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# Experimental Investigation on Glass Powder as Partial Replacement of Cement for M-30 Concrete

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## ABSTRACT

Glass is needed in several forms in today's life. Its life is limited, and after use it is either stored into sharp edged or sent to landfills. As we know glass is non-biodegradable, landfills does not recommend any environment friendly solution. In India as a most developing country, facing shortage of post consumer's disposal waste site and it's become very serious problems. Hence, there is strong need to utilize waste glasses. The aim of the present experimental investigation was to use waste glass powder as a replacement of cement to assess the Compressive, Split tensile Strength and Flexural strengthfor M30 grades of cement concrete and durability, pozzolanic activity of fine glass powder in concrete, compare its performance with percentage, size of glass powder and also perform alkalinity test on waste glass powder added concrete.The results found that 15% addition of GLP increase the higher compressive strength and flexural Strength, replacement of cement , for study of size effect of glass powder i.e. Initial strength gain is very less due to addition of glass powder on $7^{th}$ days but it is maximum increases on the $28^{th}$ days, with addition of glass powder increase the higher compressive strength and flexural Strength. The replacement of glass powder in cement by 7, 14, 21& 28 days of curing and result was found that 39.2 N/mm$^2$, 41.33 N/mm2, 45.01 N/mm2, 49.18 N/mm$^2$, 5.39 N/mm$^2$, and 5.57 N/mm$^2$, 5.4 N/mm$^2$ and 5.67 N/mm$^2$ respectively ,and also glass powder size less than 90 micron is very effective in enhancement of strength. It is also found that the average pH values 12.59 observed from all the different samples of alkalinity test showed that the samples tested found to be more alkaline nature and hence more resistant towards corrosion. The alkalinity test of GLP performed good results on adding concrete.

**Keywords: Waste** Glass Powder, Alkalinity Test, Compressive Strength, Split Tensile Strength, Flexural Strength, and Aspect Ratio.

## I. INTRODUCTION

Concrete is a being together of cement, sand, coarse aggregate and water. Today's global warming and environmental demolition have become apparent harms in recent years. Usually glass does not harm the environment in any way because it does not give off pollutants, but it can harmful for humans as well as animals, if we are not deal carefully and it is less friendly to environment because it is non-biodegradable. Thus, the development of new technologies has been required. Glass is a material which could be recycled and used in replacement of cement (Jangid, B. and Saoji, 2002) and later alkali reactivity of glass coarse particles as well as natural reactive aggregate (Shayan, A.,2002). The term glass contains several chemical diversities including soda-lime silicate glass, alkali-silicate glass.

Today, these types of glasses glass powder have been widely used in cement and aggregate mixture as pozzolana for civil works. The introduction of waste glass in cement will increase the alkali content in the cement and more alkaline nature is god for rusting effects towards corrosion. Glass is formed in many forms, including packaging of container glass bottles, jars, flat glass windows, tube light glass, bulb glass light globes, cathode ray tube glass like TV screens, etc all of which have a limited life in the form they are formed and require to be recycled in order to avoid

environmental problems that would be produced if they were to be stockpiled or sent to landfill.In the recent various attempts and research have been investigated with the effect of replacement of cement by waste glass powder on workability and strength properties of steel fiber reinforced concrete (SFRC) such as compressive strength, tensile strength, flexural strength and impact strength were studied. (Chikhalikar, S.M. and Tande, 2012),(Subramani, T. and Sankar Ram, S.B., 2015), (Arora.R, 2015).

The main purpose of this study is to make a better environment that free from polluted space and also to find a better solution for concrete mixture that can give higher strength to concrete from the waste glass product .Even it may gives less cost of using this kind of admixture rather than purchasing expensive admixture to get great and advanced strength in concrete as now days it's the admixture that in marketplace are very costly and often increase the charge of the construction.

**Objectives**

The following were the objectives of the present study.

1. To study the effect of the use of waste glass powder as a partial replacement of cement and comparative study with plane concrete.
2. To find the pozzolanic nature of waste glass powder when mixed in concrete.
3. To study the compressive strength, flexural strength & split tensile strength of the waste glass powder added concrete mix.
4. To find the optimum mix for required grade and optimum values of addition of different percentage of waste glass powder concrete.
5. Glass powder is a good contender for silica fume

## II. METHODS AND MATERIAL

**Material used**-The materials used in this work are waste glass powder, Ordinary Portland cement (43 grade), coarse aggregates and fine aggregates.

1. **Cement:-** standard Ordinary Portland cement of 43 grades was used in this experimentation confirming to I.S.-12269-1987.
2. **Sand:-** Natural river sand of maximum size of 4.75mm was used Locally available sand zone-II with specific gravity 2.65,water absorption 2% and fineness modulus 2.6,confirming to I.S. 383-1970.
3. **Coarse aggregate:-**crashed granite stone of 20mm size having specific gravity of 2.70, fineness modulus of 2.9, confirming to I.S. 383-1970.Fineness modulus of sand is more than that of waste glass powder. Means waste glass powder is finer than sand.
4. **Water:-** potable water was used for the experimentation, and distilled water used for Alkalinity test procedure.
5. **Glass powder:-**Waste glass available nearby in Pondicherry shops is been collected and made into glass powder, Waste Glass is extremely hard substance. Earlier than addition glass powder in the concrete it has to be crushed and grind to desired size. In this studies glass powder ground in ball/ pulverized intended for a stage of 30 to 6o minutes resulted in element sizes less than size 150 μm and sieved in 75 μm.

**A Chemical Composition of Glass Powder**

**Table -1** Chemical composition of Glass Powder

| Composition (% by mass)/ property | Cement | Glass powder |
|---|---|---|
| Silica (SiO2) | 20.2 | 72.5 |
| Alumina (Al2O3) | 4.7 | 0.4 |
| Iron oxide (Fe2O3) | 3.0 | 0.2 |
| Calcium oxide (CaO) | 61.9 | 9.7 |
| Magnesium oxide (MgO) | 2.6 | 3.3 |
| Sodium oxide (Na2O) | 0.19 | 13.7 |
| Potassium oxide (K2O) | 0.82 | 0.1 |
| Sulphur trioxide (SO3) | 3.9 | - |

**B. Testing of Cement:-**Testing of cement can be brought under two categories:-

**1.Field testing-** It is compulsory in the way of check the quality of cement on site at the moment of beginning inspection. It is not sufficient to verify all the engineering qualities of cement on site but near stay alive a number of field test which gives us a rough idea of characteristic of cement. Although on site we can take out these ground tests to judge the value of cement. These field tests are as follows: (1)Packing Date (2)Colour (3)Rubbing (4)Hand Insertion (5) Float Test (6)Smell Test (7) Presence of lumps (8)Shape Test (9)Strength Test.

**2. Laboratory TestingFineness test for cement (IS 4031 (Part 1):1996)**

Result:- Residue of cement is 10 percent.

**a.** Consistency -The percentage of water for normal consistency for the given sample of cement by vicat's apparatus is 35%

**b.** Initial & Final Setting Time of Cement Test :
Result:- The initial setting time of the cement sample is found to be 2:30 hrs& final setting time of the cement sample is found to be 10hrs at 5mm depth of penetration.

**Standard Test Method for Sieve Analysis of fine and Coarse Aggregates:-**

To determine the fineness modulus and grain size distribution of given coarse& fine aggregates.

**Coarse Aggregate-**Fineness modulus of coarse aggregate=2.852

**Fine aggregate-**Fineness modulus of coarse aggregate=> 2.15According to (IS-383-1970 page no.11)the all retained "fine aggregate "material reading is range up to grading zone II

**C. Mix Proportion and Testing of Specimens:**

1. There were five type of mix considered: of which one control mixture S-1(without glass powder) was designed according to Indian standard specification IS 10262-2009 (1:1.6:2.23 W/C ratio 0.42) and weight of material in all (Kg) for ssd condition is 50:117:161:: 21 to achieved 28 days strength 25Mpa.
2. The other three concrete mixes were made by replacing the cement with 5%, 10%15%, 20%&25% of glass powder weight.

**Table-2** Materials Details of Mix Proportions

| Sample | Glass powder % | Cement % | Quantity of glass powder (Kg) | Quantity of cement powder (Kg) |
|---|---|---|---|---|
| S-1 | 0 | 100 | 0 | 1.58 |
| S-2 | 5 | 95 | 0.79 | 1.501 |
| S-3 | 10 | 90 | 0.158 | 1.422 |
| S-4 | 15 | 85 | 0.237 | 1.343 |
| S-5 | 20 | 80 | 0.316 | 1.264 |
| S-6 | 25 | 75 | 0.305 | 1.185 |

**Mix Design:-Indian standard concrete mix design method**

We are adopting the Indian standard recommended method of concrete Mix Design (IS-10262-1982) was first introduced during the year 1982. In addition, the committee took long time and came up with new guidelines for concrete mix proportioning.(IS-10262-2009)

**Table 3 -** Mix Design

| **M30 CONCRETE MIX DESIGN** | | |
|---|---|---|
| **Section-1** | | **As per IS: 10262-2009** |
| **S.N** | **Grade Designation** | **M30** |
| 1 | Type of Cement | **OPC 43 grade confirming to IS-12269-1987** |
| 2 | Maximum Nominal Aggregate Size | 20mm |
| 3 | Minimum Cement Content | 320kg/m3 |
| 4 | Maximum Water Cement Ratio | 0.45 |
| 5 | Workability | 100mm |
| 6 | Exposure Condition | Severe rcc |
| 7 | Degree of Supervision | Good |
| 8 | Type of Aggregate | Crushed Angular Aggregate |
| 9 | Maximum Cement Content | 470kg/m3 |
| **Section-2** | | **Selection of Water Cement Ratio** |
| 1 | Maximum Water Cement Ratio | 0.5 |
| 2 | Adopted Water Cement Ratio | 0.42 |
| **Section-3Calculation of Cement Content** | | |
| 1 | Water Cement Ratio | 0.42 |
| 2 | Cement Content (197/0.5) | 394kg/m3 |
| **Section-4 Proportion of Volume of Coarse Aggregate & Fine Aggregate Content** | | |
| 1 | Vol. of C.A. as per table of IS 10262 | 63% |
| 2 | Adopted Vol. of Coarse Aggregate | 63% |
| 3 | Adopted Vol. of Fine Aggregate ( 1-0.57) | 43% |
| **Cement : Fine Aggregate : Coarse Aggregate : Water** | | |
| **470 : 760 : 1044 : 197** | | |
| **1 : 1.62 : 2.23 : 0.42** | | |
| **1:1.62:2.23** | | |

**Workability: -** For the test of M30 grade of concrete, it is necessary to know about the slump cone test value, although we are assuming the value of slump is 100mm for severe case design consideration. After the mix design of M30 grade of concrete I had performed the workability test with given mix proportion (1:1.62:2.23) and now we are observed that value of slump is within the range which we have considered for mix design.

**Casting & Testing**

**Compressive Strength Test:** Designed for compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm be cast for M30 grade of concrete. The glass powder was used as a partial replacement by weight of cement with different percentage such as 5%, 10%15%, 20% and 25% was added to this. The moulds were filled with 5% to 25% of glass powder by weight of cement. Shaking was known to the moulds using table vibrator. The top surface of the samples was leveled and finished. After 24 hours the samples were remolded and were shifted to curing tank wherein they were allowed to analysis for 7 days,14 days, 21 days and 28 days. After 7days, 14 days, 21days and 28 days curing, these cubes were tested on digital compression testing machine as per I.S. 516-1959. The failure load was noted. In each group two cubes were tested and their average value is reported. The compressive strength was calculated as follows.

**Figure 1.** Compression Testing Machine

**Flexural Strength Test**

Designed for flexural strength test beam samples of dimension 100x100x500 mm were cast. The specimens were demoulded after 24 hours of molding and were transferred to curing tank wherein they be permitted to cure for 28 days. These flexural strength samples were tested under a point loading as per I.S. 516-1959, over an effective span of 400 mm on Flexural testing machine. Load and resultant deflections were noted up to failure. In each classification two beams were tested and their average value is noted. The flexural strength was calculated as follows. Flexural strength (MPa) = (P x L) / (b x d2), Where, P = Failure load, L = Centre to centre distance between the support = 400 mm, b = width of specimen=100 mm, d = depth of specimen= 100 mm.

**Figure 2.**(a)Test Specimen (Beam)
(b) Flexural strength with point loading

**Split Tensile Strength Test:** For Split tensile strength test, cylinder specimens of size 150 mm diameters and300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank wherever in they were permitted to cure for 28 days. The specimens were tested under compression testing machine. In every category, two cylinders were tested and their middling value is reported. Split Tensile strength was considered as follows as split tensile strength: Split Tensile strength (MPa) = 2P / π DL, Where, P = failure load, D = diameter of cylinder, L = length of cylinder diameter of cylinder = length of cylinder length.

**Figure 3.**Compression testing machine/ Applied load on cylinder / Failure of Cylinder

**Alkalinity Test**

After the curing of 60days, the samples were taken out from curing tank. Samples were dried out in oven at 105°C for 24 hours. Then the dry Samples were cooled at room temperature. Dry sample was broken and separated mortar was grinded into fine particles form. The powder form is sieved in 150µm filter. since the total prepared sample 10 gm of mortar is in use and it is diluted in 50ml distilled water and fully stirred it. Then

pH papers immerse into solution and pH value is noted. The common pH value of the result and the level of inducing rusting in the concrete were noted .The pH value found from the alkalinity test displayed that the specimen tested found to be more alkaline nature hence it means more resistant towards corrosion.

**Following test steps have performed for finding out alkalinity test of waste glass powder are drawn:**

- ✓ 60 days curing.
- ✓ Specimen dries in oven 24 hours.
- ✓ Cooling at room temperature.
- ✓ Crushing test for using Jaw Crusher.
- ✓ Grinding into powder form by Hammer Mill.
- ✓ Sieved in 150µm.
- ✓ Serving Petri dish.
- ✓ 10 gm of mortar is taken into beaker and add distilled water.
- ✓ Then pH papers submerge into solution and pH value is noted.

(a) Hot Air oven (b) cooling at room temperature

(c)Grinder(d) Crusher

(e) Sieve Analysis Setup (f) pHMeter Specimen

## III. RESULTS AND DISCUSSION

1. Average compressive strength of conventional concrete with 0% glass powder for M30 grade (N/mm2) test results is given below.

**Table 4 (a).**Result For Conventional Concrete

| Sl.no | Dimension (mm) | Compressive strength (Mpa) | Average compressive strength (Mpa) |
|---|---|---|---|
| 7th | 150x150x150 | 26.89<br>26.33 | 26.61 |
| 14th | 150x150x150 | 29.40<br>29.89 | 29.64 |
| 21st | 150x150x150 | 33.00<br>32.24 | 32.62 |
| 28th | 150x150x150 | 37.06<br>35.66 | 36.36 |

Compressive strength of conventional (0%) concrete for M30 grade

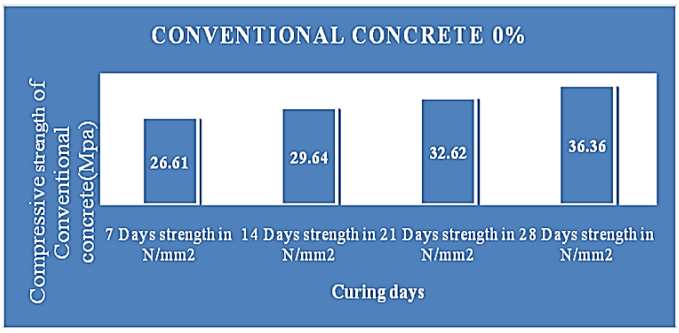


**Figure5.** Compressive strength of conventional concrete

**TABLE 4(b)** Compressive strength test results of concrete when cement replaced with glass powder

| Different % of glass powder | 7th | 14th | 21st | 28th |
|---|---|---|---|---|
| 5% | 28.88 | 33.94 | 39.96 | 41.98 |
| 10% | 36.73 | 40.89 | 42.84 | 45.66 |
| 15% | 39.2 | 41.33 | 45.01 | 49.18 |
| 20% | 29.30 | 32.50 | 35.33 | 36.52 |
| 25% | 27.83 | 38.33 | 40.22 | 41.08 |

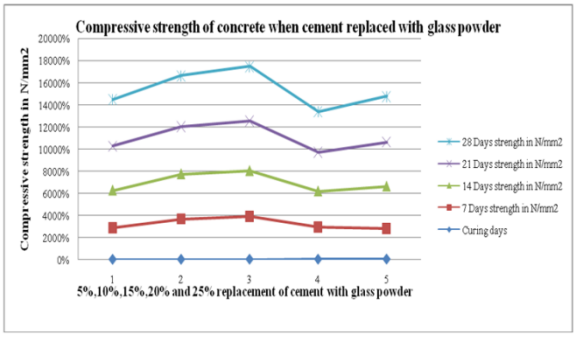


**Figure6.**Compressive strength of concrete when cement replaced with glass powder

**2.** Average value of flexural strength of M30 grade of conventional concrete and different percentage change concrete with glass powder.

**Flexural strength test specifications and results:** Result for different percentage 5% to 25% added concrete (average flexural strength)

**Table-5** Flexural strength test results

| Curing days | Dimension (mm) | 0 % | 5% | 10 % | 15 % | 20 % | 25 % |
|---|---|---|---|---|---|---|---|
| 7th | 100x100x500 | 4.32 | 4.6 | 5 | 5.39 | 3.20 | 3.98 |
| 14th | 100x100x500 | 4.36 | 4.89 | 5.55 | 5.57 | 3.82 | 4.5 |
| 21st | 100x100x500 | 4.39 | 4.92 | 5.3 | 5.4 | 3.99 | 4.78 |
| 28th | 100x100x500 | 4.8 | 5.5 | 5.55 | 5.67 | 4.89 | 5.33 |

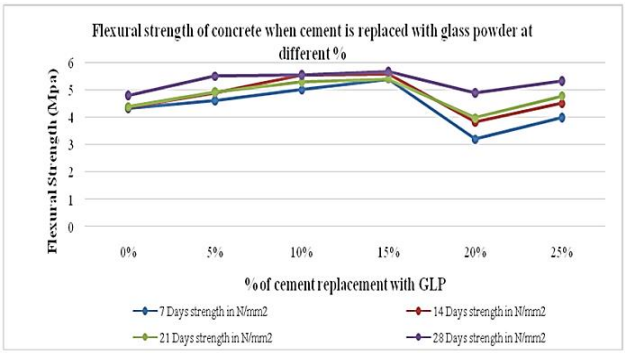


**Figure 7.**Flexural strength of concrete when cement is replaced with glass powder at 0% to 25%

**3.** Average value of splitting tensile strength of M30 grade of conventional and added different percentage change concrete with glass powder. Indicates the results of splitting tensile test on beam for M30 grade of concrete using various different percentage 5% to 25% added concrete (average splitting tensile strength)

**Table--6** splitting tensile strength test results

| Curing days | Dimension (mm) | 0% | 5% | 10 % | 15 % | 20 % | 25 % |
|---|---|---|---|---|---|---|---|
| 7th | 150 dia x300 length | 1.18 | 2.24 | 3.22 | 2.67 | 2.08 | 1.81 |
| 14th | 150 dia x300 length | 1.89 | 3 | 3.42 | 2.81 | 2.89 | 2.6 |
| 21st | 150 dia x300 length | 2.26 | 3.18 | 3.01 | 2.86 | 2.98 | 3.66 |
| 28th | 150 dia x300 length | 2.88 | 3.21 | 3.19 | 2.69 | 3.42 | 3.23 |

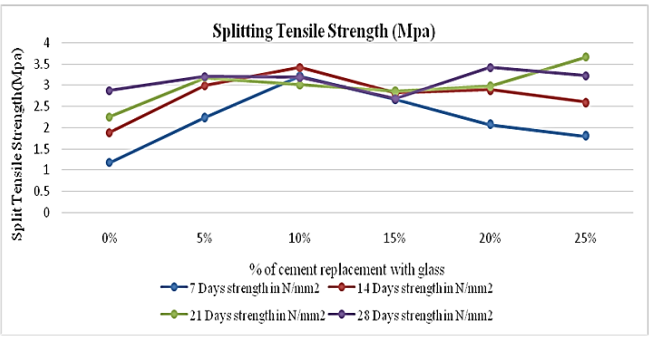


**Figure-8**Splitting Tensile Strength of concrete when cement is replaced with glass powder at 0% to 25%

**4.** Average value of alkalinity test of M30 grade. The general pH value of the solution and the level of inducing corrosion in the concrete was noted and the results are shown in table below.The Alkalinity test values after the curing of 60 days for M30 grade glass powder added concrete:

**Table-7** Average Alkalinity test results for M30 grade

| % Replacement of Glass powder in concrete | pH Value |
|---|---|
| 0 | 12.50 |
| 5 | 12.61 |
| 10 | 12.69 |
| 15 | 12.42 |
| 20 | 12.56 |
| 25 | 12.79 |

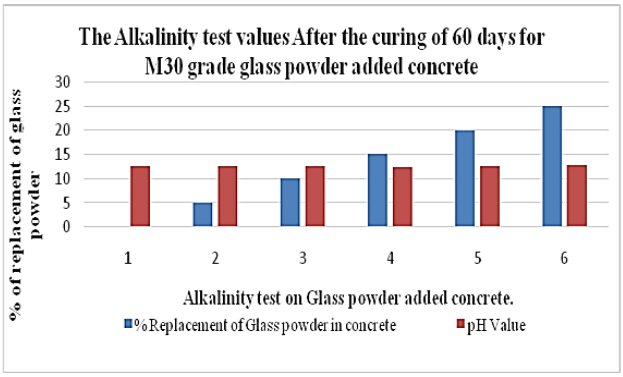


**Figure 9.** Alkalinity test on Glass powder added concrete. *Average value shown in graph is 12.59*

## IV. CONCLUSION

1. Compressive strength, Flexural strength, Split tensile strength and Alkalinity test of concrete mixes made with and without glass powder was determined at 7, 14, 21, 28 & 60days of curing. The strength gained was determined of glass powder added concrete with addition of 5%, 10%, 15%, 20% & 25% GLP for M30 grade as a partial replacement of cement in conventional concrete. The results are given in Table-4(a) to 7 and Figure-5 to 9 above Figure shows that the highest increase of compressive strength and flexural Strength is observed, when15% addition of GLP is done in concrete. Following graph and table shows compressive strength, flexural, split and alkalinity test results for M30 grade of concrete with 0%, 5%, 10%, 15%, 20% & 25% replacement of cement with glass powder. In addition to remarkable increase in above strengths it is worth to mention that due to increase in alkalinity possibility of rusting of reinforcement also reduces.
2. The finer particle size of the waste glass powder has higher activity with cement resulting in higher compressive strength in the concrete mix.
3. Glass powder of size 150µm show commencement of alkali aggregate reaction.
4. The results achieved from the existing study shows that nearby is great potential for the utilization of best glass powder in concrete as replacement of cement.
5. Workability of concrete decreases as proportion of glass powder increases.and slump value of experimentation's concrete ranges from 80 to 100 mm.
6. Maximum compressive strength, tensile strength and flexural strength was observed when glass powder replacement is about 15%, 10%, 5% respectively.
7. The average pH values of different samples were found to be 12.59. This average value shows alkaline nature of the samples, which deals resistance against corrosion or rusting.
8. The water absorption decreases and bulk dry density of samples reductions with increase in the amount of glass powder.
9. Procedure of waste glass in material can prove to be cheap as it is non suitable waste and available in great quantity, and help in resolving the problem of disposal of waste glass.
10. This one can be determined form the above outcome that 15% substitution of cement by glass powder is the best proportion.
11. Further research can be done by using plasticizers to increase the workability and strength. Also durability examination can be complete to get the long term effect of glass powder replacement.

## V. FUTURE SCOPE

**Recommendations for Future Research**

From this research, there are few recommendations to improve, to extend and to explore the usage of waste glass powder in concrete:

- ✓ Define the effect of glass powder on concrete with the replacement of mixture of coarse and fine aggregate.
- ✓ Replacement of cement with waste glass powder in different water cement ratio.
- ✓ Selected few samples of concrete with different percentage of using waste glass powder and conclude the most suitable percentage of usage to achieve the optimum compressive strength.
- ✓ Determine the durability of concrete with using waste glass powder.
- ✓ Add chemical activator into waste glass powder concrete mix for determine the compatibility by observing the compressive strength of the concrete.
- ✓ Waste glass aggregate may be used with GLP.
- ✓ Now the current research the ordinary Portland cement was used. Further its automatic

properties can be compared by using different cement.

- ✓ While soda lime glass presents a high alkali contented, utilize of ground waste glass as cement replacement in mortar, improved resistance to ASR.

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