Utilization of waste glass powder as a cementitious material in concrete

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Abstract. Disposal of waste glass derived from bundling glass, beverage bottles, and so forth is one of the significant issues in the environment. This challenge keeps on expanding with increment the measure of waste glass and reduction the limit of landfill space. Hence, studies have been carried out to locate the handy approaches to reuse waste glass in building material, for example, cement, mortar, and concrete. In this study impact of waste glass powder (WGP) as cement substitution material on the green and mechanical properties of concrete were explored. The properties of concrete researched incorporate, Density, workability, strength activity index and compressive strength. Results from the investigation demonstrate that utilization of 20% WGP in concrete cube substitute to cement increase strength around to 12.5%. Additionally, usage of WGP up to 20% improves the properties of concrete. However, the workability of concrete reduced on the substitution of WGP increases because of the fine surface area of waste glass powder.

1. Introduction:

Protecting environment is a major task for the researchers, use of cement increases the quality of construction to the larger extent but on other hand, the production of cement increases the pollution as well. The main environmental problems related to cement production are the consumption of raw material and energy use. Estimated that, for production of 1cu.m of cement, the required raw material is 85% cayenne, 13% clay or blackboard, and under 1% each of materials such as silica, alumina, and iron ore.

In Asia, Approximate industrial waste per year generated is around 62 million tons of waste generated on an annual basis. Hence we have to reuse this waste in the field of construction where we can recycled this waste & sustainable concrete.

For the recycling of glass, we need to burn the glass at high temperature i.e. around 1000oc which used generates carbon dioxide gas which indirectly affecting global warming. Hence, instead of heat, we can used this waste glass in construction as raw material in concrete.

From the previous research it is seen that many authors used waste glass as aggregate, sand & also cement. As many researches used waste glass as aggregate. It is observed that alkali-silica reaction plays vital role. Hence from the previous results it is observed; Shao et. al [8] used waste glass as a replacement to the cement up to 30% with varying the size of glass powder. It is observed that, size below 75µm shows the pozzoalnic activity. Also Khmri et al. [7] conclude that as the particle size of glass powder reduces, it shows good pozzoalnic activity. Most of the work on the hardened properties
of the concrete.

Hence, in this research we will discuss the effect on the green properties of concrete. The works complete in two phases i.e. Phase one: Initial properties of material; Phase two: Main experimental programme.

2. Experimental & Testing Programme
2.1. Materials:
2.1.1. Cement: Ordinary Portland cement of 53 grades locally available is to be used confirming to BIS 12269-1987 [6]. Specific gravity of cement is 3.12. The chemical analysis by XRF of cement is mentioned in table 1.

2.1.2. Waste Glass Powder: The waste glass powder of size less than 75µ used in the experimental study. The specific gravity of WGP is 2.25. The chemical analysis by XRF of WGP is mentioned in the table 1.

| Table 1. Chemical composition of Cement and WGP |
|-----------------------------------------------|
|      | Cement | WGP  |
| SiO2 |  20.6  |  69.5 |
| Al2O3|    4.8 |  1.98 |
| Fe2O3|    3.5 |  0.337|
| CaO  |    64  |  7.71 |
| MgO  |    0.1 |   3.20|
| K2O  |    3.4 |  0.245|
| Na2O |    0.3 |  16.9 |
| SO3  | 0.3    | 0.121 |
| Loss on ignition | -      | 0.8   |

2.1.3. Aggregate: Fine aggregate is naturally occurring river bed sand. The specific gravity of sand is 2.53. It is rounded in shape. Fineness modulus of sand is 2.71 and water absorption is 1.2%.

The coarse aggregate of around passing 20 mm sieve angular shape is obtained from Chikhli, Gujarat. The specific gravity of aggregate is 2.79 and water absorption is 0.7%.

2.1.4. Proportions & Mix design Concrete was cast with water cement ratio of 0.40 as per Department of environment code [5]. The mix design was elaborated keeping the w/c fixed and calculate the strength for different percentage of replacement of glass powder to cement. The glass powder replacement to cement for 10, 20, and 30% in this research used. The mix proportions as per DOE Code as shown in table2.

| Table 2. Mix Design Proportion |
|-------------------------------|
| Mix  | Cement (kg) | WGP (kg) | Water (kg) | FA (kg) | CA (kg) | W/C  |
|------|-------------|----------|------------|---------|---------|------|
| 0% WGP | 407               | 0        | 163         | 723     | 1026    | 0.40 |
| 10% WGP | 366           | 41       | 163         | 723     | 1026    | 0.40 |
| 20% WGP | 325           | 82       | 163         | 723     | 1026    | 0.40 |
| 30% WGP | 284           | 123      | 163         | 723     | 1026    | 0.40 |
2.2. Test Procedure

2.2.1. Workability Test: The slump test was made up as per BIS 1199-1959 [4]. This test is performed to calculate the workability of concrete. The test performed on the fresh concrete and check the outcome of substitution of WGP to the cement on workability.

2.2.2. Density: The density of concrete is compute directly by taking the total mass of the fresh concrete cube divided by its volume as per ASTM C642 [3].

2.2.3. Water absorption: The water absorption was calculated according to ASTM C642 [3]. The mass of dry samples was obtained after drying the concrete cube in 105°C for 24 hours. The water absorption calculated as

\[ \text{Absorption} = \frac{\text{Mass}_{\text{dry}} - \text{Mass}_{\text{wet}}}{\text{Mass}_{\text{wet}}} \]

2.2.4. Strength activity index: The SAI is the ratio of the strength of the average compressive strength of blended cement cube to the compressive strength of normal cube at each specific curing time. The rate of strength development of concrete cube depends principally on its hydration rate. The SAI calculated as per ASTM C311 [2].

2.2.5. Compressive strength: The performance of test as per ASTM C 109 [1]. Individually compressive strength values were a mean of three specimens of size 150 x 150 x 150 mm for 7 and 28 days respectively.

3. Results & Discussions:

3.1. Workability Test:
The results of WGP on the workability of concrete is shown in the figure 1. The outcome shows that workability of concrete gets reduced as the percentage of WGP increases in concrete. The decrease in the workability of concrete is because the glass powder is finer in size compared to cement content which has more surface area than cement. Hence, required more water than cement, which indirectly reduced the workability.

![Figure 1. Workability of concrete altered by WGP as a cement substituted](image-url)
3.2. Density
The density of concrete mixes is shown in the figure 2. The outcomes shows that density of concrete as function of age which comes from the formation of more hydrates products which comes reduced the porosity. Secondly, due to the replacement of glass powder with cement content which reduced the density because cement has higher specific gravity compared to the cement content. Hence the concrete with glass powder shows minimum strength compared to the normal concrete.

![Figure 2. Density of concrete altered by WGP as a cement substituted](image)

3.3. Water absorption:
The water absorption of concrete modified with WGP as cement addition are shown in figure 3. When a percentage of WGP level increases, it is seen that the water absorption goes on decreases. Water absorption is decreased by 16%, 33%, 51% and 60% compared to normal concrete with replacement of WGP at 10%, 20%, and 30% respectively. The increase of WGP cement addition decreases water absorption as a result of pore filling and pozzoalnic effect.

![Figure 3. Water absorption altered by WGP as a cement substituted](image)

3.4. Strength activity index:
The SAI of concrete modified with WGP as cement addition are shown in figure 4. When a percentage of WGP level increases, it is observed that the SAI increases compared to normal concrete. From the
result, it can be concluded that WGP replacement to cement can be used a pozzoalnic material.

3.5. **Compressive strength:**

Figure 4 presents the outcomes for compressive strength with different percentage of replacement of a WGP to a cement. From the results, it is observed that, up to 20% replacement of WGP to a cement shows good results compared to normal concrete. But beyond 20%, the strength of concrete goes on decreases. The maximum compressive strength at 20% replacement is 45 MPa which is 12.5% more than normal concrete cube strength at 28 days.

![Figure 4. Compressive strength of concrete replacement by WGP as a cement substituted](image)

4. **Conclusion:**

The research work evaluates the impact of WGP as a cementitious material on the fresh and hardened properties of the concrete. From the research, work conclusion can be drawn as:

1. WGP satisfies the point of a confinement of a Pozzoalnic material. The SAI of modified concrete with WGP shows maximum compared to normal concrete at 7 and 28 days.
2. The use of WGP refines the pores of cement paste and this reflects the concrete properties.
3. The workability of concrete decreases as the percentage of WGP increases, because the glass powder is finer in size compared to cement content which has more surface area than cement.
4. Density of concrete with WGP gets reduced compared to the cement content because cement has higher specific gravity compared to the cement content
5. Concrete compressive strength, absorption and SAI are improved as a result of using 20% WGP cement replacement.
6. The compressive strength of modified concrete increase as the percentage of WGP increases compared to normal concrete. At 28 days of hydration the compressive strength of concrete cubes for 10 and 20% percentage replacement of waste glass powder have maximum compressive strength compared to Normal concrete. The maximum compressive strength at 20% replacement is 45 MPa which is 12.5% more than normal concrete cube strength at 28 days.
References

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