International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-10, Issue-2, April 2023
https://doi.org/10.55524/ijirem.2023.10.2.5
Article ID IJIR2344, Pages 18-22
www.ijirem.org

Making Self-Consolidating Concrete Mixtures Using Waste Glass Micro-Particles

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ABSTRACT- As the pace of garbage production worldwide is worrying. Among these waste items include rubber, glass, wood goods, and plastic, among others. Compared to other waste materials, glass garbage is produced more often in India. However, approximately 60% of glass trash is either disposed of in landfills or stored in warehouses around the nation due to the low market value of recycled glass and expensive transit costs. The chemical inconsistencies among the many types of glasses, as well as the difficulties in separating different coloured glasses, make recycling challenging in addition to the existence of waste products such plastic caps, metals, and paper. However, in recent years it has become more difficult to replace coarse aggregate, sand, and gravel with waste glass in concrete and mortar. Since the 1960s, a number of researchers have investigated the use of waste glass larger than 4.75 mm as a coarse aggregate spare in concrete. There is a high need for aggregate and clay (brick) sources in the manufacturing of concrete. In 2015, 48.3 billion tonnes of aggregates were used annually as building materials worldwide, with 2.2 billion tonnes of them being used in India. Waste resources can be used as various types of construction material to get around the aggregate glass ultimatum. Only 45% of the 21 billion tonnes of glass trash produced in India in 2019 were recycled, demonstrating the necessity for effective waste glass procurement and management. This review provides examples of how leftover glass may be used to make building pieces. The study's primary goals are to learn more about the physical and mechanical characteristics of waste glass-based blocks and other products, to generate sustainable building materials that can replace aggregates and clay, and to lessen the amount of waste glass dumped in landfills.

This study's goal is to investigate the hardened mechanical characteristics, water absorption rate, free drying shrinkage, unit weight, and Alkali Silica Reaction (ASR) of binary mixed concrete with partial cement replacement by 5, 10, 15 and 20 weight per cent of GWG micro particles. The findings demonstrate that adding more GWG micro particles improved the workability of new concrete. The findings demonstrated that concrete with increased hardened properties is produced when GWG micro particles are used up to a maximum replacement level of 15%.

KEYWORDS- Aggregate, Cement, Concrete, Waste Glass

I. INTRODUCTION

Concrete is a composed material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens (cures) over time. Concrete is the second-most-used constituent in the creation after water, and is the utmost widely used building material. Its globalusage, ton for ton, is twice that of steel, wood, plastics, and aluminium combined.concrete, in construction, structural material comprising of a hard, chemically inert particulate substance, known as aggregate (usually sand and gravel), that is merged together by cement and water.Concrete could be a mixture of cement, water and aggregate and sometimes admixtures in obligatory proportion[1]. The mixture when placed in forms and allowed to cure toughens into a rock-like mass called concrete. The mixture entails of amalgamation of diverse sizes of gravel and sand. When water is added to cement, a chemical change takes place causing the combo to harden [2]. Cement is chiefly made of a mishmash of limestone and clay, which is crushed into anappallingly fine powder then scorched at a warm temperature in an extremelycircling kiln, thereby fusing it into a fabric called clinker. The clinker is chilled down and pulverized into a fine powder.Concrete is analogous in composition to mortar, which is employed as a bonding material in masonry works. Mortars are however typically made using sand as the sole aggregate, whereas concrete contains a generous amount of larger size aggregate. Cement is the most affluent of the constituent required supplying concrete. This proposes that so as to decrease the prices of the concrete, the amount of cement used depends on the intent that the concrete is required. Concrete for load bearing structures usually contains one part cement, two parts fine aggregate and 4 parts of coarse aggregate. Concrete used for culvert beds and foundations needs less cement than structural concrete. The compactness and strength of the finished concrete also rest on on the distribution of the particle proportions. By mixing the correct amounts of diverse sizes of gravel and sand, it's possible to comprehend a dense and prevailing concrete.The construction sector practises a rising demand for concrete due to swift infrastructure development. Growing infrastructure development devours concrete about 25 million cubic metres of concrete each year which leads to enormousremoval of natural resources such as natural aggregates. Sand and gravel are the extreme extracted natural resources in the world corresponding to 79% or 28.6 giga tonnes per year [3,12].

Concrete-Concretus, a Latin word, is where the term "concrete" originates (meaning compact or condensed). Quicklime, pozzolana, and a pumice aggregate were the main components of Roman concrete. MortaPyramid was found to be 81.5% salt and 9.5% carbonate, according to an analysis. The Roman mortar's superiority was proven by the Indian method of carefully combining and repeatedly pounding lime with or without surkhi. This method produced a strong and impenetrable mortar. For their cement and concrete to be more easily worked, they added blood, milk, and grease [5].

Cement- The most used type of cement is hydraulic cement, which was invented in England in 1824. Carbonate, which can be found in lime stone or chalk, as well as silica, alumina, and iron oxide, which can be found in clay or shale, are the primary raw ingredients used in the production of cement. The term opus cementicium, used to describe masonry that resembled modern concrete and was built of gravel with calcined lime as a binder, is where the word "cement" first appeared. The hydraulic binder created by combining volcanic ash and crushed brick with calcined lime was later referred to as cementum, cimentum, cäment, and cement. Currently, organic polymers are occasionally employed in concrete as cements [4].

Table 1: Physical Properties of cement

Sr. No.	Properties	Observation Ns
	Bulk density	1450 kg/m^3
1	Specific gravity	3.15
2	Initial setting time	30 min
3	Final setting time	600 min
4	Standard Consistency	5-7%
5	Fineness (90 micron IS Sieve)	5%
6	28-days compressive strength	42.17Mpa

Aggregate- Sand, gravel, crushed stone, slag, recycled concrete, and geosynthetic aggregates are all examples of the broad category of coarse- to medium-grained particulate material known as building aggregate. The most frequently mined materials worldwide are aggregates. In composite materials like concrete and asphalt, aggregate acts as reinforcement to increase the total composite material's strength [4]. Aggregates are frequently utilised in drainage applications such foundation and French drains, septic drain fields, retaining wall drains, and roadside edge drains due to the comparatively high hydraulic conductivity value when compared to most soils. Aggregates are frequently utilised in drainage projects such septic drain fields, retaining wall drains, foundation and French drains, and roadside edge drains. Additionally, aggregates are used as the base material for roads, railroads, and foundations. To put it another way, aggregates are used as a concrete extender that combines with more expensive cement or asphalt to create concrete, or as a strong foundation or road/rail base with predictable, homogeneous qualities (e.g. to help prevent differential settling under the road or structure).

Waste Glass-Without glass's many applications, modern lifestyle is unthinkable. Since its discovery in Mesopotamia more than 5000 years ago, glass has been manufactured for a variety of uses. Glass is produced in a variety of shapes depending on its chemical composition, including soda-lime glass, lead glass, borosilicate glass, and aluminosilicate glass. Examples of these shapes include containers, sheets, tempered ovenware, light bulbs, neon tubing, colour TV funnels, electronic components, and optical dense flint . The most common form of glass used for windows and glass containers is soda-lime glass. Waste soda-lime glass powder can be used in cementitious materials because recent study has demonstrated that it has pozzolanic characteristics [7].

Figure 1: Crushed waste glass particles

Table 2: Chemical composition of soda-lime glass

Soda-lime glass	SiO2	CaO	Na2O	Al2O3	K2O	MgO
Containers	66-75	6-12	12-16	0.7-7	0.1-3	0.1-5
Sheet	71-73	8-10	12-15	0.5-1.5		1.5-3.5
Float	73-74	8.7-8.9	13.5-15		0.2	3.6-3.8
Light bulbs	73	5	17	1		4
Tempered ovenware	75	9.5	14	1.5		

II. WASTE GLASS AS A CONSTRUCTION MATERIAL

Glass is a substance that does not biodegrade. It takes a while for it to decompose naturally. Glass debris that cannot be recycled is disposed of in landfills, which causes environmental issues. Using recycled glass in the construction sector is a practical way to divert a lot of glass trash from landfills. With varying degrees of success, a number of researchers have looked at the use of recycled broken glass as aggregate (coarse and fine aggregate) or as a cement substitute in concrete. Few of this research have looked at the usage of recycled glass in actual field applications; the majority of them have only looked at laboratory tests [6,9,11].

III. USE OF WASTE GLASS IN PLACE OF COARSE AGGREGATE

Since the 1960s, a large number of researchers have investigated the use of used glass as a substitute for coarse aggregate in concrete. Glass chip exposed aggregate for use in architecture was explored by Schmidt and Saia in 1963. Other researchers have utilised discarded glass to examine the characteristics of fresh and hardened concrete[8]

IV. CASTING, CURING AND TESTING

A. Fresh Concrete Tests

A concrete mixture can only be categorised as self-compacting concrete (SCC) if the filling, passing, and segregation resistivity requirements are met, according to the European Federation of Producers and Contractors of Specialist Products for Structures (EFNARC) guide for making self-compacting concrete (2005). The qualities of fresh concrete mix compositions have been investigated using a variety of tests in the current experimental investigation. No one approach or set of procedures has, to date, been universally embraced, but the majority of them have their supporters. Therefore, it is recommended that each mix design be tested using several test methods for various workability characteristics.

B. Hardened Concrete Tests

1) Compressive Strength of Concretes

Because strength is directly tied to the structure of the hydrated cement paste, the compressive strength test often provides an overall view of the quality of concrete. Compression testing is crucial for determining how concrete specimens gain their strength (Hamid et al. 2012). It was calculated as the highest load supported divided by the sample's cross-sectional area. For the purpose of determining the compressive strength SCCs, three 100 mm cube specimens were employed. On specimens that were 3, 7, 14, and 28 days old, the test was run.

2) Tensile and Flexural Strength of Concretes

There are three widely used methods for determining the tensile strength of concrete: I direct tensile strength; (ii) splitting tensile strength; and (iii) flexural tensile strength (3- or 4-point loading). Direct tensile strength testing is not very common because of how difficult it is to do. These test results can be transformed amongst each other. But it's unclear if these conversion factors can still be applied to SCC (Craeye et al. 2014). On three cylindrical moulds measuring 100 mm and 200 mm, splitting tensile strength tests were conducted on specimens that were 3, 7, 14, 28, 42, and 56 days old. The concrete cylinders were tested for splitting tensile strength using a compressive machine with a loading capacity of 300 tonnes after the prescribed curing period had passed. Three duplicates of each test were run, and average splitting tensile strength results were recorded.The splitting tensile strength was determined using the following equation:

$$F_t = 2P/3.14Ld$$

Where Ft is splitting tensile strength, P is the maximum applied load indicted by testing machine, and L and D are the length and diameter of specimen, respectively.

The flexural strength of concrete is conducted on prism of size 100 * 100 * 500 mm. Six concrete prisms were casted for each concrete mix proportions for 28- and 56-days. Four point loading has been used to predict the flexural strength. The average modulus of rupture (flexural strength) was determined using the following expression:

$$F_{cr} = PL/bd2$$

Where Fcr is the modulus of rupture; P is the maximum applied load indicated by testing machine; and L, b and d are the average length, width and depth of specimen, respectively.

3) Unit Weight and Water Absorption of Concretes

At the age of 28 days, the density (unit weight) of hardened concrete was determined. The aggregate density mostly determines this feature. As a result, replacing cement may not significantly alter the concrete's density [11]. The amount of water absorbed under specific conditions may be measured using a water absorption test, which reveals how porous a material is (Siddique 2013). The water absorption test was carried out by fully submerging dried specimens (the indicated specimens were dried in the oven for 722 h) in water, and after a certain period of time, recording the quantity of absorbed water percentage per mass. After the first curing, it was done here every day until the day of day 10 [11].

4) Free Drying Shrinkage of Concretes

The volumetric change brought on by the drying of concrete is known as drying shrinkage. This change in concrete volume is not equivalent to the volume of water lost. First, free water is lost; little to no shrinking results from this. The adsorbed water trapped by hydrostatic tension in the microscopic capillaries (50 nm) is expelled as the concrete continues to dry. The shrinkage brought on by this water loss is far more than the shrinking brought on by the loss of free water. Tensile tensions caused by the water loss cause the concrete to shrink (Guneyisi et al. 2010). After drying, the free drying shrinkage of the SCCs specimens was evaluated at 1, 3, 7, 14, and 28 days. We utilised two beams of dimensions for this test (50 mm 9 50 mm 9 285 mm). The specimens in this test were taken out of the moulds after 24 hours. The specimens were kept in air until the time of testing after the 28-day curing period. Following that, the strain was assessed at designated periods.

5) Alkali–Silica Reaction Test

The expansion due to the ASR was determined on three prisms with dimensions of 25 9 25 9 285 mm. A zeroreading was taken after storing the prisms in distilled water at 80 C for 24 h. The mortar bars were then transferred and immersed in 1 NaOH solution at 80 C until the testing time.

The expansion of the mortar bars was measured within 15 ± 5 s after they were removed from the 80 C water or alkali storage condition by using a length comparator. The measurements were conducted at the 1, 3, 7, 10, 14, 28 and 42 days. According to ASTM C 1260 the expansion of concrete 16 days after casting is classified as non-detrimental if it is below 0.10 %, as potentially detrimental if it is between 0.10 % and 0.20 % and as detrimental if it is over 0.20 %.

Table 3: Physical properties of aggregates

Properties	Fine Aggregates	Coarse Aggregates
Specific Gravity	2.73	2.81
Bulk Density kg/m3	1590	1565

Void Content %	36.71	47.58
Water Absorption %	1.09	0.32

Cement, fine aggregate (NFA), natural coarse aggregate, waste from glass bottles, tubes, bulbs, and window panes, crushed recycled concrete aggregate (CRCA), plasticizer (PermaPlast MF), and water are used to create the test specimens. In general, the materials will follow therequirements outlined in the applicable Indian standard codes. The following qualities were present in the materials that were going to be utilised to make concrete mix specimens:

C. *Fine Aggregates Natural Sand*

The clean sand used in this experiment was acquired from the river Jhelum close to Kakapora Pulwama and passed through an IS sieve with a 4.75 mm mesh size.

V. TESTS AND RESULTS

A. *Compressive Strength*

These cubes underwent a compression test in accordance with IS 516 (1959). The specimens were loaded till failure at a constant strain rate. With an increase in the RGP %, the compressive stress is reduced. The table below shows the results of the compressive test of cubes after seven days, fourteen days, and 28 days, and the comparison of the results is displayed as follows.

Table 4: Compressive strength

S. NO	CURING DAYS	COMPRESSIVE STRENGTH IN N/mm2				
		NORMAL CONCRETE	GLASS POWDER CONCRETE			
			5%	10%	15%	20%
1	7	20.44	19.8	23.9	25.1	27.8
2	14	24.77	22.2	26.2	28.8	33.4
3	28	31.61	38.7	41.1	44.9	45.2

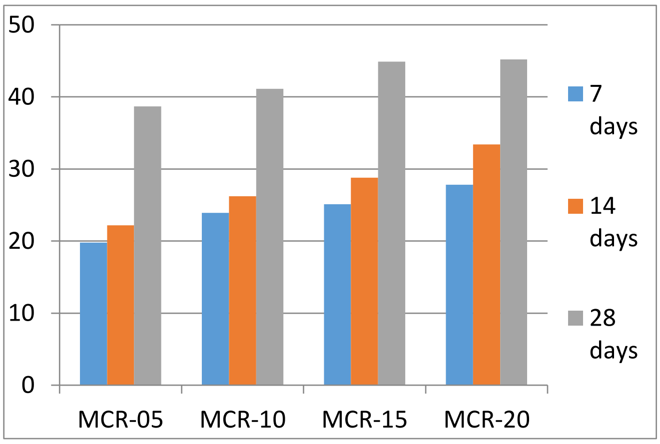

Figure 2: Compressive strength of cubes in 7,14 and 28 days

B. *Flexural Strength Test*

Prismatic specimens 150 × 150 × 500mm were tested according to IS: 516(1959). The results of flexural strength of prisms for 7 days and 28 days are

Table 5: FLEXURAL STRENGTH

S. NO	CURING DAYS	FLEXURAL STRENGTH IN N/mm^2				
		NORMAL CONCRETE	GLASS POWDER CONCRETE			
			5%	10%	15%	20%
1	7	3.46	2.78	2.97	3.08	3.85
2	14	4.28	3.56	3.78	4.78	4.96
3	28	5.86	5.43	5.95	6.86	7.08

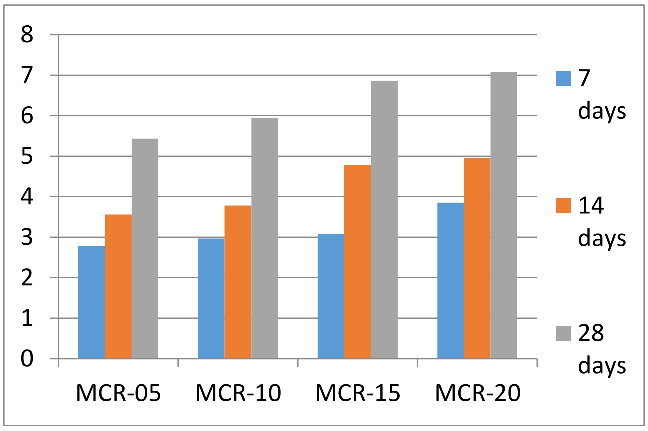

Figure 3: Graph showing the flexural strength of cubes in 7,14 and 28 days

C. *Split Tensile Strength*

According to IS: 5816, cylindrical specimens measuring 300 mm in length and 150 mm in diameter underwent testing (1999). With an increase in the amount of rubber particles in the concrete mix, the durability decreased. The split lastingness test results for the cylinder for 7 days and 28 days are listed in the table below, and a comparison of the findings is presented in Fig.

Here we find some of the readings of samples w.r.t split tensile strength of concrete and glass powder mixture in 7 ,14 and 28 days

Table 6: Split tensile strength

S. NO	CURING DAYS	SPLIT TENSILE STRENGTH IN N/mm^2				
		NORMAL CONCRETE	GLASS POWDER CONCRETE			
			5%	10%	15%	20%
1	7	5.23	1.79	1.68	1.72	1.48
2	14	5.41	2.34	2.19	2.23	1.98
3	28	5.62	2.84	2.47	2.53	2.19

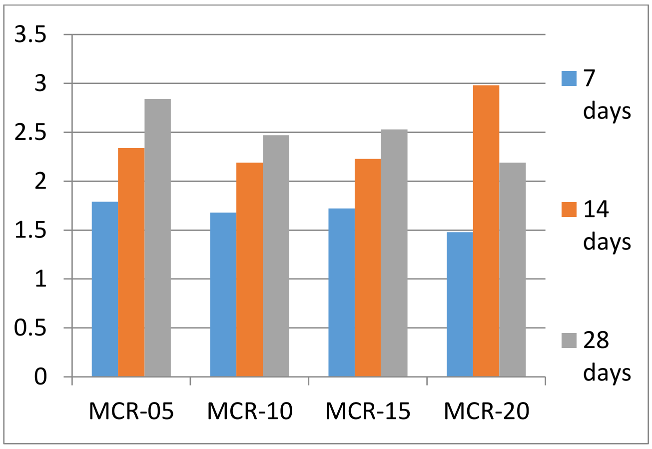

Figure 4: Split tensile strength of cylinders in 7,14 and 28 days

VI. CONCLUSION

The utilisation of discarded glass in concrete has been the subject of several investigations. To determine if recycled glass may be used in concrete, however, relatively few field tests have been conducted. The kind and source of glass trash affect the characteristics and functionality of recycled glass sand. The purpose of this research was to determine whether recycled glass might be used to partially replace cement and sand in concrete. The following findings from this research are provided below: A series of experimental studies were undertaken to evaluate the impact of RGS and RGS concerning strength characteristics and durability features.

- To study the acceptability of employing recycled waste glass sand (RGS) in concrete, a number of experiments were carried out to ascertain the attributes of the components, fresh concrete, and cured concrete, including its durability characteristics. RGP was used to create concrete by substituting 5%, 10%, 15%, and 20% of natural river sand. All concrete mixes, and most crucially, in 7 days, 14 days, and 28 days, reached the desired compressive strength. When natural sand was substituted with RGS up to 25%, no deleterious effects on strength were seen.
- A concrete mixture including recycled glass powder was evaluated with a goal characteristic strength of 32 MPa at 28 days. The mechanical strength and durability of concrete with partial cement replacements of 5%, 10%, 15%, and 20% of RGP were evaluated and compared to conventional concrete.
- In the Indian setting, the advantages of producing 1 m^3 of concrete from recycled glass were evaluated. The usage of RGS as a sand substitute in concrete has a little impact on the environment. However, as a portion of cement was replaced by RGP, such as 5% as the replacement level climbed to 25%, global warming was subsequently reduced. Using RGS and RGP concrete, ozone layer thinning can be reduced by up to14% and 22%, respectively.
- When recycled glass is successfully incorporated into concrete, it may minimise sand dredging, cement production, and the amount of glass trash dumped in landfills. This study may be successfully applied in industrial applications because it also strives to support sustainable development.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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