International Journal of Modern Trends in Engineering and Research
www.ijmter.com
e-ISSN No.:2349-9745, Date: 2-4 July, 2015

Experimental Investigation on properties of concrete made using glass cullet as a partial replacement to fine aggregates

Preeti Kulkarni[1], Raj Shah[2], Mohak Mantri[3], Mohit Patidar[4], Sankalp Nahar[5]

[1]Asst. Prof., Vishwakarma Institute of Information Technology, Pune, deshpandeneela@yahoo.com [2]B.E Student, Vishwakarma Institute of Information Technology, Pune, rajshah0606@gmail.com [3]B.E Student, Vishwakarma Institute of Information Technology, Pune, mohakmantri@gmail.com [4]B.E Student, Vishwakarma Institute of Information Technology, Pune, mohitp289@gmail.com [5]B.E Student, Vishwakarma Institute of Information Technology, Pune, sanklapnahar@gmail.com

Abstract- Construction industry is the major consumer of natural resources and one of the main material is river sand which is an integral part of concrete. On the other hand environmental threat caused due to glass waste is well-known. This paper is an attempt to understand the feasibility of using glass waste as aggregates in concrete. Waste glass termed as glass aggregates (GA) were partially repl aced in concrete at water-cement ratios of 0.4 and 0.48. Experimental investigation of workability, compressive strength, split tensile strength, flexural strength and modulus of elasticity was done. It was found that the slump of concrete containing glass aggregates as fine aggregate replacement decreased with increases in the glass aggregate content but without loss of workability. The compressive strength with 3% glass aggregates in concrete is similar to the target strength of M25 grade concrete. There was a decrease in split tensile strength and tensile strength of concrete at higher water-cement ratio. The increase in percentage of GA in concrete, reduces the modulus of elasticity.

Keywords- Glass aggregates; water-cement ratio; modulus of elasticity.

I. INTRODUCTION

Construction industry is a larger consumer of natural resources of which natural fine aggregate derived from river bed is a material of major concern as its reserves are depleting at a rapid rate. Thus a necessity arises to find an alternative material to natural fine aggregates. On the other hand waste glass is derived in larger quantities from broken glass panels, bottles etc. which are either recycled or used for landfill which further adds up to environmental threat. Annually, Asia alone generates 4.4 billion tones of solid wastes of which about 48 (6%) MT is generated in India [1]. In India, 0.7% of total urban waste generated comprises of glass [2]. Thus to address both the above stated issues, use of glass in the form of aggregates, as partial replacement to fine aggregate in concrete can be an option to be explored. Previous studies done on glass added concrete suggests that glass can be used in concrete in three forms; as coarse and fine aggregate, and in powder form. The effect of using waste glass on the mechanical properties of concrete indicated that the waste glass aggregate generally reduced strength [3,4,5].They attributed this behavior to that the silica in glass can be highly reactive with the alkalis in cement paste which lead to expansion and cracking of concrete. An experimental work indicates that the concrete mixes containing 20% waste glass show slightly reduction in compressive and tensile strength as compared with reference mixes [6]. Compressive strength of the concrete increases with partial replacement of sand by finely crushed waste glass at the later ages indicating the contribution of pozzolanic reaction. Water absorption decreased with increase waste glass aggregate ratio and with 20% of glass aggregate replacement a reduction of 14.68% at 28-day age compared to control can be seen [7]. Concrete with glass mixtures exhibit a faster setting, larger elastic modulus, greater abrasion resistance, lower chloride ion penetrability, lower water absorption, and lower drying shrinkage [8]. In a study the use of recycled glass bottles as an alternative fine aggregate for concrete mix decreases the water-cement ratio depending on the amount present in the mixture and unit weight of concrete [9]. The crushed glass was also used as coarse aggregate in concrete production but due to its flat and elongated nature which enhances the decrease in the workability and attributed the drop in compressive strength [10]. With the above concept the current study attempts to use glass bottle waste termed as glass aggregates (GA) in concrete. The significance is to understand the feasibility and acceptability of concrete with reference to its strength characteristics which contains percentage of aggregates as GA. Details about materials used and their properties comprise the next part of the paper followed by results and discussion on experimental investigations on concrete with GA.

II. OBJECTIVES

The objective of the project can be defined in the following points

1. To study the basic physical and mechanical properties of glass cullet aggregates (GA) and to compare them with similar properties of artificial fine aggregate (AS).
2. By using IS 10262:2009, design M25 grade of concrete with an aim of maximum utilization of GA as (percentage of) fine aggregates with other materials.
3. Study the properties of fresh and hardened concrete properties as workability, compressive strength, split tensile and flexural strength, modulus of elasticity and density, made using GA.

III. METHODOLOGY

The aim of the project is maximum utilization of GA in concrete. GA will be used as replacement to AS in concrete. In the initial phase conventional concrete with cement, fly ash, AS, coarse aggregates and water will be made which will act as a control specimen and further percentage replacement of GA will be done with water cement ratios (w/c) of 0.4 and 0.48. The methodology adopted is: Cement, AS, coarse aggregates, water and GA (1%, 2%,5% and 10% replacement to AS). The proportion of materials selected for the mix was arrived by designing using IS: 10262:2009 and trial mixes [11]. This was done to ascertain the % of flyash in mixes**.**

IV. MATERIALS USED IN PROJECT

The material used in the project is the glass cullet which is derived from crushing of glass bottles from crushing plant to a size of 4.75mm and below (refer figure 1) and referred as glass aggregates (GA). Container glass is formed from a specific type called soda-lime glass, composed of approximately 75% silicon dioxide (SiO_2), sodium oxide (Na_2O) from sodium carbonate (Na_2CO_3), calcium oxide (CaO), and several minor additives. The other materials used are 53 grade cement, coarse aggregates-20mm and artificial fine aggregate (AS).

The other materials used in the project are cement of 53 grade, coarse aggregates-20mm and artificial or machine made fine aggregate (AS), Super plasticizer- SP500 and water.

Figure 1: Glass aggregates

Figure 2: Slump of concrete at 5% GA.

V. RESULTS AND DISCUSSIONS

The section discusses the properties of materials used in the project followed by experimental investigation on concrete with an aim of maximum utilization of GA as partial replacement to fine aggregate. The concrete with GA will be addressed as glass aggregate concrete (GAC).

5.1 Properties of materials

GA have smooth texture and irregular shape with size ranging from 4.75mm and below. Table 1 shows the properties of GA, AS and conventional coarse aggregates-20mm (NA-20mm). characterized by lower specific gravity which can further lead to concrete with less density as compared to conventional aggregate concrete. Higher fineness modulus of GA shows the presence of coarser particles which can further lead to presence of voids and decrease of strength. Due to the presence of varied sizes of particles in GA i.e. from 4.75mm and below, the surface area increases, and the water clinging to the surface increases the water absorption. Also smaller GA particles absorb some amount of water and thus its moisture content shows an increase trend.

Table No. 1 Properties of aggregates

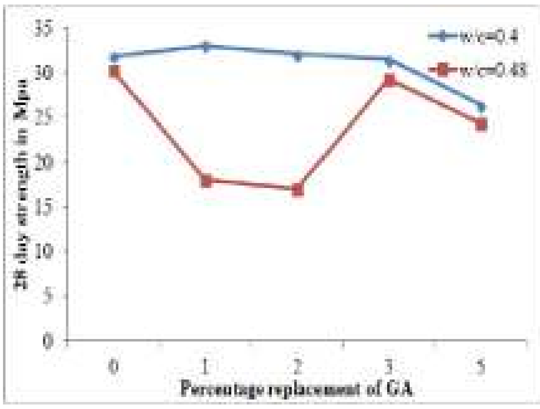
Property of Aggregate	GA	AS	NA-20mm
Specific Gravity	2.29	2.89	2.81
Fineness Modulus	3.15	3.05	-
Moisture Content	3.18	2.83	-
Loose Bulk Density	1.43kg/lit	1.35kg/lit	1.48kg/lit
Water Absorption	8.52%	3.86%	2.71%
Material finer than 75µ	3.60%	2.85%	-
Impact value	-	-	16.22%
Crushing value	-	-	21.67%

5.2 Workability and Compressive strength of GA

Workability is the ease with which concrete can be mixed and placed. In fresh GAC, GA show an interlocking action between the mortar and other materials and thus the slump stands upright and do not collapse at w/c ratio of 0.4 and 0.48, showing a slump of 300mm however the concrete is easy to work with. The trend is seen in all replacement ratios; however as the replacement ratios increase the buckling action at the bottom part of the slump is seen prominently. Figure 2 above shows slump obtained at w/c = 0.48 for 5% replacement of GA. Presence of 15% fly ash contributes towards slump of 300mm. Compressive strength at 7 and 28 days is shown in Table 2 below. In the initial phase, trials were done to ascertain the percentage replacement of fly ash in concrete and it was seen to be 15% to gain strength of 25 MPa at 28 days for convectional concrete. In all the mixes used in the project 15% fly ash and 1% superplasticzer is used.

Table No. 2 Mixes of concrete with glass

Mix No.	w/c	Proportion of materials Binder: fine aggregate: coarse aggregate	Fine aggregate glass Kg/m^3	Percentage of GA	7 days strength N/mm^2	28 days Strength N/mm^2
1	0.40	1:2.69:3.83	0	0%	18.93	31.84
2	0.40	1: 2.69 :3.83	8.97	1%	18.94	27.49
3	0.40	1:2.66:3.83	17.94	2%	21.31	32.08
4	0.40	1:2.66:3.83	26.91	3%	21.20	31.45
5	0.40	1:2.58:3.83	44.85	5%	21.10	26.33
6	0.48	1:2.70:3.54	0	0%	20.66	30.20
7	0.48	1:2.70:3.542.70:3.54	9.02	1%	12.77	17.95
8	0.48	1:2.68:3.54	18.05	2%	15.07	16.88
9	0.48	1:2.68:3.54	27.06	3%	21.20	29.25
10	0.48	1:2.59:3.54	45.13	5%	17.83	24.28



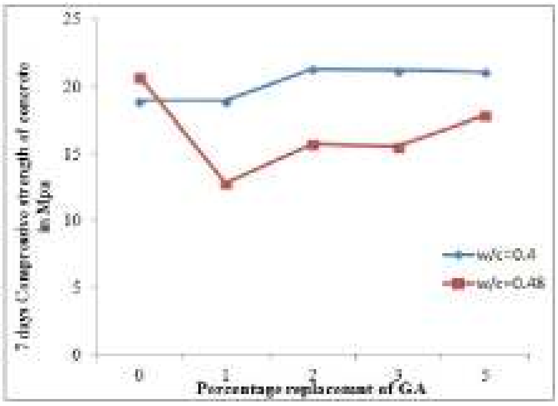


Fig. 3 7 day strength of GAC ***Fig. 4 28 day strength of GAC***

Figure 3 and figure 4 above show the compressive strength of concrete with GA at various replacement percentages. At 7 days, with increase in percentage of GA in concrete, the strength shows an increasing trend at w/c ratio of 0.48. Lower w/c ratio contributes towards increase in strength. A change in the pattern of strength gain is due to the presence of fly ash. Reduction of concrete permeability and diffusivity due to fly ash reaction with the calcium hydroxide produced by the hydration of the cement takes place. At lower w/c ratio better strength can be gained and 3% presence of GA in concrete gains the characteristic strength of M25 grade concrete. Fig. 5 shows the closure view of concrete with GA.

Fig. 5 ITZ between aggregates and mortar

The figure 5 shows two ITZ's, one with mortar and GA and next mortar with conventional aggregate. The ITZ with mortar and GA is seen to be weak as compared to the later, due to the smooth surface of coarser GA.

5.3 Split and Flexural strength

The results for split tensile strength and flexural strength of GAC are as shown in the Table 3. At w/c ratio of 0.4, the split tensile strength and flexural strength are higher than that of w/c ratio of 0.48. A slight decrease can be seen in split tensile strength at 1% which can be attributed towards conditions of mixing and placing the concrete. At 3% of GA in concrete, a decrease of 0.31N/mm^2 of split tensile strength can be seen than the control mix for w/c ratio of 0.4. However, at w/c = 0.48, a decrease in the strength can be seen than its control mix. A similar pattern can be observed for flexural strength of GAC with w/c ratio as 0.48. At w/c ratio as 0.4, the flexural strength shows an increase of 4.25 N/mm^2 at 1% of GA in concrete. At 2% of GA in concrete, an acceptable flexural strength can be achieved. Presence of GA in concrete and their alignment along the loading direction is the important factor deciding the flexural and split tensile strength of concrete. At lower w/c ratio, the ITZ between mortar and GA particles is better than that of ITZ at w/c ratio of 0.48. Thus an increase in strength can be seen in lower w/c ratio than that in higher w/c ratio. The significant increase in the later-age flexural strength of concrete mixes with incorporation of partial replacement of GA, is realized by the pozzolanic reactions of GA and fly ash with calcium hydroxide (CH) resulting in its conversion into C–S–H

Table No. 3 Split tensile strength and flexural strength of concrete

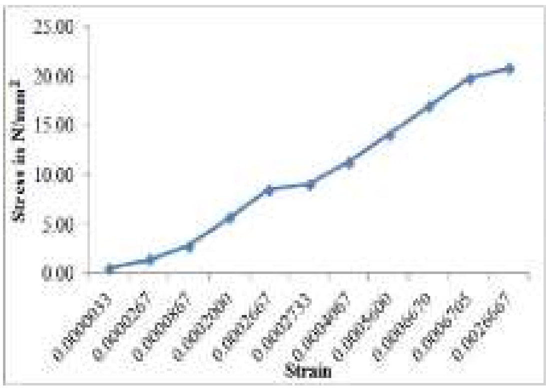
Mix	W/C	Percentage of GA	7dayssplit tensile strength N/mm^2	28 days split strength N/mm^2	28 days flexural strength N/mm^2
1	0.4	0%	3.02	3.50	4.12
2	0.4	1%	1.97	2.73	8.37
3	0.4	2%	1.94	3.24	4.13
4	0.4	3%	1.90	3.19	3.2
5	0.4	5%	1.84	3.00	2.64
6	0.48	0%	2.19	3.56	3.78
7	0.48	1%	1.96	2.61	4.18
8	0.48	2%	1.47	2.06	2.29
9	0.48	3%	1.58	2.39	3.05
10	0.48	5%	1.75	2.52	3.78

5.4 Density and Modulus of elasticity of concrete

Table 4 below shows the density and modulus of elasticity of concrete. GA are characterized by lower specific gravity and thus leads to concrete with lower density. As the table 4 shows, as the percentage of GA in concrete increases, the density of concrete shows a decrease. A decrease of 5.33% in density can be seen at 5% replacement of GA in concrete at w/c ratio 0.4, and at 0.48 of w/c ratio 0.56% decrease can be seen. Modulus of elasticity (E) of concrete is a value determining the capacity of concrete to sustain stresses and is a key factor for estimating the deformation of buildings and members, as well as a fundamental factor for determining modular ratio which is used for the design of section of members subjected to flexure its value is dependent on the characteristics of cement and aggregates used, age of concrete and strengths. Figure 6 below shows the setup done for testing

Mix	W/C	Percentage of GA	Density of concrete Kg/m^3	Modulus of elasticity N/mm^2
1	0.4	0%	2707.82	26336.60
2	0.4	1%	2605.43	26083.05
3	0.4	2%	2597.531	25376.83
4	0.4	3%	2563.50	24328.24
5	0.4	5%	2552.06	22186.52
6	0.48	0%	2709.14	26052.43
7	0.48	1%	2627.16	23397.61
8	0.48	2%	2566.91	23175.03
9	0.48	3%	2560.25	22145.50
10	0.48	5%	2556.05	21797.28

Table 4 shows that as the percentage replacement of GA in concrete increases, the value of E decreases. A decrease of 15.75% of E value can be seen in 5% replacement of GA in concrete than that of its control mix at 0.4 w/c ratio and a* decrease of 16.33% in E value than its control mix at w/c of 0.48. Presence of GA with high crushing strength than conventional aggregate decreases the modulus of elasticity of concrete. Figure 7 and 8 below show the strain vs. strain graph for concrete with 3% replacement of GA and 0% replacement of GA in concrete at 0.4 w/c ratio respectively.



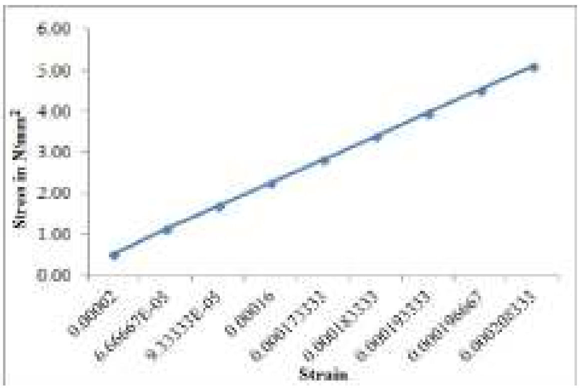


Fig. 7 Stress vs. strain for concrete with 3% GA Fig. 8 Stress vs. strain for concrete with 0% GA

An attempt was also made to understand the alkalinity of solution in which the fine mortar of

GAC was dissolved. As the pH, or alkalinity, of the solution increases, potential for the alkali-silica reaction increases which can cause distress in concrete. In the current GAC the ph for 0% GA concrete was seen to be 20 and with 5% GA in concrete the ph value was seen to be 23.4 thus indicating that as the percentage of GA increases the alkalinity of the solution also increases.

VI. CONCLUSIONS

The current project aims at studying the fresh and hardened characteristics of concrete made with percentage replacement of GA. The study leads to the following conclusions:

Compressive strength of the concrete with G A increased with the increment of GA, especially at the later ages, with compressive strength at 28 days being 9.96% higher compressive strength for 2% replacement compared to controlled concrete, which also indicated the contribution of pozzolanic reaction. 3% of GA in concrete can achieve the target strength of M25 grade concrete.

- At 3% of GA in concrete a decrease of 0.31N/mm^2 of split tensile strength can be seen than the control mix for w/c ratio of 0.4. At 3% of GA in concrete an acceptable flexural strength can be achieved for 0.4 w/c ratio.
- Density of concrete decreases with increase in percentage of GA in concrete. At 3% replacement of GA in concrete, density of 2563.5 kg/mm^3 is being seen.
- With increase of GA in concrete, the modulus of elasticity decrease. With 3% of GA in concrete a decrease of 7.6% can be seen in modulus of elasticity than the concrete with 0%

REFERENCES

1. Asokan, P. Solid wastes generation in India and their recycling potential in building materials. Building and Environment, Vol. 42, No. 6, pp. 2311-2320, June 2007.
2. Malik, M., Bashir, M., Ahmad, S., Tariq, T., and Chowdhary, U. Study of Concrete Involving Use of Waste Glass as Partial Replacement of Fine Aggregates. IOSR Journal of Engineering, Vol. 3, No.7, pp. 08-13, July. 2013.
3. Gautam, S., Srivastava, V., and Agarwal, V. Use of glass wastes as fine aggregate in Concrete. Journal Acad. Indus, Res. Vol. 1, No. 6, pp. 320-322, Nov. 2012.
4. Abdallah, S., Fan, M. Characteristics of concrete with waste glass as fine aggregate replacement. International Journal of Engineering and Technical Research, Vol. 2, No.6, pp. 11-17, Jun. 2014.
5. Corinaldesi, V., Gnappi, G., Moriconi, G. and Montenero, A. Reuse of ground waste glass as aggregate for mortars. Waste Management, Vol. 25, No.2, pp. 197–201, 2005.
6. Batayneh, M., Marie, I., and Asi, I. Use of selected waste materials in concrete mixes. Waste Management, Vol. 27, pp. 1870–1876, 2007.
7. Sadoon, A., Mizi, F. Characteristics of concrete with waste glass as fine aggregate replacement. International Journal of Engineering and Technical Research, Vol. 2, No. 6, pp. 11-17, 2014.
8. Jared, R.W., Chris,C., Dan, F., and Farshad, R. Fresh and hardened properties of concrete incorporating recycled glass as 100% sand replacement. Journal of materials in civil engineering, Vol. 26, pp. 1-11, 2014.
9. Tomas, U., Ganiron Jr. Use of recycled glass bottles as fine aggregates in concrete mixture. International journal of advanced science and technology, Vol.61, pp.17-28, 2013.
10. C. Christopher, "Production of sintered light weight aggregate using waste ash and other industrial residues", Belgium, 2011.
11. Bureau of Indian Standards. (2009). Cement and concrete sectional committee, CED2. IS: 10262: 2009.

