Study of Bond Characteristics of Reinforced Waste Glass Aggregate 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 (150mm x 150mm 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 and depletion 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 cement of 53 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 glass passing 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 carried out as 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.

2.2 Casting and Curing
Specimens were cast and kept in the mould for 24 hours. 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.
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).

3. Results and Discussions
3.1 Material property
Fineness moduli of the materials are 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.

| 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.

| 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.

| S.No | Type of cube specimen | Average peak load(kN) | Compressive stress(N/mm²) |
|------|-----------------------|-----------------------|---------------------------|
| 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.

| S.No | Type of specimen                     | Average Load(kN) | Tensile stress(N/mm²) |
|------|--------------------------------------|------------------|-----------------------|
| 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 showed good bond strength between the reinforced bar and WGA concrete. The failure has been occurred in the enclosing concrete as per [12].

| 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).

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.
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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