Utilization of Recycled Glass Waste as Partial Replacement of Fine Aggregate in Concrete

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Abstract - Concrete is mainly used as construction material and its demand is increasing day by day. The main intention of utilizing recycled glass waste as partial replacement for fine aggregate in concrete is to promote sustainability by reducing the environmental impact of waste disposal and the consumption of natural resources. Using recycled materials can lower construction costs by reducing the need for traditional, often more expensive, aggregates.

In this project, waste glass powder is used as partial replacement of sand in M2O grade concrete. Concrete cubes are casted with 0%, 5%, 10%, 15%, 20% and up to the maximum percentage where the strength get maximum with replacing fine aggregate. The compressive strength and tensile strength of these mixes was tested at different curing ages 7 days, 14days, and 28days to assess the performance of the concrete containing recycled glass powder. The strength of values of concrete are comparable with that of the nominal mix. Additionally, the study examines the potential environmental benefits of reducing the consumption of natural resources and mitigating waste disposal issues through the utilization of recycled glass waste.

Key Words: fine aggregate replacement, sustainable concrete, waste utilization , glass powder in concrete , compressive strength ,workability ,durability , environmental impact.

INTRODUCTION

Concrete is the most commonly used commercially produced building material, and its popularity is expanding rapidly day by day. The most important constituent materials used in the manufacture of concrete are cement and aggregate. These are essential materials for the construction field.The quantity of waste glass (WG) produced has gradually redoubled in recent years due to the increasing demand for glass products such as packaging or container glass, bulb glass, and flat glass. The majority of WG has a limited life and has been dropped in lowland areas; it must be reused to minimize environmental concerns because it is not biodegradable. Recycling and reducing waste are key parts of This work is licensed under a Creative Commons Attribution 4.0 International License, whichpermits unrestricted use, distribution, and reproduction in any medium, provided the originalwork is properly cited.Tech Science Press waste-management system since they contribute to conserving natural resources, reducing requests for wastelandfill space, and reducing pollution of water and air .Various unique properties of natural glass such as the silicate nature of glass, non-water absorbing, highhardness, and high resistance against corrosion and heat encouraged different researchers to use glass in theconcrete mixture and study its effect on the properties of concrete . Various studies have verified thepartial replacement of glass powder as a partial substitute for fine aggregates in concrete. Ling et al.investigated the effects of recycled glass cullet as a partial substitute for river sand at 10%, 20%, and30% on the slump, tensile strength, compressive strength, static modulus of elasticity, and density of selfcompactconcrete (SCC) and found a direct proportion between the results of the slump and thereplacement ratios, while a clear decrease in the other mechanical characteristics of (SCC) mixes as theglass aggregate content increased [16–18]. Shekhawat et al. [16] used four different percentages (10%,20%, 30%, and 40%) of glass waste as a partial substitute for fine aggregate in ordinary concrete (M-25)to study the hardened properties such as compressive strength, tensile strength, and density in addition toa slump. The highest results for slump were recorded by replacing sand by 40% with WG, while for theother characteristics, it was noted that there was an increase in compressive strength up to 30% replacement of fine aggregates by WG, and splitting tensile strength decreased with increasing wasteglass content .Arivalagan et al. verified the effect of glass dust (GD) on some properties ofconcrete such as compressive strength, tensile strength, and flexural strength by replacing fine aggregateswith GD at (10%, 20%, and 30%). They found a significant decrease in a slump was reached with anincrease in the replacement ratio of GD. In comparison, the compression resistance increased up to 20%.replacement level, as well as the tensile strength and flexural strength, which started decreasing after 20%replacement of GD by fine aggregate. They studied the effects of the partial replacement of glass powder.with fine aggregates (10%, 20%, 30%, and 40%) on the compressive strength, tensile strength, and workability of concrete. Kassed et al. [20] studied the effects of the partial replacement of glass powderwith fine aggregates at various rates (10%, 20%, 30%, and 40%) on the compressive strengthtensile strength, andworkability of concrete. Kassed et al. Studied the effects of the partial replacement of glass powderwith fine aggregates at various rates (10%, 20%, 30%, and 40%) on the compressive strength, tensilestrength, and workability of concrete. A clear decrease was found in the results of the slump when increasing the percentage of glass powder in the mixture. The compressive strength was increased for10% replacement, after which it began to decrease gradually by increasing the percentage of glasspowder content. The tensile strength decreased significantly when adding glass powder compared to the reference concrete mix. The main goal of the current study is to check the properties of normal concrete (compressive strength, tensile strength, density, and slump) by recycling glass waste at rates of10%, 20%, 30%, and 40% as a partial replacement for fine aggregate.

OBJECTIVES

Glass is prepared by melting a mixture of materials such as silica, soda ash and caco3 at high temperatures followed by cooling where solidification occurs without crystallization. The various forms in which it is produced includes packaging or container glasses(bottles, jars),flat glass(windows, windscreens),bulb glasses ,cathode ray tube glass(TV screens, monitors) etc., all these glasses have very little life. The waste glass which cannot be recycled, like mixed colour glass is generally sent for landfills. Land - filling has become a problem and a waste in itself. In this In this project soda-lime glass is used because it is inexpensive and easily melt and shape.Various forms of soda-lime glass is bottlesjars, bulbs. Glass used in concrete offers several advantages and serves specific In this project soda-lime glass is used because it is inexpensive and easily melt and shape. Glass can improve the mechanical properties of concrete, such as compressive strength, flexural strength, and impact resistance. Utilizing glass in concrete can lower the carbon footprint of construction projects by reducing the need fortraditional cement, which is a significant source of carbon emissions. Glass can enhance the thermal insulation properties of concrete, contributing to energy-efficient buildings : Properly processed glass particles can help mitigate the alkali-silica reaction, a common issue in concrete that leads to cracking and deterioration. Glass can improve the workability and flow properties of concrete, making it easier to handle and place during construction. Overall, incorporating glass into concrete can enhance the material's performance, sustainability, and visual appeal, making it a valuable addition to modern construction practices.

GLASS

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In this project soda-lime glass is used because it is inexpensive and easily melt and shape.

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Fig:1 Soda lime glass

POSSIBLE IMPACT OF WASTE GLASS ON ENVIRONMENT

The major impact of glass production is caused by atmospheric emissions from melting activities.

The combustion of natural gas/fuel oil and the decomposition of raw materials during the melting lead to the emission of CO2. this is the only greenhouse gasses gas emitted during the production of glass.

Sulphur dioxide (SO2) from the fuel and/or from decomposition of sulphate in the batch materials can contribute to acidification and formation of SMOG.

Benefits Of Use Of Waste Glass Powder In Concrete

□Elimination of waste glass disposal problems resulting in green and clean environment.

□Minimizes the ill effects of river dredging of sand like erosion of river bed, sinking of bridge piers, denudation of river banks, changes in the original path of rivers and streams.

□Use of waste glass powder in concrete paves a possible path for greener construction, thereby, establishing sustainable development.

GLASS MANUFACTURING

□Glass is typically made by melting raw materials like silica sand, soda ash, limestone, dolomite, and recycled glass at high temperatures.

□The composition of the raw materials can be varied to achieve specific properties.

□The molten glass is then shaped and cooled to form the desired glass product.

Sustainability Benefits

The use of recycled glass powder can refine the pores of cement paste, leading to improved concrete properties.

Strength Enhancement

Studies have shown that replacing fine aggregate with recycled glass can lead to an increase in compressive strength, with some research indicating that concrete containing up to 30% fine glass aggregate exhibits higher compressive strength development than traditional concrete.

Pozzolanic Properties

Waste glass, particularly when finely ground, exhibits pozzolanic properties, meaning it can react with calcium hydroxide in cement to form stronger, more durable concrete.

Optimized Replacement

Research suggests that the optimal replacement percentage of fine aggregate with recycled glass can vary depending on the specific application and desired properties of the concrete.

Durability

Incorporating recycled glass can improve the durability of concrete, especially in terms of resistance to chloride ion penetration and alkali-silica reaction (ASR).

Microstructure Improvement

The use of recycled glass powder can refine the pores of cement paste, leading to improved concrete properties.

Partical Considerations

The properties and performance of recycled glass sand depend on the source and type of waste glass, so careful consideration of these factors is necessary when implementing this sustainable solution.

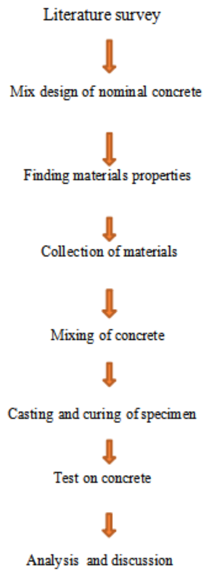
Sieved glass powder glass powder being mixed with sand

Fig : Partical consideration

Processing crushed glass

Glass can be recycled and used to produce additional glass products in an indefinite closed-loop cycle. The recycling process begins by collection, where glass types and colours are separated to ensure the correct chemical composition for the intended use. The recycled glass must be free of other contaminants such as food waste, dirt, and ceramics as these may cause impurities in the final product. The crushed glass can then be mixed with raw materials then heated in the manufacturing kiln at high temperatures (1200–1400 °C) to melt the glass mix [15]. The liquid glass mix then leaves the kiln to be blown or pressed into new glass products. The process of manufacturing glass is resource and energy heavy but incorporating waste glass can cut the consumption of these down. The use of 10% crushed glass by weight in the manufacturing process can reduce the required raw materials by 5%

METHODOLOGY



MATERIALS USED

Cement:

Cement is a key to infrastructure industry and is used for various purposes and also made in many compositions for a wide variety of uses. Cements may be named after the principal constituents, after the intended purpose, after the object to which they are applied or after their characteristic property. Cement used in construction are sometimes named after their commonly reported place of origin, such as Roman cement, or for their resemblance to other materials, such as Portland cement, which produces a concrete resembling the Portland stone used for building in Britain.

Fig: Cement

Aggregates:

Aggregates are generally classified into two group sizes, coarse and fine aggregate. In so many cases two or more actual sizes of material has been used, because of a further subdivision by size of material either present in one or both of the groups. Generally fine aggregate is taken as, which has been passing from the 4.75mm sieve. As a results it also must have specific gravity of 2.6. Coarse aggregate is consider as the particle which was retained on the IS sieve 4.75 mm.

Fig: Aggregates

Recycled glass waste

Using recycled glass waste as a partial replacement for fine aggregate in concrete is a viable and sustainable approach, offering potential benefits like reduced waste disposal and improved concrete properties.

Fig: Glass Recycled

Water: Water is a one of the important ingredient in the concrete and this will help chemical reaction with cement. In the concrete, strength is mainly depending on the binding operation of hydrated cement gel. The water is added to get required consistency for the suitable workability. Water used for the concrete preparation must be fresh and potable, Ocean water and drainage water should not be used because of sulphate reaction.

Fig: Adding of water in concrete mix

CONCEPT OF MIXDESIGN

It will be worthwhile to recall at this stage the relationship between aggregate and paste which are the two essential ingredients of concrete. Workability of them as is provided with the lubricating effect of the paste and is influenced by the amount and dilution of paste. The strength of concrete is limited by the strength of paste, since mineral aggregates with rare exceptions are far stronger than the paste compound. Essentially the permeability of concrete is governed by the quality and continuity of the paste, since little water flows through aggregate either under pressure or by capillarity Further, the predominant contribution to drying shrinkage of concretes is that of paste. Since the properties of concrete are governed to a considerable extend by the quality of paste it is helpful to consider more closely the structure of the paste. The fresh paste is as us pension, nota solution of cement in water.

The more dilute the paste, the greater the spacing between cement particles, and thus the weaker will be the ultimate paste structure. The other conditions being equal for workable mixes, the strength of concrete varies as an inverse function of the water/cement ratio. Since the quantity of water required also depends upon the amount of paste, it is important that as little paste as possible should be used and hence the importance of grading.

Mix design

Physical Properties of Materials Recycled Glass Waste Particle Size Distribution: Matches fine aggregate grading (ASTM C136).

Specific Gravity : 2.4–2.6 (slightly lower than sand). Water Absorption : <1%, reduces water demand.

Shape and Texture : Angular, smooth particles affect workability. Bulk Density : Lower than natural sand.

Other Materials

Cement : Specific gravity ~3.15, ensures strength development.

Fine Aggregate : Specific gravity ~2.65, water absorption ~1%.

Coarse Aggregate: Specific gravity ~2.7, size: 10–20 mm. Water : Clean and free from impurities.

Fig: Lab Testing

Replacement Levels: 10–30% recycled glass as a partial replacement for fine aggregate.

1.Target Strength: Based on concrete grade.

2.Water-Cement Ratio: Typically 0.4–0.5 for strength and workability.

3.Aggregate Proportions: Replace part of fine aggregate with glass waste.

Trial Mixes: Prepare batches with 10%, 20%, and 30% replacement. Testing: Conduct slump tests (workability) and compressive strength tests

Casting and curing of specimens Casting of Specimens

1.Materials: Prepare concrete mix with cement, fine aggregate (sand + recycled glass waste powder), coarse aggregate, and water as per mix design.

2.Mould Preparation: Clean and oil moulds (e.g., cubes, cylinders,).

3.Mixing: Batch and mix all materials thoroughly to ensure uniformity.

4.Placing: Fill moulds in layers and compact each layer using tamping rods or a vibrating table.

Surface Finishing: Level the surface with a trowel.

Fig: Casting of Cubes

Casting of cubes

1.Standard Cube Mould size – 150mm * 150mm * 150mm

2.Cube moulds should be non absorbent, non reactive and metal moulds to be used (Cast iron).

3.These faces must be thinly coated with mould oil to prevent leakage during filling, and a similar oil film should be provided between the contact surfaces of the bottom of the mould and the base. The inside of the mould must also be oiled to prevent the concrete from sticking to it.

4.Fill the mould with concrete in 50 mm layers using the tamping bar, compact the concrete with no fewer than 35 tamps for each of the three layers in a 150 mm mould

5.The slump of the sample should be 80 – 100mm.

6.After tamping of each layer, tap the sides of the mould with the hide hammer until large bubbles of air cease to appear on the surface and the holes left by the tamping bar are closed

7.Remove surplus concrete and smooth over with a float

8.Wipe clean the mould edges.

9.Number the moulds for identification and record details

10.Cover each mould with a damp cloth and plastic sheet.

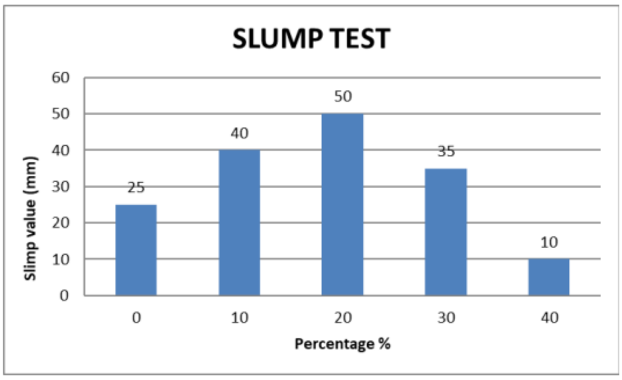
11.Store the cube moulds at room temperature and free from vibration.

De-mould the cubes after 24 hours.

TEST ON CONCRETE

Slump test

%	0	10	20	30	40
Slump value	25	40	50	35	10



Graph: Slump Values

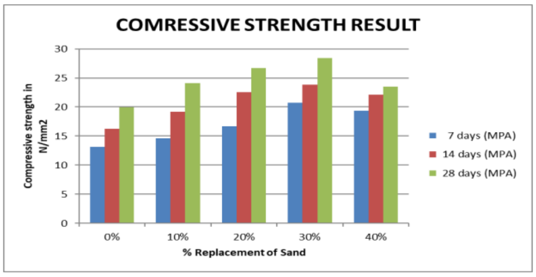
Compaction factor test

Compaction factor test used for concrete with low workability such as stiff or fluid mixes.A concrete sample is placed in a compacting factor apparatus

The weight of the concrete is measured before and after compaction The compaction factor is calculated by dividing the weight of the compacted concrete by the weight of the partially compacted concrete.

Table: Compressive Strength Result

Mixes	7 days	14 days	28 days
0%	13.12	16.23	19.95
10%	14.61	19.16	24.11
20%	16.64	22.54	26.64
30%	20.74	23.84	28.42
40%	19.36	22.14	23.46



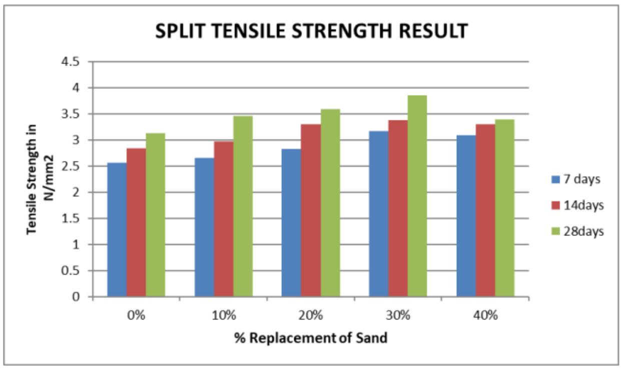
Graph: Compression Strength Values

TENSILE STRENGTH TEST

The tensile strength test measures the maximum amount of tensile (pulling or stretching) stress a material can withstand before breaking or failing. It is commonly conducted on materials like metals, plastics, and fibers to assess their strength properties.

Table: Tensile Strength Results

Mix	7 days	14days	28days
0%	2.56	2.84	3.13
10%	2.66	2.98	3.46
20%	2.83	3.31	3.6
30%	3.173	3.38	3.86
40%	3.09	3.31	3.4



Graph: Tensile Strength

CONCLUSION

1. The percentage increase in compressive strength in case of 10% replacement of sand with glass powder is found to be 25% at 28 Days
2. The percentage increase in compressive strength in case of 20% replacement of sand with glass powder is found to be 32% at 28 Days
3. The percentage increase in compressive strength in case of 30% replacement of sand with glass powder is found to be 52% at 28 Days
4. The percentage increase in compressive strength in case of 40% replacement of sand with glass powder is found to be 18% at 28 Days
5. The Percentage increase is observed to be maximum incase of 30% replacement of sand.
6. The cost analysis has been done as per the present rates in Andhra Pradesh. It is observed that there is only 2% reduction in the cost when 30% of the sand is replaced by the waste glass powder but there is a significant increase in the compressive strength of concrete when compared to the conventional concrete.

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