Study of Bond Characteristics of ReinforcedWasteGlassAggregate Concrete

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Abstract. The conformity of properties of waste glass aggregate with conventional aggregate was found out. Nine cubes (150mm x 150mm x 150mm) were cast out of which three were used for control concrete, three were fully replaced with waste glass as coarse aggregate, three were partially replaced(50%) with waste glass as fine aggregate. Six cylinders (150mm x 300mm) were cast out of which two for control concrete, two cylinders with coarse aggregate fully replaced with waste glass aggregate(WGA) and remaining two cylinders with partially replaced (50%) fine aggregate with waste glass aggregate. Cured specimens were subjected to compression and split-tensile test to ascertain the characteristic compressive strength and split tensile strength. Since the surface of the coarse aggregate plays a significant role in bonding of the rebar in reinforced concrete, pull-out test on both control and Waste Glass Aggregate (WGA) cube specimens(150mmx150mm with 20mm diameter steel rods) were conducted. Scanning Electron Microscopy (SEM) analysis has been done for better understanding of bonding properties in waste glass fine aggregate(WGFA) and waste glass coarse aggregate(WGCA) concrete.Comparison of the results with that of control specimens showed that waste glass could be effectively used as aggregates in reinforced concrete construction.
Keywords: Reinforced concrete beam, glass aggregate, pull-out test, bond strength

1. Introduction
The serviceability of a building depends on the quality of the materials used for its construction. The usage of cement,sand and aggregate in concrete construction give great ecological impact. To bring down the usage of these materials researchers have concentrated on potential use of waste material as an alternate concrete construction. The different waste material concentrated were fly ash, plastics, glass etc. Among the different waste materials, disposal of waste glass is still a major problem existing worldwide. Recycle of waste glass also has its limitation to ensure the quality of the manufactured new glass products. Earlier studies concentrated on suitability of utilizing the waste glass in production of construction concrete.Replacement of coarse and fine aggregate with waste glass is the recent research. The different types of waste glass generated from various industries and the problem of their disposal was concentrated[1].Past studies were concentrated on the use of waste glass as aggregate in concrete [2,3,4]. Retarders were used to suppress the alkali-silicate reaction in waste glass aggregate concrete. It was also confirmed that alkali silica reaction was predominant in the micro cracks of crushed coarse glass particles rather than finer glass particles. Even the absence of retarders gave good bonding effect for mortar with finer glass aggregates.The impurities present in glass, combination of different colors and cost of disposed glass have compelled for a development of marketing of mixed types of waste glass[5].

The usage of glass aggregate as a substitute for natural aggregate in both ordinary cement mortar and water glass activated flyash mortar were concentrated [6]. It was found that the alkali silica reaction of fly ash based mortar was less even for full replacement of natural aggregate. The optimum value of replacement of recycled coarse aggregate with natural coarse aggregate for achieving required compressive and bond strength was determined[7].Past studies confirm the effective utilization of waste glass for partial or complete replacement of natural aggregate in production of cement mortar and concrete.

1.1 Research significance

Disposing waste glass anddepletion of natural aggregates were arising problems. The study was concentrated in replacing natural coarse aggregate with waste glass. Workability and strength characteristics of WGA concrete were confirmed. Since the surface of aggregate play a role in binding the concrete, bond characteristics of WGA concrete was carried out. Bond strength of control and WGA concrete was compared.

2. Experimental procedure

2.1 Materials and methods

Ordinary Portland cementof53 gradewas used in present study.Specific gravity of the cement was found to be 3.12[8]. The maximum size of coarse aggregate and waste glass was limited to 20 mm. Natural sand and waste glasspassing 4.75mm sieve were used as fine aggregate [9]. Potable water was used to cast concrete. Waste glass was procured from bus depot located on the way from Thanjavur to Kumbakonam.Design mix was carriedoutas per [10] for M30 grade along with water cement ratio as 0.45. Fineness modulus test has been conducted for the materials used in the study [11]. The slump test (Fig.1) was carried out for both control and WGA concrete to check the workability.

Figure 1. Slump Test

2.2 Casting and Curing

Specimens were cast andkept in the mould for 24hours. The specimens were demoulded and kept immersed in clear fresh water until taken out for further test. The cast cube, cylinder and pull out specimens were shown in Fig.2, Fig.3 and Fig.4 respectively.

Figure 2. Cube Specimens

Figure3. Cylinder specimens

Figure 4. Specimens forPull Out test

2.3 Methods

Both compression and split tensile strength were carried out in CTM of 3000kN capacity as shown in Figure 5(a) and 5(b) respectively. The pull out test as per[12]were conducted in UTM of 1000kN capacity as shown in Fig.5(c)

(a) Cube under compression **(b)**Split Tensile Test **(c)** Pull-out Test

Figure5. Specimen under test

3. Results and Discussions

3.1*Material property*

Fineness moduli of the materials are given in Table 1. It was found that glass aggregate and coarse aggregate values were almost in the allowable range which finally denotes that glass aggregate can be effectively used in the partially replacement with the coarse aggregate in concrete.

Table 1. Fineness modulus for aggregates

Type of aggregate	Fineness modulus
coarse aggregate	7.29
fine aggregate	2.46
glass aggregate	6.04

3.2 Slump for different mix

The slump values for both control and WGA concrete are given in Table 2. Comparison of the results showed that both control and glass aggregate concrete produced similar slump values. Hence it was inferred that medium workability was achieved by control and waste glass concrete.

Table 2. Slump value for specimens

S.No.	Type of specimen	Slump (mm)
1	Control concrete	60
2	Waste glass as coarse aggregate	80
3	Waste glass as fine aggregate	70

3.3 Compressive strength

Compressive stress values of the specimens are displayed in Table 3. From the table, average peak stress for control and WGFA concrete showed minor differences and further studies are required to improve the strength of WGA concrete.

Table 3. Compressive strength for cube specimens

S.No	Type of cube specimen	Average peak load(kN)	Compressive stress(N/mm^2)
1	Control concrete	720	32
2	Glass as coarse aggregate	554	24.6
3	Glass as fine aggregate	677	30

3.4 Split Tensile strength

Tensile stress of the specimens are given in Table 4. The test values for WGFA concrete denotes that the peak load and stresses were almost nearer to that of control concrete.

Table 4. Tensile strength for cylinders

S.No	Type of specimen	Average Load(kN)	Tensile stress (N/mm^2)
1.	Control concrete	219	3.1
2.	Glass as coarse aggregate	152	2.2
3.	Glass as fine aggregate	206	2.9

3.5 Pull-out strength

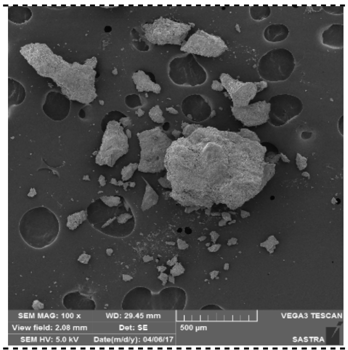
The pull-out force for the specimens is displayed in Table 5. Test results inferred that the maximum force for WGFA concrete value was greater than control concrete, which showedgood bond strength between the reinforced bar and WGA concrete. The failure has been occurred in the enclosing concrete as per [12].

Table 5.Bond strength of cube specimens

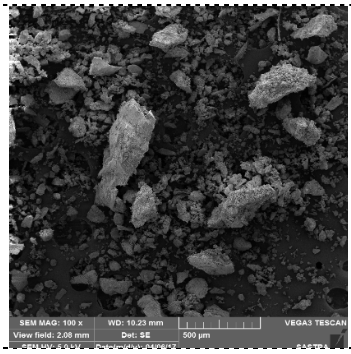
S.No	Type of specimen	Maximum force(kN)
1.	Control concrete	42.5
2.	Glass as coarse aggregate	31.4
3.	Glass as fine aggregate	45

3.6 Scanning Electron Microscopy Analysis

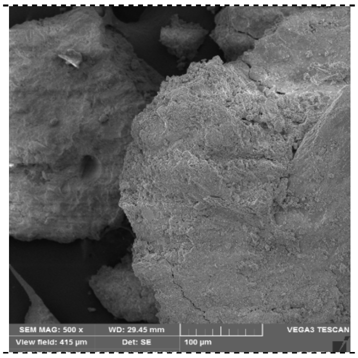
Scanning electron microscope analysis was conducted on waste glass coarse aggregate sample (WGCA) and fine aggregate sample (WGFA).



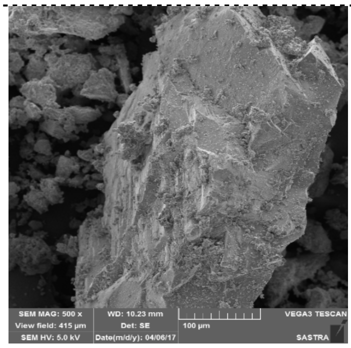
(a) WGFA



(a)WGCA



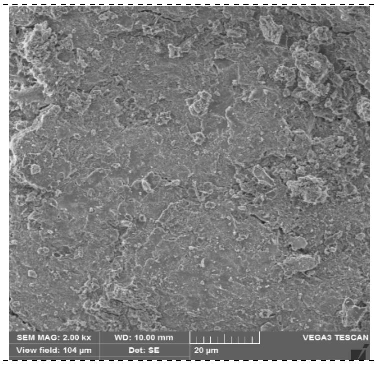
(b)WGFA



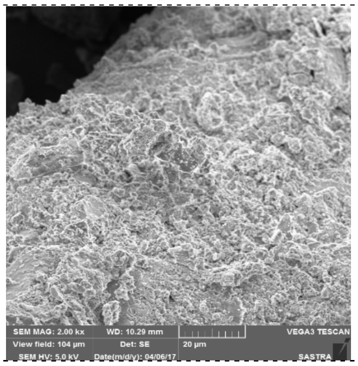
(b)WGCA

Figure 6. (a) 100x Magnification, (b) 500x Magnification

The surface of the WGFA sample was found to be smoother than that of WGCA sample.The silica present in glass particles has bonded better in fine aggregate than in coarse aggregate samples. The enhancement of bond strength of fine aggregate concrete might be due to the silica particles.



(a)WGFA



(b)WGCA

Figure 7. 2000x Magnification

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4. Conclusion

Strength characteristics of concrete produced with full and partial replacement of natural coarse and fine aggregate with waste glass was carried out and following conclusions were arrived.

- Slump test for the waste glass aggregate concrete were conducted and medium workability condition has been achieved.
- Compressive stress of WGFA concrete showed a percentage reduction of 5%, compared to control concrete
- Compressive stress of WGCA concrete showed a percentage reduction of 20%, compared to control concrete.
- Compared to control concrete, split tensile strength of WGFA concrete showed a reduction of 5%.
- Compared to control concrete, split tensile strength of WGCA concrete showed a reduction of 30%.
- Failure of pull out specimens occurred due to failure of the concrete enclosing the rebar. Pull-out test on specimens showed that the bond strength of WGFA concrete increased by 5%, compared to control concrete.
- Pull-out test on specimens showed that the bond strength of WGCA concrete decreased by 25%, compared to control concrete.
- The surface of the fine aggregate sample was found to be smoother than that of coarse aggregate sample.
- The silica present in glass particles has bonded better in fine aggregate sample than in coarse aggregate sample. Due to better bonding of fine aggregate glass in concrete,the bond strength of fine aggregate concrete was better than control concrete.
- Partial replacement of waste glass as fine aggregate gave more desirable results than replacement of glass as coarse aggregate.

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