Advancement and Optimization of Waste in High-Strength Concrete

Ankush Kumar[1], Vaibhav Chauhan[2]

[1, 2] *Department of Civil Engineering,*
Radha Govind Group of Institution, Meerut.
ak2247826@gmail.com

***Abstract* – This study investigates various waste materials, their potential as partial replacements for conventional constituents, and their impact on the properties of HSC. One of the biggest and most popular materials on earth is glass. In its current condition, glass looks to have a relatively short shelf life. One method of disposal that is both economical and safe for the environment is to reuse this trash in construction materials. To avoid environmental issues, glass must be recycled or repurposed. River sand supply and pricing have also become key concerns in recent decades. Examining the impacts of employing waste glass as a partial substitute for fine aggregate and steel slag as a partial substitute for coarse aggregate is the goal of this study. The amount of discarded glass that was crushed was changed to produce different concrete compositions.**

In the amounts of 0%, 10%, 20%, 25%, 30%, 40%, and 50%, waste crushed glass powder was used to replace fine aggregate. This investigation concentrated on qualities like compressive strength. Another effort to substitute coarse aggregate with steel slag was made, and different concrete combinations were formed by varying the amount of steel slag. After determining the individual optimum replacement, combined replacement is obtained, when waste glass powder kept 20% constant throughout, we observe the optimum coarse aggregate replaced by steel slag is 50%. The article focuses on understanding the behavior of waste-based HSC in terms of strength, durability, and sustainability, thus providing valuable insights for the construction industry.

Keywords: Concrete, Compressive strength, Glass powder, Optimization, Steel slag.

1. INTRODUCTION

Environmental problems are brought on by the building industry's major contribution to the world's resource use and waste production. The most popular building material, concrete, considerably adds to these problems. High-strength concrete (HSC) is particularly favoured for its enhanced mechanical properties, making it suitable for various structural applications. However, the production of HSC typically requires large amounts of cement, resulting in high carbon dioxide emissions and depletion of natural resources. To address these concerns, the incorporation of waste materials into concrete production has emerged as a sustainable approach.

In many aspects of modern building, concrete has gained importance as an essential component. Finding a different building material with the same qualities as concrete is exceedingly difficult. When strength, stability, impermeability, fire resistance, and absorption resistance are required in a building material, concrete is a fantastic choice. Concrete is made comprised of sand, cement, gravel, and water. Environmental concerns, as well as a shift away from the mass-waste, mass-consumption, and mass-production culture of the past, are critical given the challenges of climate change and damaging the environment today.

Waste glass does not release pollutants, therefore it has no effect on the environment, but if it is not treated properly, it can harm living things, making it less eco-friendly. It became necessary to create new technologies as a resultA few examples of the numerous chemical forms that glass can take are alkali-silicate glass, soda- lime glass, and borosilicate glass.

One of the better options is to use waste products instead of natural resources, as waste may be avoided. Because the volume of waste produced on a regular basis is rising. In India, glass makes up for 0.7

percent of the total urban waste production. As we know that concrete is the highly demanded used building material, and its popularity has increased rapidly. Natural sand aggregate use results in resource extraction, groundwater level reduction, bridge pier sinking, and river bed erosion. As a consequence, it is advisable to use a different substitute in lieu of the sand. However, it is difficult to use residual glass trash in concrete because to the alkali silica reaction (ASR).

Additionally, steel slag can be utilised in place of coarse aggregate in some applications. By successfully using these byproducts, which would otherwise be thrown away, excellent environmental conditions will be obtained.

Steel slag particles are also utilised as boulders in flexible paving roads due to its superior mechanical strength, hardness, wear resistance, porosity, abrasion resistance, and poor water holding capacity. Research is being done to see whether steel slag may replace conventional concrete. In comparison to ordinary concrete, the test results for workability and strength are the same. Utilizing waste materials as an alternative to natural resources is one of the most efficient and effective ways to make the concrete industry more environmentally friendly. The amount of garbage glass that is produced on a global scale is significant. Glass makes up 0.75 percent of

the total amount of urban waste produced in India. Every year, the United Kingdom generates about three million tonnes of discarded glass.

Glass waste is a significant component of many countries solid waste streams and is frequently disposed of in landfills. In contrast, broken glass can serve as a low-cost replacement for traditional concrete aggregates or be left exposed as an aesthetically pleasing addition to architectural concrete products (high value). In wet conditions and with highly alkaline cements, ASR between glass particles and cement paste can be quite high. When aggregates include reactive silica, this reaction can occur. However, it is now widely understood that the reaction may be reduced by managing the cement alkali level and moisture.

Table 1.1 Major Constituent Present in Glass Powder

S.N.	Constituent present in glass powder	Proportion (%)
1	Silica(SiO_2) sand	71.00
2	Magnesium Oxide (MgO)	1.49
3	Oxide of Iron (Fe_2O_3)	1.70
4	Oxide of Calcium (CaO)	10.66
5	Oxide of Aluminum (Al_2O_3)	3.82
6	Oxide of Sodium (Na_2O)	10.16
7	Potassium Oxide (K2O)	0.95
8	SO_3 & LOI	<1

Grinded glass powder has the correct chemical composition, including SiO2, to combine with alkalis in cement (Pozzolanic process) and produce compounds that help in strength development. The use of suppressants such as pulverized fuel ash (PFA) and metakaolin (MK) can reduce the alkali silica reaction (ASR) of glass aggregate concrete.

Construction has always been at the forefront of making extensive use of these waste products. In addition to reducing greenhouse gas emissions, adding slag to concrete also helps to produce goods that are more ecologically friendly. Fluxes (limestone and dolomite) are used in blast furnaces in addition to coke as fuel to create iron and steel. Iron ore (Fe) becomes molten iron product when coke is burned, which also creates carbon monoxide. Fluxing agents remove impurities during the steel separation process, and slag is produced. Slag is an inert, nonmetallic waste byproduct composed primarily of silicate minerals, alumina silicates, and Calcium-alumina silicates.

Steel slag is now utilised as the surface gravel in asphalt pavements, but further research is required to determine whether or not this industrial by-product may replace both fine and coarse components in a typical concrete mixture. Currently, asphalt pavements employ steel slag as the surface gravel. When liquid steel is refined by being removed from impurities in the furnaces used to make steel, steel slag is produced as a byproduct.

Table 1.2: Steel slag chemical composition

S. N.	Major Constituent	Proportion (%)
1	Calcium Oxide (CaO)	41-53
2	Silicon Oxide (SiO_2)	9-18
3	Oxide of Iron (FeO)	11-41
4	Oxide of Manganese (MnO)	6-9
5	Oxide of Magnesium (MgO)	5-9
6	Oxide of Aluminum (Al_2O_3)	0.5-4
7	S & Phosphorus Oxide	<1

The elemental analysis performed with x-ray diffraction using X-Ray Diffraction machine is typically used to derive the simple oxides that make up the slag's chemical composition. The chemicals that can be found in steel slag that was produced in a standard base oxygen furnace are listed in Table 1.2. Although nearly all steel slags satisfy certain chemical requirements, this does not mean that all steel slags can be used as aggregates. Some steel slags are more suitable for this use than others. The rate at which the slag is chilled during the production of steel has a significant impact on the mineralogical form of the slag, making it the most important aspect to consider.

1.1 Steel slag as coarse aggregates

More important is the slag's mineralogical morphology, which is heavily influenced by the rate of steel chilling in the iron-making process. This kind of waste material use has the potential to ease gravel shortages at various construction sites while simultaneously minimizing environmental difficulties related with gravel mining and rubbish disposal. Construction has always been at the forefront of making extensive use of these waste materials.

Not only does the addition of slag to concrete lower emissions of carbon and other greenhouse gases, but it also helps contribute to the manufacturing of environmentally friendly products. Fluxes like limestone or dolomite are mixed with coke to function as fuel in blast furnaces for the manufacturing of iron and steel. It's also possible to employ other fluxes.

Burning coke to make it and turning iron ore into molten iron product both produce carbon monoxide. Slag is produced as a result of impurities being removed from the molten steel by fluxing chemicals. Blast litter is a non-metallic, inert waste byproduct. Alumina silicates and calcium-alumina silicates make up the majority of its silicate mineral composition.

A significant percentage of the sulphur from the charge is absorbed by the liquid slag, which makes up roughly 20% of all iron production. Aggregate properties are crucial because they can have a significant impact on the characteristics of concrete (Beshret al. 2003). Maslehuddinet al. (2002) found that crushed limestone aggregate was not as durable as steel slag cement concrete.

2. LITERATURE REVIEW

Haramkar et al. (2016) conducted experimentation by replacing fine aggregates with discarded glass powder. This study examined concretes with glass particle waste fine aggregate. Glass dust waste replaced natural sand in concrete at 10%, 20%, and 30%. C concrete compressive strength was compared to natural fine aggregate concrete after seven, fourteen and twenty-eight days. After 4 weeks, the results showed that glass dust waste produced the highest level of activity. The findings indicate that using glass waste as a fine aggregate substitution material in concrete is advantageous and may be used in the future. After 28 days, the impact of glass trash on concrete becomes more obvious. The ideal percentage of glass waste for producing the maximum compressive strengths is 10%. The objective of this study was to devise effective methods for reusing glass powder as fine concrete production. The information presented in this article demonstrates that using waste glass in concrete is a practical alternative; more study into how it will affect the quality of concrete in the long run may be done.

Siram (2020) examine substituting fine aggregate in different concrete classes (M20, M25, M30, M35, and M40) with varying amounts of glass powder. Fine aggregate replacement is done in the range of 10% to 50% at 10% intervals for this purpose, and compressive strength is tested at 7 and 28 days. For each grade, the appropriate glass powder content to substitute fine aggregate is determined.

Compressive tests revealed that recycled glass powder concrete had a higher strength than traditional concrete. The highest results were

obtained by substituting fine aggregate with glass powder at 20%, while 30% substitution also demonstrated minimal variance.

Ammash et al. (2009) investigated whether or not it would be possible to use waste glass with a particle size of up to 5 millimetres as a fine aggregate in concrete and mortar. Glass scraps were mixed in at percentages of 10, 20, 30, and 40%, respectively, to partially replace the weight of sand. According to the data, increasing the percentages of sand replacement by waste glass has an effect on the compressive and tensile strength of both mortar and concrete. Concrete and mortar have 28-day compressive strengths that are approximately 92% and 95% of the reference standards, respectively, representing up to 20% replacement. It was also revealed that when the waste glass component in the mix grows, so does the expansion of mortar specimens. The expansion is somewhat greater than that of the control specimens at 20% sand replacement by waste glass.

Sawant (2018) replaced grass recycled in concrete as it reduces energy consumption, and waste glass is being used more frequently in a variety of applications. One of its greatest accomplishments was the utilisation of waste glass to produce concrete. Crushed and screened waste glass may substitute sand in concrete without compromising safety or cost, according to several studies. According to the study, scrap glass may take the place of fine aggregate without sacrificing strength. When employing waste glass as a substitute for fine aggregate after 28 days, the strength is marginally greater up to a 10% replacement level and significantly lower at a 20% to 30% replacement level of glass powder with fine aggregate.

Mishra et al. (2020) studied the effect of different percentage of glass powder in M20 concrete. For the M-20 mix, fine aggregates will be replaced by waste glass powder in weight ratios of 5%, 10%, 15%, 20%, and 40%. After 4, 7, and 28 days, the compressive strength of the concrete specimens will be evaluated and contrasted with ordinary concrete. A more sustainable future is made possible by concrete that contains glass powder (GP). A typical store response to non-recyclable waste that ends up in landfills is glass shards and flat solid slices. The increasing use of concrete poses a severe challenge to resource management and economic sustainability. The possibility of replacing the fine mixture in concrete with glass waste powder is being looked at.

Glass powder would replace up to 0% to 40% of the river sand in concrete. The compressive strength may be compared to a control mix made with natural sand after 28 days. According to ASTM Standard, the chemical makeup of regular glass and coloured glass powders is relatively comparable, making the goods pozzolanic. 15% is the suggested glass concentration after which the strength starts to deteriorate. After 4 weeks, it was discovered that the concrete specimen's compressive strength was marginally (2%) greater than the control concrete specimen's. If the replacement material performs comparably to the original, glass addition can save cement manufacturing costs by up to 20%. The usage of glass powder concrete significantly reduces greenhouse gas emissions and particle formation, saving an extra tonne of CO_2 for every 6T of cement produced.

Melinamani et al. (2020) carried investigation out on the exploitation of glass powder in building would lessen the environmental effect as well as the problem of land disposal. The compressive strength of concrete (partial replacement by glass powder) M25 grade for 28 days is 17 N/mm2, Concrete (sand) has a compressive strength of 18 N/mm2. Concrete costs 20% less when glass powder replaces natural sand (Sand-cement).

Reddy (2016) Reddy (2016) examined the usage of waste glass as a partial substitute for fine aggregates in concrete to address environmental and financial concerns. The M20 grade mix contained waste glass powder (WGP) at proportions of 10%, 20%, and 30% by mass in place of fine aggregates. At 7 and 28 days of age, the compressive strength of the concrete test samples was measured and compared to that of normal concrete.

Waste glass has some pozzolanic properties when mashed to a very fine powder due to its high SiO_2 concentration, and thus partially substitutes cement and aids in strength development.

The results showed that waste glass powder can replace 30% of fine aggregates for particle sizes 0 to

1.18mm. Glass is utilized in a wide range of products, including vacuum pipes, jars, glassware, flasks, and transparent materials. Glass is a great recyclable material.
Utilizing recovered glass promotes energy efficiency. Research into the utilization of discarded glass in various forms has been stimulated by the rising understanding of the value of recycling and reusing glass. Its contribution to the building sector, where waste glass was recycled to produce concrete, was one of its most notable achievements. Concrete used in architectural glass still has to be improved. The study discovered that waste glass may replace fine aggregate up to 20% of the time without losing strength.

Premalatha and Srinivasan (2019) replaced river sand with glass trash in landfills. Reuse in the building sector has to be studied since it pollutes the environment. At 7, 14, and 28 days after curing, the following parameters were measured: slump, weight, compressive strength, split tensile strength, flexural strength, elastic modulus, ultrasonic testing velocity, maximum dry density, and chloride penetration test. On uncured and cured concrete, glass powder at 0%, 5%, 10%, 15%, and 20% was evaluated. Conventional experiments evaluated the mechanical strength, stress-strain behavior, and durability of concrete using waste glass powder in place of some of the natural sand. The waste glass powder content was ideal in concrete specimens M20, M30, M40, M50, and M60. Utilizing slump cones, new concrete mixtures were evaluated for workability. According to experiments, the value of fresh concrete's slump increases steadily with the replacement of glass powder by up to 40%.
Compressive, flexural, and split tensile strengths were improved up to 30 by using waste glass powder. The concrete strength is the same for the control mix, 40% and 50% replacements. Glass powder increases concrete density and elastic modulus from 0% to 50%. According to the Rapid Chloride Penetration Test (RCPT), glass powder enhances concrete permeability by up to 50% replacement levels while reducing chloride penetration. In order to replace fine aggregates while keeping strength, durability, and positive effects on the environment and the economy, a glass powder proportion of 50% is ideal.

Vatkar et al. (2021) addressed environmental and monetary issues by substituting crushed waste glass powder at 0%, 20%, 25%, 30%, and 40% by weight for fine aggregates in M-25 concrete mix. An experiment was conducted to measure a concrete cube's compressive strength after 1, 2, and 4 weeks. The best partial substitute for fine aggregates up to 25% by weight for 1, 2, and 4 weeks was crushed waste glass powder, which had compressive strengths of 20 N/mm2, 29 N/mm2, and 34 N/mm2.
Kittur et al. (2019) conducted experiment using waste glass powder to be used to replace fine aggregates in the M-20 mix in amounts of 0%, 5%, 10%, 15%, 20%, and 25% by weight. The specimens' density, water absorption capacity, durability (water absorption), and compressive strength were assessed after 28 days in comparison to regular concrete. It was discovered that waste glass powder may replace fine aggregate by 15%.

Muzafar et al. (2013) conducted a trial for the M-25 mix, waste glass powder was used in place of fine aggregates in weight ratios of 10%, 20%, 30%, and 40%. After 4 weeks, the concrete samples underwent testing to compare them to ordinary concrete in terms of compressive strength, density, split tensile strength, and durability.
Logeshwaran (2018)- IS 10262-2009 and IS 456-2000 were used to create the M30 grade mix. The compressive strength of coarse aggregate was evaluated after it was replaced with steel slag at a rate of 15%, 30%, 45 percent, and 60%. The term "durability" in reference to concrete refers to the material's capacity to withstand deteriorating processes such as weathering, chemical attack, abrasion, or any other such process. When exposed to the elements, concrete that is durable will keep its original shape, as well as its quality and its ability to be used. As part of our durability testing, we will measure the water absorption, sulphate attack, and sorptivity of the material.

Chinnaraju et al. (2013) researched on concrete as steel slag and ecosand were substituted for fine and coarse aggregates, respectively, in the investigation on concrete. In this study, a steel industry by-product called steel slag is being used to substitute coarse aggregate in concrete. In addition, an effort is made to replace fine aggregate with eco sand, which is a commercial by-product of the cement production process that was launched by ACC Cements.

First, a 7-day strength was used to optimum the materials. The grade M30 of concrete was used. The best possible replacement of slag material was discovered to be 60% and the probable ideal substitute for eco sand was discovered to be 40%.
The specimens' split tensile strength, compressive strength, flexural strength, and moisture content were assessed at 1 and 4 weeks. In place of coarse aggregate, steel slag enhanced strength. Using steel slag and ecosand in place of around 60% of the fine aggregate had no adverse effects on the concrete's strength, according to the data.

Mani et al. (2016) utilized steel slag in place of coarse particles to conduct research on concrete qualities such as compressive strength. Steel slag, a byproduct of the steel industry that pollutes when dumped, was used to replace 60%, 70%, and 80% of the coarse particles in M20 grade concrete with a water/cement ratio of 0.45. The results show that steel slag may be used as coarse aggregate in all concrete applications and boosts concrete's compressive strength by 7 to 8% compared to control mixtures. The findings demonstrate that concrete with steel slag as a coarse aggregate has higher density and stability in specimens with steel slag as a coarse aggregate, as well as higher compressive strength. It has been determined that a 70% substitution for steel slag works best.

Abhijit and Nigade (2015) – This study replaced coarse aggregate with steel slag at 0%, 25%, 50%, 75%, and 100% for M30 concrete with a water cement ratio of 0.48. After 1, 2, and 4 weeks, compressive strength is tested. Split and flexural strength are measured over four weeks. 75% steel slag replaces coarse aggregate for maximum strength.

Thangaselvi (2015) examined the feasibility of replacing traditional coarse aggregate in building with steel slag. When replacing coarse aggregate in concrete of the M-40 grade with a water to cement ratio of 0.40, steel slag was used at percentages of 0%, 20%, and 80%. After four weeks, we measure the specimens' compressive, split tensile, and flexural strengths. For maximum strength, steel slag can be used in place of up to 60% of the coarse aggregate.
Sathwik et al (2016) - In this study, ferrochrome slag is replaced with conventional coarse aggregate at 25% increments up to 100% replacement in high strength (M50 Grade) concrete. The Slump cone test, VB consistometer test, and C/F test are the three most used methods for determining how well concrete has held up since it was initially poured. After 1, 2, and 4 weeks, concrete's hardened properties are assessed by casting cubes to measure its compressive strength, split tensile strength, and flexural strength. The results are compared to those of traditional coarse aggregate-made concrete.

Adedokun et al. (2018) - This study summarises the literature on replacing natural coarse aggregate with steel slag in construction projects. Steel slag's physical and chemical properties, as well as its advantages and disadvantages when used in concrete, are studied. Steel slag has been argued to be cost-effective because it can replace conventional aggregates for about the same price. It is determined that a percentage of coarse aggregate substitution with steel slag between 30 and 60 percent yields concrete with superior mechanical characteristics compared to conventional concrete.

Behrera & Behera (2016) - The calculation and comparison of self-compacting concrete with varied amounts of blast furnace slag aggregates are the main objectives of this work. The material was put through a workability tests, including a Slump flow test, a V funnel test, an LBox test, a V funnel test for 5 minutes, a Slump flow test for 50 centimetres, a compression test, and a splitting tensile test.
There have been six batches of concrete mixtures, each with a 0% to 60% in order of 10% increase in slag aggregate replacement for a given mix proportion. The project is divided into two stages to achieve the objectives. During Phase-I, actual samples of a specified quality were cast and evaluated. Phase II involves a comparison of test results to possible coding interpretations.
The results of trials to evaluate the fresh and hardened properties parameters of self-compacting concrete mixes are summarised below. All self-compacting concrete mixtures with close to 60% slag substitution for coarse aggregate performed well when they were still new.
Piraimathi (2017) - In this study, 20%, 30%, 40%, and 50% steel slag was used to partially substitute fine aggregate. Compressive strength, E for concrete, flexural strength, quick chloride penetration, and sorptivity were tested. The results of trials to evaluate the fresh and hardened properties parameters of

self-compacting concrete mixes are summarised below. All self-compacting concrete mixtures with close to 60% slag substitution for coarse aggregate performed well when they were still new. The results suggest that substituting steel slag for coarse aggregate improves strength properties, elastic modulus, and flexural in traditional

concrete. When compared to the control mix, the compressive for 10% substitution was 11% higher, 20% substitutions were 12% higher, 30% substitution was 12.2% higher, and 40% substitution was 9% higher. Because 30% steel slag provides the most strength among these various replacements, 30% replacement was ideal for compressive strength.

Bhat (2018) - The use of industrial waste materials has been consistently stressed in the study effort. In the current project, steel slag is being used to partially replace coarse material. The current study focuses on M35 concrete that has steel slag utilized in place of some of the coarse aggregate. This experiment determined compressive strengths of 1 and 4 weeks based on the material properties studied. The results were compared to standard concrete properties.
According to the study, adding steel slag from 0 to 45% increases concrete strength. After 45% replacement, concrete strength decreases slightly but not significantly.
Dattatreya et al. (2015) - This paper describes an experimental study that was conducted to examine the impact of substituting standard coarse aggregate with steel slag on the characteristics of concrete. Concrete is utilised more than almost any other material on the planet, thus its usage is necessary; nonetheless, aggregate shortage is on the rise. In the construction industry, they have been used successfully for partial and total concrete replacement.
Concrete grades M-20, M-30, M-40, and M-50 having different water/cement ratios were explored for coarse aggregate substitution of 30%, 60%, and 100% by steel slag. According to the results of this study, compressive strength improves by 5 to 10% across all concrete classes. Steel slag may be utilized to substitute close to 60% of the aggregate in all concrete grades. Complete replacement with steel slag weakens strength greatly.

Padmapriya (2019) - The global steel industry produces 780 Mt of crude steel and 400 Kg of solid byproducts per tonne. Steel slag and M-Sand will partially replace coarse and fine aggregate in this study. Using 150mm3 cubes and replacement rates of 20, 40, 60, and 80% of coarse aggregate, a compressive strength test lasting four weeks is conducted to identify the ideal steel slag replacement percentage. The highest strength and performance are obtained when river sand and coarse aggregate are substituted by 25% M sand and 40% steel slag, respectively.
Saravanan and N.Suganya (2016) - The purpose of this study is to compare steel slag aggregate concrete to ordinary natural aggregate concrete. Because of rising demand for construction materials and an increase in the number of abandoned waste goods, suppliers and researchers are looking into alternative materials that may protect natural resources and the environment. Traditional concrete used steel slag as aggregate. Steel oxidation produces calcium carbonate slag. Steel slag was chosen because it has similar properties to natural aggregate and is readily available as a manufacturing byproduct.

Babu and Nandini (2016) addressed the issue arise from continuous use of coarse and fine particles in concrete, including a lack of high-quality aggregates. Eco-sand and steel sag were used in place of aggregates to alleviate this problem. The project's main goal is to strengthen concrete using steel slag as the coarse aggregate and eco sand as the fine aggregate (30% replacement). According to the literature, steel slag is changed from 0 to 90% in 15% increments, resulting in 7 mixes (M1, M2, M3, M4, M5, M6).
Following several studies, we may conclude that M1, M2, M3, M4 mixtures are stronger than conventional mixes. In all tests, the M3, M4 mixtures with 30 and 45 percent slag demonstrated good strength. Because the strength revealed is rather low when compared to a standard mix, it is obvious that 50% or more is not feasible.

Rajendran (2018) partly replaced the natural fine aggregate with crumb rubber in varying ratios of 5%, 10%, and 15%. To find the optimal way to use steel slag in concrete, the natural coarse aggregate was partially replaced with steel slag aggregate in various ratios of 10%, 20%, 30%, and 40%. A grade M30 concrete's compressive strength was assessed. The results were compared to standard concrete. The compressive strength of typical concrete was found to be 22 N/mm2 after two weeks. The greatest compressive strength was 23 N/mm2 after two weeks of replacing 30% of the coarse aggregate with steel slag. Based on different aspects of concrete literature review was carried based on available literature in library.

In summary, the literature review highlights the potential of waste materials, including supplementary cementitious materials, recycled aggregates, industrial by-products, and waste plastic fibers, in improving the performance and sustainability of high-strength concrete. Understanding the effects of these waste materials on concrete properties is essential for their effective incorporation and optimization in concrete mix designs. The subsequent chapters will delve into experimental investigations to further explore the utilization of waste materials in high-strength concrete and assess their impact on mechanical properties, durability, and sustainability.

A number of writers looked at the compressive strength of concrete mixes that comprised steel slag as the coarse material and waste glass powder as the fine aggregate. Concrete strength dramatically rises with various replacement levels. According to the WHO, humans consume concrete third after food and water. Constructing infrastructure requires concrete. Aggregate makes almost 75 percent of concrete. Stones and riverbanks would deteriorate as a result. Due to aggregate requirements and environmental concerns, other sources are required. To substitute coarse and fine aggregate, steel slag was used. As a result, discarded glass powder and steel slag might take the place of coarse and fine aggregate. It was observed that less work has been carried out on the following topics as per best of the knowledge of the authors.

- After reviewing several study papers, it was discovered that each concrete mix requires a distinct replacement.
- Steel slag and waste glass powder have been used to replace both coarse and fine aggregate in a single concrete mix with less effort.
- Large-scale experiments are required to investigate the compressive strength of concrete mixes that have both coarse and fine aggregates replaced at the same time while keeping any of its ideal constants during replacements.

3. EXPERIMENTAL METHODOLOGY

Several materials, including OPC43 grade cement, sand, aggregate, and steel slag, are put through a series of essential tests to determine their suitability for use in the production of concrete. The proportions of the concrete mix are altered to allow for the use of waste glass powder as a separate replacement for fine aggregate and steel slag as a partial replacement for coarse aggregate. In order to create the cubes, the coarse aggregate was gradually replaced by 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80% steel slag. As
opposed to replacing fine aggregates with 0%, 5%, 10%, 20%, 25%, 30%, 40%, and 50%.

The mix ratios are followed while pouring the specimens. Testing is done after a sufficient cure. Compressive strength of 150mmx150mmx150mm cubes is tested and compared to that of regular concrete.

Change the replacement of the coarse aggregate by 10% to 80% while maintaining the replacement of the fine aggregate after determining the optimal replacement for both types. The casting of the cubes would be followed by curing and testing.

One of the first materials made by mankind was glass. In order to prevent landfill stockpiling or burial, it is produced into packing or vessel glass, containers, and light bulb glass, all of which have a short lifespan and should be recycled. The recycling of rubbish and industrial waste, notably used glass, has advanced significantly in the building sector.

It is made into packing or vessel glass, containers, and light bulb glass, all of which have a short lifespan and should be recycled to avoid landfill stockpiling or burial.

The process of turning this waste into aggregate components through recycling has the potential to lower the demand for the extraction of natural raw materials for use in construction activities, which in turn will save space in landfills.

In general, utilizing high-quality cement provides a number of advantages when it comes to producing strong concrete. While they are slightly more costly than low grade cement, they save 10 to 20% on cement consumption and give a number of other unnoticed benefits. The higher rate of strength gain is one of the most significant advantages.

3.1 CEMENT TEST RESULTS

Cement Used: ACC OPC 43 Grade.

S.NO.	Test Conducted on cement	Result	IS 8112 Requirement
1	Nmr Consistency	34.1%	-
2	SG	3.16	-
3	ST(Initial)	35M	>30M
4	ST(Final)	32 M	>600M

a. Fine Aggregate (FA)

Material that may pass through a 4.75 mm mesh screen is referred to as fine aggregate. It is made from readily available river sand that is free of organic pollutants. In this study, sand that has been filtered through a 4.75 mm filter and kept on a 150 micron IS sieve is employed. The sample must be given time to air dry before it can be weighed or graded. This goal can be accomplished by either heating to a temperature of between 100 and 110 degrees Celsius or by drying at room temperature. The air-dry sample must be weighed before being sieved through a series of progressively smaller sieves, starting with the largest sieve. Before using the sieves, make sure they are clean. Table 5.1 displays the results of a simple laboratory test on fine aggregate, and the findings are consistent with IS guidelines. These findings will need while development of a concrete mix design.

3.2 COARSE AGGREGATE (CA)

Concrete's main ingredient is aggregate. In addition to giving the concrete a body, they also reduce shrinkage and have an impact on the economy. Choosing the right gradation of coarse aggregate is one of the most important steps in producing workable concrete. The coarse material in this experiment was crushed gravel that had been passed through a 20mm IS filter. Utilised were aggregates that met IS-383-1970 standards. While crushed aggregate enhances strength owing to angular particle interlocking, spherical aggregate improves flow due to lower internal friction. Avoid using long aggregates.

3.3 WASTE GLASS POWDER

Glass scraps gathered from merchants in Gurugram are used to make glass powder. Glass scraps are a hardy substance. Before being added to concrete, glass powder needs to be finely ground. In this investigation, glass powder crushed in a ball for 30 to 60 minutes resulted in particle sizes less than 4.75mm.

3.4 STEEL SLAG

The basic oxygen furnace slag from Jindal Steel Works Pvt. Ltd. is required for this formula. Bellary District, Karnataka, India, Sandur Village, Ltd. Blast furnaces employ coke and fluxes (limestone and/or dolomite) as fuel to create iron and steel. Burning coke to create molten iron releases carbon monoxide into the air. Slag is produced by molten steel separation and impurities are removed by fluxing agents. Despite the fact that practically all steel slags are air-cooled, modern slag producing equipment often struggles to provide rapid cooling, which might compromise slag quality. Due to this, it isn't always suitable for use in the future, which is why quality control in the production of steel slag is necessary (Cerjan et al. 1995; National Slag Association 1982). Due to their great density, steel slags are utilised as protective armour stones for rivers, sea and coastal erosion schemes, and land reclamation projects, but some are still discharged (National Slag Association 1982). Aggregate made of steel slag expands and performs badly.

4. RESULTS AND DISCUSSION

The experimental examination undertaken to assess the advancement and optimisation of waste materials in high-strength concrete is presented in this chapter along with a discussion of the findings. An overview of the experimental plan opens the chapter, which is then followed by a thorough presentation and interpretation of the data. The significance of the findings on the effectiveness and sustainability of waste-based high-strength concrete are investigated and addressed in relation to the study goals.

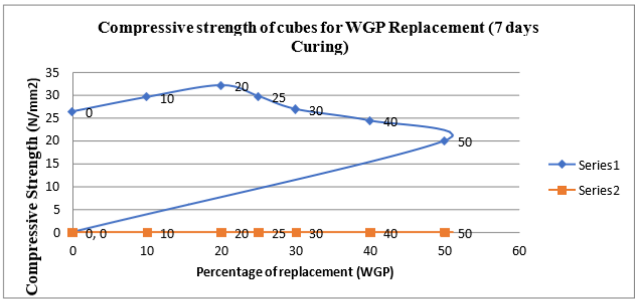

Figure 4.1 a. Seven days compressive strength for Waste glass powder

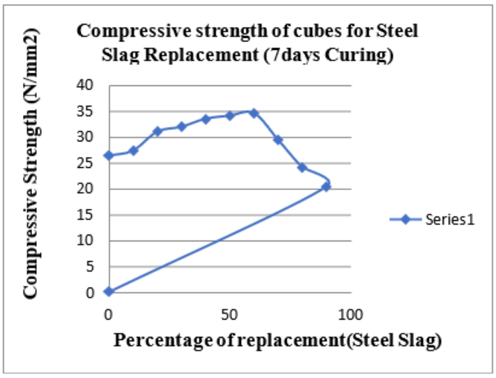

Figure 4.1b Seven days compressive strength for Steel slag replacement

The effect of employing waste glass powder in place of fine particles on the compressive strength and other properties of hardened concrete is depicted in Figure 4.1a. It has been shown that the compressive strength of seven-day cubes rises initially up to a replacement percentage of 20% glass powder, but that when the replacement percentage is increased after that point, the compressive strength decreases. We discovered as a result that 20% is the recommended replacement percentage for glass waste powder with fine particles in concrete mix.

The compressive strength of cubes in this experiment that contained 20% waste glass as fine particles clearly demonstrates the increase in strength compared to standard concrete cubes. The strength of the concrete steadily declines as the amount of glass in it rises.

Figure 4.1b above shows different replacement levels for coarse aggregate replacement with steel slag, including 0% (Convential Concrete), 10%, 20%, 30%, 40%, 50%, 60%, 70%, and up to 90%. The results of the compressive strength test on seven-day cubes show that concrete's strength initially rises by up to 60% replacement before declining. Based on the findings, 60% of the coarse particles in the concrete mix should be replaced with steel slag.

The second time coarse aggregate is replaced with steel slag, the strength increases up until a certain point before progressively declining.

Therefore, we discovered that 60% is the ideal replacement rate for steel slag in concrete mix.

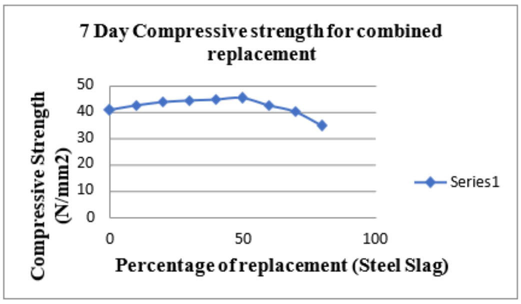

Figure 4.2: Seven days compressive strength for combined replacement

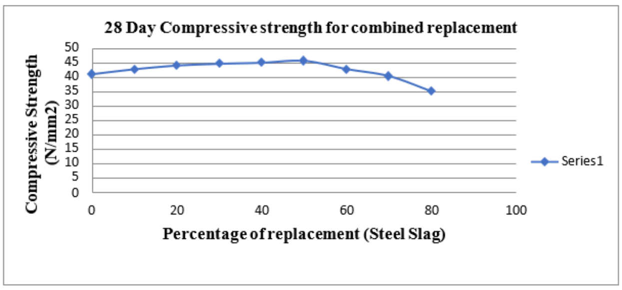

Figure 4.3: 28 days compressive strength for combined replacement

Best proportion for replacing steel slag in concrete at 7 and 28 days of compressive strength is 50%, with 20% of that percentage being replaced by glass powder, as shown in Graphs 4.3 and 4.4 above.

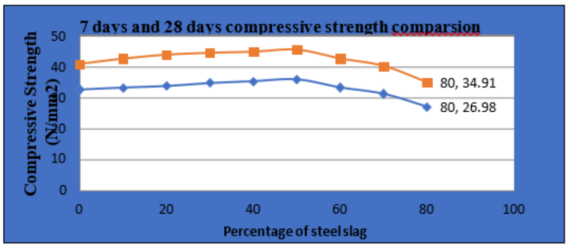

Figure 4.4 Comparison graph between 7days and 28 days compressive strength

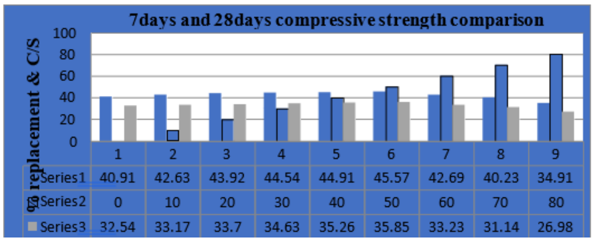

Figure 4.5 Comparison graph between 7days and 28 days compressive strength

After seven days of testing, 60% of steel slag as coarse aggregate is the best replacement. The compressive strength increased by 31.18 percent above the standard mix. The test was also conducted with combined replacement, with steel slag being substituted for the coarse aggregate in increments of 0%, 20%, and eventually 80% while maintaining the fine aggregate replacement at 20%. The test findings also show that 50% replacement of mixed materials while keeping 20% waste glass powder and 50% replacement of coarse aggregate are the optimal percentages.

5. CONCLUSIONS

The research on the advancement and optimization of waste materials in high-strength concrete has demonstrated the potential of waste-based concrete in enhancing mechanical properties, durability performance, workability, and sustainability aspects. The findings contribute to sustainable construction practices by reducing waste generation, utilizing waste materials, and minimizing environmental impacts. The recommendations provided will guide future research and assist practitioners in effectively implementing waste-based high-strength concrete in construction projects, promoting a more sustainable built environment.

The inferences that may result from the research findings are listed below in brief.

6. After 7 days, concrete mixtures containing 10%, 20%, 30%, 40%, and 50% waste glass powder have compressive strengths that are 21.82 percent higher than standard concrete mixtures.
7. Concrete that contains 30%, 40%, and 50% waste glass powder loses some of its compressive strength. A seven-day GP cure is applied to concrete.
8. After 7 days of curing, the compressive strength of concrete mixtures containing 10%, 20%, 30%, and so on up to 80% steel slag is 31% higher than that of regular concrete mixtures.
9. Concrete mixes having more than 60% coarse steel slag have a lower compressive strength. Using variable steel slag as a partial substitute for coarse aggregates, a combined replacement for steel slag that is best at 50%, and waste glass powder remaining constant at 20%.
10. As the amount of glass powder in concrete rises, its density decreases.
11. Concrete made from recyclable waste glass lowers construction expenses.
12. This material can reduce the maximum amount of sand mining and the environmental effects of garbage.

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