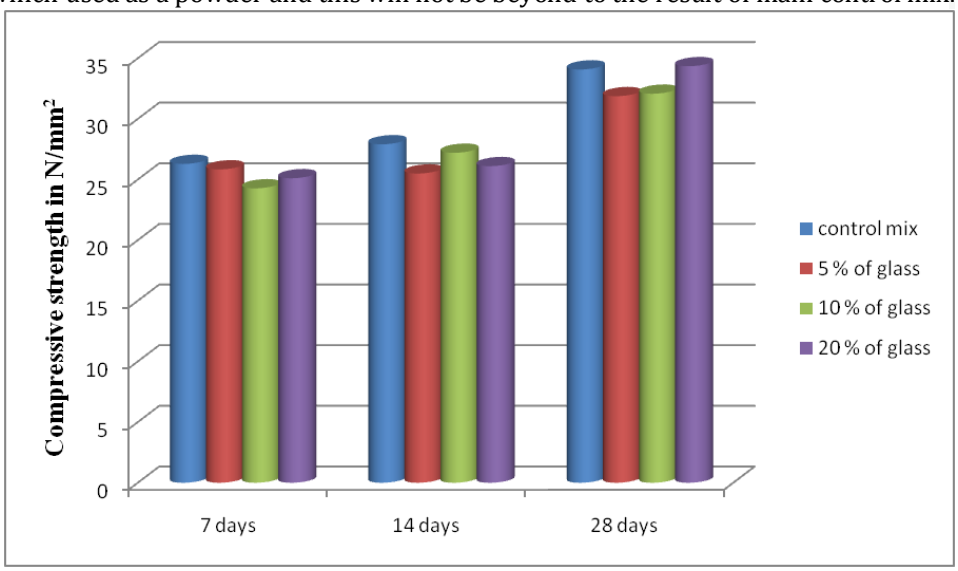

Figure6.2: Compressive strength of hardened concrete cubes VS days of curing

Flexure strength

Table 6: Flexure strength results (N/mm²)

% and days	7 days	14 days	28 days
0 %	10.9	11.08	11.18
5 %	10.95	11.28	11.22
10 %	8.57	9.17	9.38
20 %	8.1	8.6	8.78

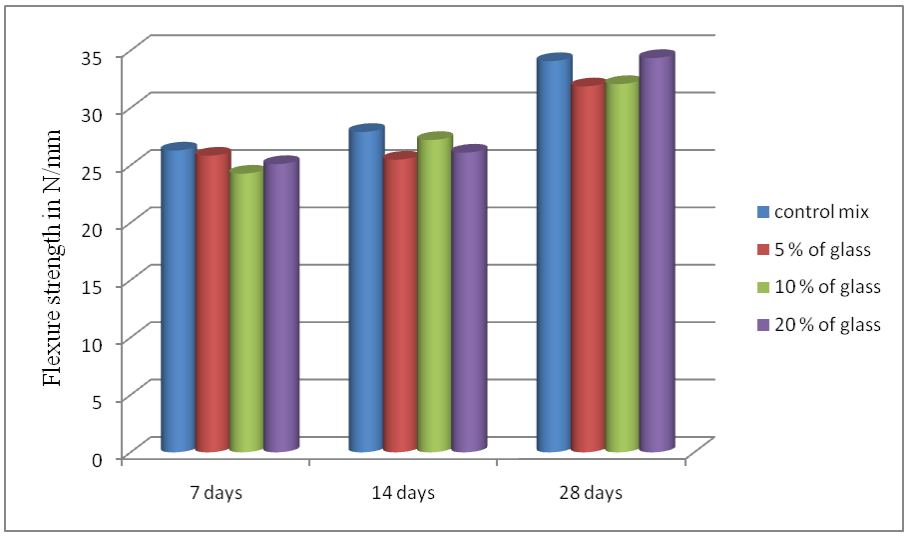

Figure 7: Flexural strength of hardened concrete cubes VS days of curing

Split tensile strength

Table 7: split tensile strength result (N/mm²)

% and days	7 days	14 days	28 days
0 %	3.83	4	4.2
5 %	3.45	3.6	3.82
10 %	3.67	3.66	3.95
20 %	3.77	3.78	4.14

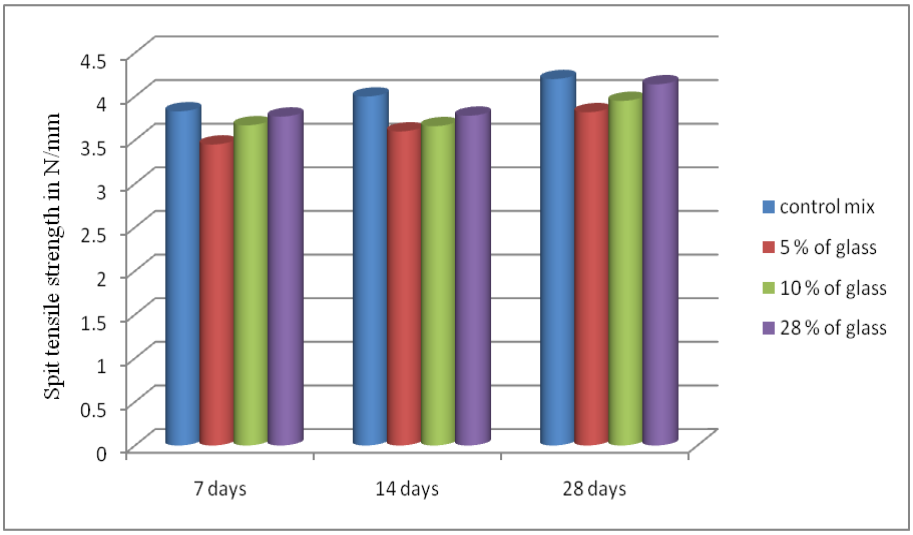

Figure 7: Split tensile strength of hardened concrete cubes VS days of curing

Conclusion

In previous experiment study of this topic, the problem of the alkaline reaction was observed in concrete, but in the same study, the compressive, flexural and tensile strength was increased by comparing to the normal concrete (concrete without glasses)

As we are improving this study and correct those issues of alkaline reaction, we will adopt a technique of using small sieved glass and less quantity, which will minimize that alkaline reaction in our experimental study.

After resolving this issue of alkaline reaction, the concrete with glass will be mostly economic because of using those waste glass, this will give us also a good strength of a concrete and a best-looking concrete.

Reference

1. Nasser Almesfer1 and Jason Ingham(2014) "Effect of Waste Glass on the Properties of Concrete" American society of civil engineers
2. SadoonAbdallah, Mizi Fan (2014)"Characteristics of concrete with waste glass as a fine aggregate replacement" International journal of engineering and technology research volume-2
3. Sara de Castro, Jorge de Brito*(2013) "Evaluation of the durability of concrete made with crushed glass aggregate "Journal of cleaner production 41(7-14).
4. S.P GatamVikasSrivastava and V.C Agarwal,(2012)'Use of glass wastes as fine aggregate in Concrete".J.acad .indus.res vol-1(6)
5. RichidaIdir, Martir Cyr*, ArezkiTagnit-Hamou (2011) "Pozzolanic properties of fine and course color-mixed glass cullet". cement and concrete composites 33(19-29)
6. Her-Yung Wang* (2009)"A study of the effects of LCD glass sand on the properties of concrete "Waste management 29(335-341).
7. Zainab Z. Ismail*, Enas A. Al-Hashmi (2009) "Recycling of waste glass as a partial replacement for fine aggregate in concrete". Waste management 29(655-659).
8. Mukesh C Limbachiya(2009) "Bulk engineering and durability properties of washed
9. glass sand concrete", construction and building materials volume 23 issue 2
10. Bashar Taha* and GhassanNounu,(2008)"Properties of concrete contains mixed color waste recycled glass as sand and cement replacement". construction and building material 22 (713-720)
11. Mohammad J Terro(2006)"Properties of concrete made with recycled crushed glass at elevated temperatures". Building and Environment 41(633-639)
12. Seung Bum Park*, Bong Chun Lee, Jeong Hwan Kim (2004)"Studies on mechanical properties of concrete containing waste glass aggregate". cement and concrete research 34(2181-2189)
13. Ahmad Shayan*, AiminXu(2004)"Value-added utilization of waste glass in concrete" Cement and concrete research 34(81-89)
14. IS 456 2000 Plain and reinforced concrete code of practice
15. IS 10262:2009 Concrete mix proportioning -guidelines
16. IS 383:1976 Specification for coarse and fine aggregates from natural sources for concrete
17. IS 8112:1989 Code for Ordinary Portland cement
18. IS 516:1959 Methods of test strength of concrete
19. IS 5816:1959 Split Tensile Strength of concrete
20. Concrete technology: Theory and practice By M.S Shetty S.Chand Publications
21. Concrete technology A.R. Santakumar Oxford University Press India Publications
22. Concrete technology: Theory and practice By Murari Lal Gambhir, Tata McGraw-Hill Education Publications
23. Concrete technology Neville Pearson Education India, Publications