DURABILITY PERFORMANCE OF CONCRETE (M-60) FINE AGGREGATE PARTIALLY REPLACED WITH CRUSHED WASTE GLASS

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ABSTRACT
Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environmental conditions and properties desired. The retrogression of concrete structures is due to effect of attrition of reinforcing bars which is occurred due to the chloride incursion so it is necessary to study the concrete durability nature before making its usage in present construction. The present research is focused on studying the effect of using sustainable material in concrete preparation. To know the effective usage of crushed waste glass in concrete and significance in Durability properties for different replacements was studied. The present research work was done using materials like cement, Fine aggregate, coarse aggregate, waste crushed glass, super plasticizer in order to know that at which combination of mix there will be optimum effect on properties of concrete. Fine aggregate was replaced with 10%, 20%, 30% and 40% with crushed waste glass. The durability tests like Acid attack, Rapid chloride penetration and abrasion tests were done. The optimum value of acid resistance was observed when fine aggregate was replaced with 30% of fine aggregate with crushed waste glass, less abrasion loss at 30% replacement and chloride penetration also effective at 30% replacement.

Keywords: Fine aggregate, Crushed glass, Acid attack, Abrasion resistance

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1. INTRODUCTION
Concrete is the major construction material plays a vital role in the development of current civilization and is considered as the second most consumed substance on earth. The construction industry is the second largest industry of the country after agriculture. Development of construction industry is increasing enormously all over the world especially in the developing countries due to rapid economic and industrial developments. So, increasing concrete demand, in turn increase demand for the raw materials of Concrete. Worldwide, about three tons of concrete is being used annually per person. The use of crushed waste glass in fine aggregate has attracted a lot of interest worldwide due to the depletion of natural resources and increased disposal costs. When concrete replaced with the waste toughens glass, it has observed that the crack width goes on increasing after 25% replacement [2]. The waste crushed glass using in concrete gives best replacement for river sand. By following this amount of usage of natural sand in concrete can be reduced. The ground glass was used as a partial replacement for both the cement and fine aggregate found that SCC with satisfactory fresh properties can be produced by incorporating up to 104 kg/m ground glass, replacing about 10% cement and 10% sand, without the need for VMA [3]. It reduces the total cost of Concrete with 10–20% glass replacing the cement exhibited a high resistance to chloride ion penetration making such an aggregate in construction materials [4]. The usage of river sand in concrete leads to consumption of natural resources, lowers the water table, Hydraulic structures will settle down and erosion of the river bed. If fine aggregate is replaced by waste glass by specific percentage and in specific size range, it will reduce fine aggregate content and thereby reducing the effects of river dredging and thus making concrete manufacturing industry sustainable. In my present investigation the glass preferred was carefully made into tiny pieces as a fine aggregate replacement. The composition of the glass consists of silica (SiO$_2$), calcium oxide (CaO), and sodium oxide (Na$_2$O). The main contribution of the glass powder in concrete is increasing the density of concrete thereby reduction in the pore system and generating higher durability properties. The utilization of glass powder in concrete increases the mechanical properties (compressive strength, splitting tensile strength, flexural strength, and Elastic Modulus). These mechanical characteristics are improving with time due to the pozzolanic activity of the glass powder [5]. The following durability tests were done on M60 grade concrete fine aggregate partially replaced with Waste crushed glass which finds to be more effective in durability considerations of concrete. The optimum value of acid resistance was observed when fine aggregate was replaced with 30% of 

2. MATERIALS
2.1. Cement: Ordinary Portland cement of 53 grade was used. One of the major role of cement is it has a great ability to hold the particles Used for Preparing concrete together.

2.2. Fine Aggregate: The particles of size less than 4.75mm size which can easily passed through 4.75mm sieve are termed as finely graded aggregates. Code for fine aggregate is IS 2386 Part-II Fine aggregate of (River sand of Zone II) with specific gravity 2.6 was used for concrete mix.

2.3. Waste Crushed Glass: The Collected and crushed waste glass is used partially in the place of fine aggregate and of fineness modulus of crushed glass was found to be 2.64. The glass is very hard material and has been mixed with fine aggregate in different proportions.

2.4. Coarse Aggregate: The coarse aggregate integrate sand and limit the size and shape that influence the amount requirement of cement and also reduce the occurrence of shrinkage. The coarse aggregate used in my research work is of size 10 mm and specific gravity of 2.7.
2.5. Water: Water is a crucial element in concrete formation. Addition of water to the concrete mix forms a chemical reaction when it comes in contact with cement. Potable water has been used for concrete mix.

2.6. Super Plasticizer: Are high ranged water reducers avoids segregation reduces water ratio which improves strength and mainly increases workability. In this research work super plasticizer SP430 was used.

![Figure 1](a) Cement (b) Fine aggregate (c) Coarse aggregate (d) Super plasticizer (e) Waste crushed glass

Table 1 Mixes for different replacements of fine aggregate by crushed waste glass

| S.N | Mix   | Cement Kg/m³ | Fine Aggregate Kg/m³ | Coarse Aggregate Kg/m³ | W/C Ratio |
|-----|-------|--------------|----------------------|------------------------|-----------|
| 1   | MC0   | 552.8        | 581.2                | 1046.5                 | 0.35      |
| 2   | MC10  | 552.8        | 523                  | 1046.5                 | 0.35      |
| 3   | MC20  | 552.8        | 469.9                | 1046.5                 | 0.35      |
| 4   | MC30  | 552.8        | 348.42               | 1046.5                 | 0.35      |
| 5   | MC40  | 552.8        | 333.12               | 1046.5                 | 0.35      |

3. TESTS CONDUCTED

- Acid attack test
- Rapid Chloride Penetration Test
- Abrasion resistance of concrete

3.1. Acid Attack Test

After immersion of cube specimens of size 150mm*150mm*150mm for curing. They are allowed to dry without any moisture content for 1day before the Acid attack tests to be conducted. After the drying period of specimen, initial weights are to be taken. Cubes must be placed in prepared HCl and H₂SO₄ solution for a period of 56 days in acidic solutions. In this test (5%) Hydrochloric acid and H₂SO₄ were used. The PH was supervised periodically and has kept stable throughout the test process. The weight loss and loss in compressive strength have been calculated after 56days of immersion in acid solution. The Loss of strength and weight were calculated as per the IS 456(PART-1 And PART-2)1967guidelines. The values
were tabulated. The formula to be used for calculation of weight loss and strength loss are given below.

\[
\% \text{Loss in weight of cubes} = \left( \frac{W_I - W_F}{W_I} \right) \times 100
\]

Where \( W_I \) = Initial weight of the specimen in kg
\( W_F \) = Final weight of the specimen in kg

Figure 2 Specimens in HCL & H\(_2\)SO\(_4\) Solution

| S.N | MIX | Average weight of cubes (KG) | Average% loss in weight -HCL |
|-----|-----|------------------------------|------------------------------|
|     |     | Before immersion in Solutions | After immersion in HCL for 56 days |                          |
| S.N | MIX | Average weight of cubes (KG) | Average% loss in weight -HCL |
|-----|-----|------------------------------|------------------------------|
|     |     | Before immersion in Solutions | After immersion in HCL for 56 days |                          |
| 1   | M0  | 8.47                         | 8.38                         | 1.06                      |
| 2   | M10 | 8.42                         | 8.37                         | 1.07                      |
| 3   | M20 | 8.38                         | 8.29                         | 1.07                      |
| 4   | M30 | 8.30                         | 8.28                         | 0.24                      |
| 5   | M40 | 8.25                         | 8.22                         | 0.36                      |

Figure 3 Weight of cubes before and after immersion in HCL & H\(_2\)SO\(_4\) solution
3.2. Rapid Chloride Penetration Test

RCPT is a quick process for determination of permeability nature of concrete specimen. Test was conducted by preferring the cylindrical specimens of size 50mm height and 100mm dia. First the RCPT diffusion cell has been filled with 2 different prepared NaCL and NaOH solutions of desired quantities. Silica gel is used as glue after insertion of concrete specimen between the two diffusion cells. The role of silica gel is to control the solution flow out of the cells during the current passage i.e., it is applied in order to stop the flow of fluids which has been poured. NaCL of 2.4M is filled in one chamber and NaOH of 0.3M is taken in another chamber. The migration of chloride ion was allowed through centrally inserted vacuum saturated RCPT specimen under DC voltage of 60 volts. The concrete resistance to chloride ion penetration has no bias because the value will be defined by ASTM-C1202 Code provisions. After six hour exposure period, If the interpretation is larger the coulomb it indicates more permeable the concrete specimen to the electricity. Low coulomb indicates the concrete is less permeable to the electric current. The average current flow through the cell is calculated by the formula:

\[ Q = 900(I_0 + 2I_{30} + 2I_{60} + 2I_{90} + 2I_{120} + \ldots + 2I_{300} + 2I_{330} + I_{360}) \]

\[ Q = \text{Flow of current through cells} \]
\[ I_0 = \text{Current in Amperes after application of voltage} \]
\[ I_t = \text{Current in amperes at T minutes after voltage is applied} \]

![Figure 4 RCPT apparatus](image)

Table 3 Results of Rapid chloride permeability Test

| S.NO | Time(minutes) | Measured current(mA) |
|------|---------------|----------------------|
|      |               | M0       | M10      | M20      | M30      | M40      |
| 1)   | 0             | 40       | 39       | 35       | 25       | 25       |
| 2)   | 30            | 42       | 41       | 37       | 25       | 27       |
| 3)   | 60            | 44       | 43       | 38       | 25       | 29       |
| 4)   | 90            | 47       | 45       | 38       | 25       | 29       |
| 5)   | 120           | 48       | 46       | 39       | 25       | 29       |
| 6)   | 150           | 49       | 46       | 40       | 25       | 29       |
Table 4 Rating of chloride permeability as per ASTMC-1202-97

| S.NO | Charge passed (coulombs) | Chloride ion penetration |
|------|--------------------------|--------------------------|
| 1)   | >4000                    | High                     |
| 2)   | 2000-4000                | Moderate                  |
| 3)   | 1000-2000                | Low                      |
| 4)   | 100-1000                 | Very low                 |
| 5)   | <100                     | Negligible               |

3.3. Abrasion Resistance of Concrete

The capability of a material to tolerate to friction is said to be abrasion resistance of concrete. In order to make the original structure look as it seemed as new one i.e., without any structural ruptures or damages this test was conducted. The compressive strength is closely related to abrasion resistance of concrete. The abrasion resistance of materials and durability
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of structure can be evaluated by different test processes such as under water method, sand blasting, revolving disk machine, dressing wheel machine etc. The procedure indicates the abrasion action of water borne particles (silt, sand, gravel, and other hard materials). This test was performed according to ASTM C1138-1997. The machine which have been used for conductance of test is abrasion testing machine with rotating device, container and agitation paddle .70 grade 100 chrome steel grinding balls, weighing basket ,seating block, measuring scale seating block to test the specimen of size 300mm diameter and 100mm height.

3.3.1. Test to find the Average Depth of Abrasion

First weight of specimen is taken when it is exposed to air and water and also measured the dimensions of the specimen when it is going to be placed in the abrasion machine on the seating block. The specimen should be placed in such a way that its surface must corresponds with the drill shaft. Ascend the agitation paddle with drill press on to the specimen surface. The mass of the abrasion charge must be calculated.

After placing the specimen in the machine it should be run for 12 hours and after time period it will be lifted out with the help of wiring tied around the specimen After removal of the specimen, first thing we have to do is to rub off the tear off material which is adhered to the surface of the specimen and then the respective weights must be taken in presence of air and water and weighed values are to be noted. The test will be continued for 72 hours time period and for every 12 hours completion the readings must be taken as per the rules of code mentioned. While the test is going to be conducted we have look carefully whether the shaft drill is rotating and see the level of water and ensure if any leakages are observed before the start of running of machine.

Calculations:- Volume of specimen at any time

$$V_t = \frac{(W_{air} - W_{water})}{G_w}$$

Where $$V_t$$=Volume of specimen at desired time in m³

$$W_{air}$$=Weight of the specimen in kg

$$W_{water}$$=Weight of specimen in kg

$$G_w$$=Unit weight of water in kg/m³

The volume of concrete lost at the end of any time is

$$V_{L_t} = V_{t} - V_{l}$$

Where $$V_{L_t}$$=volume of material lost at the end of the test in m³

$$V_{t}$$=Volume of specimen before testing in m³

$$V_{l}$$=Volume of specimen at the end of the test in m³

For calculation of average depth of the wear=$$ADA_1 = V_{lt}/nA$$

Where $$A$$=Area of the top of specimen in m²
Figure 6 Abrasion testing

Table 5 Average depth of abrasion:

| S.NO | Time(hrs) | M0   | M10  | M20  | M30  | M40  |
|------|-----------|------|------|------|------|------|
| 1    | 12        | 0.55 | 0.45 | 0.22 | 0.062| 0.089|
| 2    | 24        | 0.73 | 0.55 | 0.30 | 0.064| 0.086|
| 3    | 36        | 0.90 | 0.66 | 0.43 | 0.074| 0.094|
| 4    | 48        | 1.21 | 0.72 | 0.56 | 0.078| 0.098|
| 5    | 56        | 1.30 | 0.84 | 0.64 | 0.080| 0.26 |
| 6    | 72        | 1.63 | 1.32 | 0.74 | 0.092| 0.47 |

Figure 7

4. CONCLUSIONS

- The increment prapornality of waste crushed as a partial substitute of fine aggregate hikes the durability.

- The utilization of Waste crushed glass depicted many benefits such as high strength, toughness, as a good binder of all substances, and acts a resistor to chemicals temperature and exposure conditions with environment friendly nature.
  - The loss in % of weight was very low M30 mix i.e., for fine aggregate replaced with 30% waste
  - Crushed glass was noticed with less weight loss.

- The % crushed glass from durability point of view was found that 30% replacement is the optimum.
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