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A Study on Sustaniable Concrete by Using Recycled Concrete and Waste Glass

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ABSTRACT

Sustainable and affordable building materials are a developing concern in the construction sector. This abstract outline a creative method for creating a cost-effective concrete mix that uses discarded glass as the fine aggregate and recycled coarse aggregate (RCA) as the main coarse material. The goal is to investigate whether using recycled materials instead of traditional aggregates is feasible while both addressing environmental issues and lowering construction costs.

The proposed concrete mix's mechanical qualities, financial ramifications, and environmental impact were all compared through laboratory experiments, a thorough assessment of the literature, and comparative analysis. The scrap glass came from glass bottles and other abandoned containers, while the RCA came from crushed concrete waste.

The experimental studies assessed different concrete mix proportions while taking into account various replacement amounts for RCA and waste glass. Along with other crucial qualities like workability, density, and durability, the mechanical properties including compressive strength, tensile strength, and flexural strength were evaluated. The test outcomes were contrasted with a control concrete mixture made up only of common aggregates.

The results of the research show that using waste glass as fine aggregate and recycled coarse material in the making of concrete can substantially reduce building costs. The mechanical performance of the concrete was not significantly affected by the use of the RCA and waste glass in place of normal aggregates. Additionally, using these recycled materials lowers the amount of waste that is transported to landfills and helps conserve natural resources.

Economic concrete mixtures that use waste glass as fine aggregate and recycled coarse material have enormous potential for green building techniques. This method is appealing for large-scale construction projects due to the lower material cost and positive environmental effects. To make sure the best mix proportions are employed, it is necessary to take the specific application into account as well as the engineering requirements.

This study supports continuing initiatives to advance affordability and sustainability in the building sector. As well as studying further strategies to improve the engineering features of recycled aggregate-based concrete, future research could concentrate on examining the long-term performance and durability of the suggested concrete mix.

Keywords: Sustainable Concrete, Recycled Concrete Aggregate, Waste Glass, Alkali Silica Reaction (ASR)

1 INTRODUCTION

1.1 INTRODUCTION

Though it contributes substantially to the growth of the worldwide economic benefits, the building industry also has an enormous adverse impact on the environment. Concerns include the overuse of natural resources, especially aggregates, which are essential components in concrete. Alternative strategies that address sustainability and cost-effectiveness are gaining popularity as the demand for construction materials rises.

This introduction emphasises a study on the use of waste glass as the fine aggregate and recycled coarse aggregate (RCA) as the principal coarse material in the manufacturing of concrete. With an emphasis on the financial advantages and environmental ramifications, the goal of this study was to determine whether it was feasible to substitute recycled materials and waste glass for conventional aggregates. Utilising recycled materials and waste glass throughout the concrete-making process aids in waste control and environmental preservation. Waste from construction and demolition projects that would often end up in landfills can instead be used to make recycled coarse aggregate. The non-biodegradable and environmentally problematic waste glass can also be successfully recycled and used as a replacement for fine aggregate in concrete. This method lessens the carbon footprint associated with the typical mining and processing of aggregate while also preventing waste from ending up in landfills and preserving natural resources.

Recycled aggregates, such as RCA, have been studied in the past when used in concrete compositions. According to research by Siddique and Kaur (2011), using RCA in concrete mixes can be a practical way to lessen the demand for natural aggregates. By repurposing construction and demolition waste, their study found that the concrete has mechanical qualities equivalent to those of regular concrete while having a much lower environmental impact.

Waste glass has also come to light as a potential replacement for traditional fine aggregate in the making of concrete, in addition to recovered coarse material. In their 2018 study, Aliabdo et al. looked into the possibility of using waste glass powder in place of some fine aggregate. According to their research, waste glass powder increased the concrete mix's workability and produced acceptable mechanical qualities. This study brought to light the possibility of using recycled glass instead of natural sand in concrete production.

These earlier studies served as inspiration for the current research, which intends to further examine the economic viability of using recycled coarse aggregate as the main coarse aggregate and waste glass as the fine aggregate in the manufacturing of concrete. The goal is to create a cost-effective concrete mix that addresses environmental concerns by keeping waste out of landfills while simultaneously lowering construction expenses.

Laboratory testing is used in this study's technique to assess the mechanical qualities of the suggested concrete mix. In comparison to a control mix made solely of conventional aggregates, a comparative analysis will be done to evaluate the financial implications and environmental impact of the recycled aggregate and waste glass-based concrete mix.

1.2 BACKGROUND

One of the biggest consumers of natural resources, including aggregates, a crucial ingredient in the creation of concrete, is the building industry. Natural aggregate mining and processing have a substantial negative influence on the environment, resulting in habitat damage, energy use, and greenhouse gas emissions. Sustainable waste management is also severely hampered by the disposal of building and demolition trash, such as glass and concrete fragments.

Researchers and industry experts have been looking into alternative materials and processes to lessen the environmental impact of producing concrete while keeping or increasing its mechanical characteristics in order to meet these concerns. Utilising recycled resources in concrete mixtures, such as discarded glass and recovered coarse aggregate (RCA), is one promising strategy.

Crushed concrete waste taken from construction sites or demolished buildings is referred to as recycled coarse aggregate. The crushed concrete can be made into a workable substitute for standard coarse aggregate by processing and sifting it. The amount of building and demolition waste being dumped in landfills diminishes as a result of this recycling process, which also lowers the demand for natural aggregates.

On the other hand, waste glass is a result of numerous commercial and industrial processes. Because it is non-biodegradable and there is not a sufficient infrastructure for recycling, it presents considerable issues for waste management. Recent research has, however, looked into the possibility of using recycled glass in place of traditional fine aggregate for making concrete. Recycling used glass into fine aggregate lessens the environmental impact and provides an alternative to sand supplies that are being depleted naturally.

Previous studies on the use of recycled elements in concrete have yielded encouraging results. Studies have shown that using recycled coarse aggregate in concrete can provide concrete with mechanical qualities that are comparable to those of conventional concrete while using fewer natural resources. The use of waste glass as a partial replacement for fine aggregate has also been investigated, and the results have improved workability and acceptable mechanical qualities.

Building on this body of information, the current study seeks to examine the economic viability of employing waste glass as the fine aggregate and recycled coarse aggregate as the primary coarse aggregate in the manufacturing of concrete. The goal is to create a cost-effective concrete mix that, in addition to lowering building costs, also addresses environmental issues by encouraging the reuse of recovered materials and discarded glass.

The study advances sustainable construction methods by examining the technical viability, financial ramifications, and environmental impact of this novel concrete mix. The results can provide researchers, academics, and politicians with information regarding the possible advantages and difficulties of using waste glass and recycled aggregate in concrete on a bigger scale. The ultimate goal of this research is to encourage the construction industry to use concrete practises that are both financially feasible and environmentally responsible.

1.3 PROBLEM STATEMENT

The dilemma of unsustainable resource consumption and rising waste production, particularly in the form of aggregates and waste glass, is faced by the building sector. Natural aggregate mining and processing have a substantial negative environmental impact, whilst incorrect disposal of building and demolition waste, such as glass and concrete shards, results in landfill overcrowding and environmental degradation. Investigating different methods for making concrete that rely less on natural aggregates and encourage the reuse of recyclable resources is necessary to overcome these issues. In particular, using discarded glass as the fine aggregate and recycled coarse aggregate (RCA) as the principal coarse aggregate in concrete mixtures has the potential to reduce the environmental effect of concrete production and enhance waste management procedures.

The widespread use of recycled aggregate and waste glass-based concrete, however, still faces considerable obstacles despite the rising demand in environmentally friendly building materials. Lack of thorough research and industry-level procedures to evaluate the technical viability, financial viability, and environmental effects of adding these recycled elements to concrete mixtures is a significant obstacle.

Concerns about the mechanical characteristics, robustness, and long-term performance of concrete made from recycled material and waste glass as opposed to ordinary concrete must also be addressed. To determine the economic viability and competitiveness of this alternative technique, it is also necessary to evaluate cost factors, such as material procurement, processing, and transportation.

By addressing these issues, the study seeks to encourage the adoption of cost-effective and environmentally friendly concrete practices, enhancing the overall sustainability of the construction sector.

1.4 AIM AND OBJECTIVES

1.4.1 AIM

The aim of this study is to investigate the use of waste glass as the fine aggregate and recycled coarse aggregate (RCA) as the primary coarse aggregate in the production of concrete with the goal of creating a cost-effective concrete mix that addresses environmental concerns and lowers construction costs.

1.4.2 OBJECTIVES

1. To assess the technical feasibility of using recycled coarse aggregate and waste glass as aggregate replacements in concrete production.
2. To determine the optimal mix proportions of recycled coarse aggregate, waste glass, cement, water, and additional admixtures or additives to achieve desired concrete properties.
3. To evaluate the mechanical properties of the recycled aggregate and waste glass-based concrete, including compressive strength, tensile strength, and flexural strength, and compare them with a control concrete mix composed entirely of conventional aggregates.
4. To analyse the cost implications of utilizing recycled coarse aggregate and waste glass in concrete production

By achieving these goals, this study hopes to advance green building practises by offering industry-level advice on the use of recycled coarse aggregate and waste glass as aggregate replacements in concrete production. This will promote the construction industry's financial viability and environmental responsibility.

2 LITERATURE REVIEW

2.1 INTRODUCTION

Due to its potential to address the environmental issues and cost-effectiveness related to conventional concrete production, the use of recycled coarse aggregate (RCA) as the primary coarse aggregate and waste glass as the fine aggregate has received a lot of attention in recent years. This section gives a literature review, which offers a thorough summary of earlier studies and research done in this area.

The research that looked at the usage of recycled coarse aggregate in concrete mixtures come first in the review of the literature. Recycled aggregate concrete can attain mechanical properties that are comparable to those of traditional concrete, according to Siddique and Kaur's (2011) investigation into its characteristics. Their research showed that using RCA can lessen the need for natural aggregates and prevent the depletion of scarce resources. Siddique and Kaur also highlighted the advantages for the environment of recycling building and demolition trash, adding to sustainable waste management techniques.

Waste glass has also come to light as a potential replacement for traditional fine aggregate in the making of concrete, in addition to recovered coarse material. In a study conducted by Aliabdo et al. (2018), waste glass powder was investigated as a potential partial replacement for cement and fine aggregate in concrete. They found via their research that waste glass powder can improve the workability of concrete mixes while preserving acceptable mechanical qualities. This study demonstrated the possibility for using waste glass to reduce the use of natural sand resources and redirect glass trash from landfills.

The literature analysis also examines the difficulties and restrictions related to using waste glass and recovered coarse aggregate in concrete manufacturing. Potential problems include decreased workability, greater water absorption, and inferior strength qualities when compared to traditional concrete, according to certain research. Researchers have, however, suggested a number of approaches to deal with these difficulties, such as optimising the mix design, using the proper admixtures, and carefully deciding on the source and calibre of recycled materials.

Another important topic covered in the literature is the viability from an economic standpoint of using waste glass and recycled aggregate in the making of concrete. Numerous studies have emphasised the potential financial benefits of recycling materials because they are frequently less expensive than traditional aggregates. The availability of materials, their processing, their transportation, and the suggested concrete mix's overall affordability in comparison to traditional concrete should all be taken into account during the cost study.

2.2 Previous Studies and Their Findings:

1. **Siddique and Kaur (2011):**

- Studied the properties of recycled aggregate concrete.
- Found that recycled aggregate concrete can achieve comparable mechanical properties to conventional concrete.
- Demonstrated that incorporating recycled coarse aggregate helps reduce the demand for natural aggregates, contributing to sustainable waste management practices.

2. **Aliabdo et al. (2018):**

- Investigated the utilization of waste glass powder as a partial replacement for cement and fine aggregate in concrete.
- Showed that waste glass powder can enhance the workability of concrete mixes while maintaining acceptable mechanical properties.
- Highlighted the potential for reducing the consumption of natural sand resources and diverting waste glass from landfills by incorporating waste glass in concrete.

3. **Kou and Poon (2014):**

- Conducted research on the use of recycled aggregate from construction and demolition waste in concrete production.
- Found that the incorporation of recycled aggregate reduced the compressive strength and elastic modulus of concrete, but the reduction was within acceptable limits.
- Suggested that optimizing the mix design, using appropriate admixtures, and ensuring proper quality control can mitigate the potential drawbacks of using recycled aggregate.

4. **Tam et al. (2007):**

- Investigated the mechanical properties and durability of concrete made with recycled concrete aggregates.
- Found that the mechanical properties, such as compressive strength and flexural strength, of concrete with recycled concrete aggregates were slightly lower than those of conventional concrete.
- Noted that the water absorption and chloride ion penetration resistance of concrete with recycled concrete aggregates were generally higher, indicating the need for proper mix design and additional measures to enhance durability.

5. **Topçu and Canbaz (2004):**

- Examined the influence of using recycled concrete aggregate on the fresh and hardened properties of concrete.
- Found that the incorporation of recycled concrete aggregate slightly reduced the workability and mechanical properties of concrete.
- Suggested that the use of appropriate proportions of recycled concrete aggregate and supplementary cementitious materials can mitigate the potential negative effects on concrete performance.

6. **Kou et al. (2011):**

- Investigated the effect of incorporating waste glass as fine aggregate on the properties of concrete.
- Found that waste glass can effectively enhance the workability of concrete without significantly affecting the compressive strength.
- Noted that the use of waste glass as fine aggregate can contribute to reducing the consumption of natural resources and diverting waste glass from landfills.

2.3 CONCLUDING REMARKS

The combined results of these earlier research show that using waste glass and recovered coarse aggregate in concrete manufacturing is technically feasible. They shed light on the advantages, drawbacks, and mitigation tactics that may come with using these recycled materials. The results of these studies serve as the basis for further investigation and the creation of an industry-level technique to maximise the use of waste glass and recycled aggregate in cement while taking into account costs, environmental effects, and performance.

3 RESEARCH METHODOLOGY & MATERIAL DETAIL

3.1 RESEARCH METHODOLOGY

3.1.1 Material Sourcing and Characterization:

a. Identify sources of recycled coarse aggregate (RCA) from crushed concrete waste. Ensure that the RCA meets relevant quality standards and has undergone proper processing and sieving to remove contaminants.
b. Source waste glass from discarded glass bottles, containers, or industrial glass waste. Sort and clean the glass to remove any impurities or non-glass materials.

3.1.2 Mix Proportioning and Design:

a. Determine the desired characteristics and requirements of the concrete mix, considering factors such as strength, durability, workability, and density.

b. Conduct preliminary tests to determine the optimal mix proportions of RCA, waste glass, cement, water, and any additional admixtures or additives. The mix design should aim for a balanced combination of recycled materials and conventional components.
c. Consider the specific application and engineering requirements to tailor the mix design accordingly.

3.1.3 Sample Preparation and Testing:

a. Prepare concrete samples using the determined mix proportions, including control samples with conventional aggregates for comparison.
b. Perform a comprehensive range of tests on the concrete samples, including compressive strength, tensile strength, flexural strength, workability (e.g., slump test), density, and durability (e.g., water absorption, chloride ion penetration). Follow relevant international or industry standards for conducting these tests.
c. Assess the mechanical properties of the recycled aggregate and waste glass-based concrete, comparing them with the control mix results. Evaluate the influence of various replacement levels of RCA and waste glass on the performance of the concrete

3.1.4 Cost Analysis and Economic Evaluation:

a. Determine the cost implications of using recycled coarse aggregate and waste glass in concrete production. Compare the cost of these materials to conventional aggregates, considering factors such as transportation, processing, and availability.
b. Conduct a life cycle cost analysis, considering the potential savings in material costs, waste disposal, and environmental benefits. Assess the overall economic feasibility and potential cost savings of implementing the proposed concrete mix on an industry scale.

3.2 EXPERIMENTAL PROGRAM

3.3 INTRODUCTION

The experimental program's goal is to learn more about using waste glass as the fine aggregate and recycled coarse aggregate (RCA) as the major coarse aggregate in the creation of concrete. Assessing the technical viability, mechanical qualities, and durability of the produced concrete mixtures is the goal. The experimental programme will involve a number of lab tests on various concrete mix designs in comparison to a control mix made solely of standard aggregates.

The experimental program's main goal is to identify the ideal mix ratios of recycled coarse aggregate, used glass, cement, water, and any other admixtures or additives to obtain desired concrete qualities. To assess their impact on the mechanical performance of the concrete, various replacement amounts of conventional aggregates with recycled coarse aggregate and waste glass will be explored.

In order to evaluate the qualities of the recycled aggregate and waste glass-based concrete, the experimental programme will comprise a number of significant tests. To assess the concrete's ability to support a load, tests for compressive strength will be performed. In order to evaluate the material's resistance to cracking and deformation, tensile strength and flexural strength tests will be conducted. Workability tests, such as slump tests, will be performed to gauge the mix's consistency and ease of installation for concrete.

Durability tests will be carried out in addition to the mechanical parameters to evaluate the long-term performance of the recycled aggregate and waste glass-based concrete. To assess the material's resistance to moisture ingress, chemical attack, and cyclic weathering conditions, these tests may include water absorption tests, chloride ion penetration tests, and freeze-thaw tests. The outcomes of the durability tests will reveal whether the concrete mix is appropriate for various construction applications.

The experimental programme will be carried out in a carefully supervised lab setting to ensure uniform sample preparation, curing conditions, and testing procedures. Different mix proportions, including various replacement levels of recovered coarse aggregate and waste glass, will be used to create concrete samples. These samples' performance will be compared to the control mix, which will only contain common aggregates.

The results of the experimental programme will advance knowledge of the mechanical characteristics, resilience, and overall effectiveness of concrete based on waste glass and recycled aggregate. The outcomes will offer information on mix design optimisation and demonstrate the technical viability of using these recycled resources in concrete production. In order to utilise recycled coarse aggregate and waste glass in the manufacturing of concrete on a bigger scale, industry-level methodologies will be developed using the data collected from the experimental programme.

3.4 CONCRETE COMPOSITE MATERIAL

A composite material, concrete is frequently referred to as such because of its distinct composition and structural qualities. Cementitious paste and aggregates make up its two main parts. These elements work together to create a substance with better qualities than any of its basic parts. The majority of concrete is made up of aggregates, which are made up of both coarse and fine particles. Crushed stone, gravel, or recycled concrete are typical coarse aggregates, while sand is the typical fine aggregate. These particles give the concrete structure and add to its stability and strength. They are essential in defining the concrete mixture's usability and durability.

The binder that keeps the particles together is cementitious paste. Cement, water, and different admixtures make up its composition. Hydration is the name given to the chemical process that occurs when cement and water are combined. This procedure creates a solid matrix that encloses and binds the aggregates, giving the concrete strength and cohesiveness.

The interaction of the particles and cementitious paste gives concrete its composite composition. Similar to the reinforcement in other composite materials, the aggregates act as reinforcement within the cementitious matrix. The cementitious paste binds the aggregates together and distributes the applied loads throughout the material, while the aggregates' strength and stiffness contribute to the concrete's total load-bearing capability.

3.5 MATERIALS DESCRIPTION

3.5.1 CEMENT

In the building business, cement is a key component of building materials and is utilised extensively. It is a fine powder that serves as a binder, bringing aggregates together to create cement-based products like mortar and concrete. When cement and water are combined, a chemical process known as hydration occurs, creating a strong and solid material.

Because of the importance of cement, the Indian Standards has set guide lines to follow for the make-up of cement. For experimental program of this research study, normal Portland Cements is used.

In this work, Ordinary Portland cement (OPC) of brand Khyber (43 grade) confining to IS 8112- 1989 was used throughout the investigation. The specific gravity was 2.96 and fineness was 2800 cm2/gather typical chemical composition of ordinary Portland cement of 43 grades is as under:

CHEMICAL	WEIGHT BY PERCENTAGE
Tri-calcium silicate -C3S	55
Di-calcium silicate -C2S	18
Tri-calcium aluminate -C3A	10
Tetra-calcium Alamino ferrite -C4AF	8
Calcium sulphated hydrate -CSH2	6

Table 1: Typical composition of Ordinary Portland cement.

3.5.2 AGGREGATE

There are mainly two types of aggregates; coarse aggregates and fine aggregates.in this research we use crushed recycled concrete aggregate and for fine aggregates we will use grounded waste glass for fine aggregate. Coarse aggregates will add volume to the concrete and fine aggregates will improve permeability and we can use less cement to get the desired strength. coarse aggregates are mainly larger than 4.75mm while as fine aggregates are smaller than 4.75mm in size.

If only coarse aggregates are used, they will increase the voids between the concreate and increase permeability of water. With this it will be not give the required strength as when the water is evaporated due to sunlight it will create honeycombed structure which will untimely reduce the strength of concrete. For reducing honeycombing and reducing the amount of cement used we use fine aggregates to make it denser as it occupies the voids formed due to coarse aggregate. When fresh aggregates are used for preparation of concrete it will get the water from the surrounding environment. In this experiment coarse aggregates are washed with clean water to remove the dust surrounding them.

The aggregates which are oven dried will increase the water cement ratio as they will absorb significant amount of water to fill their internal voids present in these particles. the increase in water cement ratio will reduce the strength of the concrete. Saturated dry aggregates will use less water cement ratio as their internal voids are filled with water hence, they will increase strength of concrete. For this research the water content for the aggregate was prepared under saturated surface drying (SSD) conditions in order to avoid any possible under or over estimation of water amount. As when water cement ratio is increased it will decrease the strength of concrete.

3.5.3 COURSE AGGREGATE

Crushed recycled concrete from local demolition site was used as coarse aggregate. The grade of concrete demolished was M20. the concrete was cursed to a size of 12 mm and then was cleaned. the different tests were conducted to see different properties like specific gravity, fineness modulus, bulk modulus etc. The physical characteristics are tested according to IS:2386-1963.

GRADING OF AGGREGATE

Sieve analysis of aggregates were conducted as per IS:383-1970.below table present the sieve analysis of samples used in the preparation of concrete. the curve obtained was S curve which means the samples are well graded.

3.5.4 Recycled concrete aggregate

The concrete crushed from demolished buildings is referred to as recycled concrete aggregate (RCA) and is used in place of natural aggregates when creating new concrete. It is a green and sustainable strategy that encourages the recycling of construction waste and lowers the need for new resources. Crushing and screening the demolished concrete to create pieces of different sizes is how recycled concrete aggregate is made. In numerous concrete applications, such as road base, sub-base, and the creation of new concrete mixtures, these fragments can therefore be utilised in place of natural aggregates. RCA has a number of advantages. First off, by keeping concrete scraps out of landfills, it lessens the environmental impact of building. As less virgin aggregate needs to be extracted and processed, it also conserves natural resources. Utilising RCA can also help reduce greenhouse gas emissions and energy use in the process of making new concrete. However, using recycled concrete aggregate may come with some difficulties. The origin of the demolished concrete and the processing techniques used, for example, can affect the quality and qualities of RCA. For RCA to be suitable for a given application and achieve the necessary performance standards, it must be properly characterised and tested. The use of recycled concrete aggregate in concrete mixtures has been the subject of growing research and development in recent years. This includes researching how it affects the long-term performance, durability, and mechanical characteristics of concrete. Recycled concrete aggregate can be successfully used to create long-lasting concrete structures with suitable design and quality control procedures.

Fig 1 Recycled concrete aggregate

3.5.5 FINE AGGREGATE

The fine aggregate used for this research is soda lime waste glass from a landfill site. The aggregate is cleaned, grounded and then tested for various properties specific gravity, fineness as per IS :2386:1963.

3.5.6 WASTE GLASS

Recent years have seen a substantial increase in interest in the use of waste materials in the manufacturing of concrete as a result of the growing emphasis on environmentally friendly building techniques. Waste glass, which is produced by a variety of industries and by households, presents a possible alternative for fine aggregate in concrete. The successful recycling of waste glass can be seen in a variety of applications, including as a cullet in the production of glass, a raw material for the manufacture of abrasives, in sandblasting, as a pozzolanic additive, in road beds, pavement, and parking lots, as raw materials to produce glass pellets or beads used in reflective paint for highways, to produce fibreglass, and as fractionators for lighting matches and firing ammunition.

Glass waste creates environmental problems because it builds up in landfills from sources like the production of glassware, bottles, and construction demolition waste. But using discarded glass as a fine aggregate in concrete not only offers a sustainable method for getting rid of it, but also may improve the qualities of the concrete. Utilising scrap glass can reduce the need for conventional fine aggregates, conserve natural resources, and lessen the environmental impact of producing concrete. Waste glass can affect a variety of qualities, including workability, strength, and durability when used as a fine aggregate in concrete. Results from earlier investigations in terms of enhanced workability and enhanced strength qualities have been encouraging.

The discarded glass materials employed in this experimental study were sourced from neighbourhood stores and govt polytechnic college avantipora construction site disposals. Empty bottles and pure, transparent glass windows were the main sources of these materials. The entire quantity was cleaned of all contaminants and dirt before being crushed into various particle sizes in crushing equipment.

The representative waste glass samples were then subjected to a subsequent sieve analysis using the same standard process, and in accordance with the IS standards, the samples were categorised as fine aggregates. The sieve studies showed that the majority of the fine waste glass material had a pretty good gradation pattern with particle sizes ranging from 4.75 mm to 150 micron.

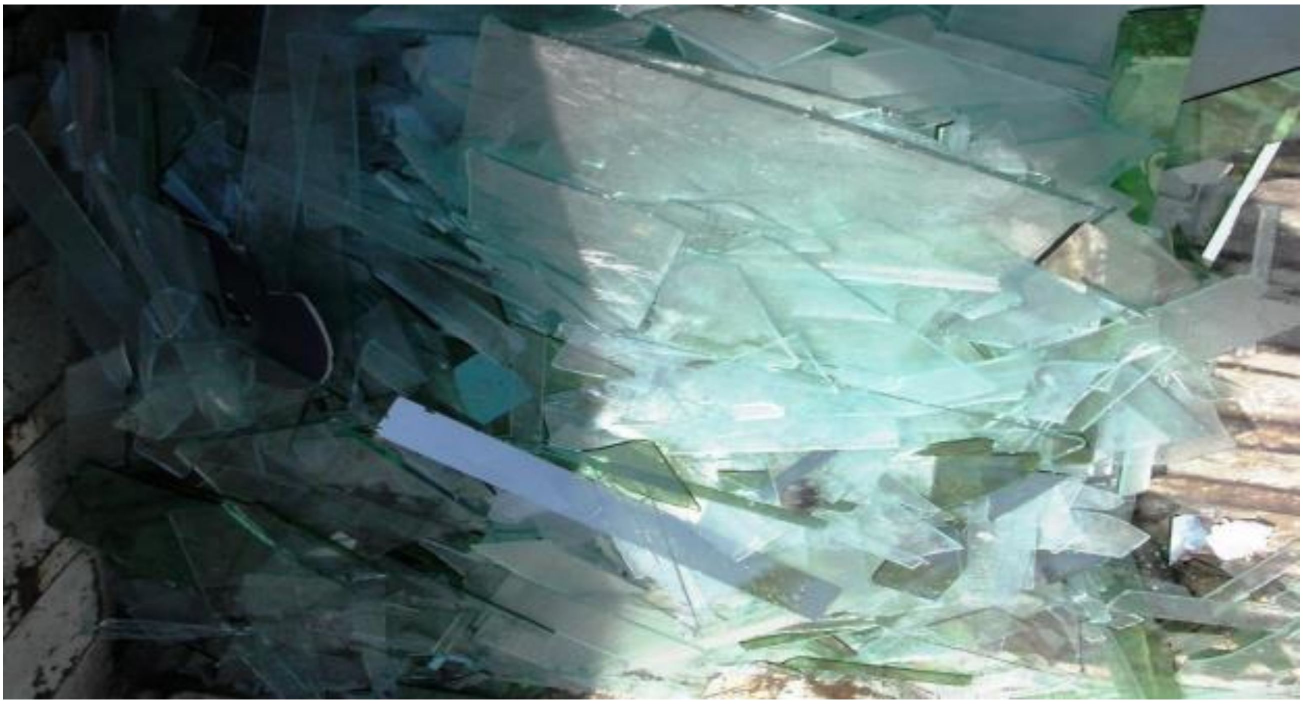


Fig 2 Shows waste glass materials as collected before crushing and sieving

Fig 3 : Shows sieving of waste glass after crushing

Fig 4: Shows waste glass after sieving and cleaning

Composition	Percentage by mass
Silica (SiO2)	20.2-72.5
Calcium oxide (CaO)	9.7-61.9

Alumina (Al2O3)	0.4-4.7
Iron oxide (Fe2O3)	0.2-3.0
Magnesium oxide (MgO)	2.6-3.3
Sodium oxide (Na2O)	0.19-13.7
Potassium oxide (K2O)	0.1-0.8
Sulphur trioxide (SO3)	0.43-0.9

Table 3: Typical chemical composition of waste glass materials

3.5.7 WATER

Water is an essential ingredient in the creation of concrete since it is responsible for the hydration process, which fuses the cement granules and creates a solid matrix. The performance, strength, and longevity of the finished concrete building can be greatly influenced by the nature and characteristics of the water used in its production. Therefore, it's crucial to make sure the water used to produce concrete adheres to certain norms and specifications. Water must be present in adequate quantities to allow the reaction to proceed fully, but if too much water is introduced, the strength of the concrete will be reduced. The ratio of water to cement is a significant idea since, in addition to the concrete mix recipe, the amount of water utilized would also affect the strength of the concrete.

More specifically, if there was insufficient water provided, the reaction would not be able to be completed and some of the cement would harden and join with other dry cement, shortening the hydration process. On the other hand, if too much water were supplied, the cement would be in a slurry solution while it was being hydrated, which would reduce the likelihood of cement bonding with aggregates. As a result, the cement component would still be in a slurry solution and lack strength once the hydration process is finished.

Water is used to start the hydration reaction, in which cement interacts with water to create a product that resembles rock. Additionally, the reaction is exothermic, meaning that heat is produced throughout the chemical processes. This is significant information since the heat emitted from particularly massive structures, such as concrete dams, may cause issues. Concrete mixing requires potable water, which is essentially water that has no discernible taste or odour. Basically, water with a total dissolved solids content of less than 2000 ppm can be used. Thus, regular tap water was used to mix concrete throughout the testing programme, with care taken to ensure that contaminants were not present.

Water used for mixing and curing is fresh potable water, conforming to IS: 3025 – 1964 part 22, part 23 and IS: 456 – 2000.

3.5.8 ADMIXTURES

These are chemicals that can be used to enhance the qualities of concrete. Accelerators, water-reducers, retarders, and plasticizers are examples of additives that can change the workability, setting time, and other characteristics of concrete, which in turn can change the mix percentage.

ALKALI SILICA SUPPRESOR

By 1.5 percent of the weight of glass, barium hydroxide is utilised as an alkali silica reaction suppressor.

3.6 ALKALI SILICA REACTION

The Alkali-Silica Reaction (ASR) is a chemical reaction that can take place between some reactive types of silica present in aggregates and the alkaline cement paste used in concrete. ASR frequently happens when concrete contains aggregates rich in reactive silica, such as chert or specific types of volcanic rocks. The reactive silica in the aggregates undergoes a chemical process that results in the formation of a gel-like substance when moisture and alkalis (such as sodium and potassium ions) formed from the cement are present. This gel has the potential to grow over time, applying pressure to the nearby concrete and leading to structural integrity loss, cracking, and spalling.

3.6.1 BACKGROUND AND PROPOSED TECHNOLOGY

In concrete constructions, Alkali-Silica Reaction (ASR) has been identified as a significant durability problem on a global scale. Since its first discovery in the early 1940s, the response has been thoroughly investigated to better understand its causes, consequences, and preventative and remedial measures. Alkali-Silica Reaction (ASR) in concrete structures is still a complicated process whose full scope is still unknown in some respects. When siliceous aggregates are combined with high alkali cements, ASR is known to occur. Concrete's pore solution's high pH causes non-ordered silica to dissolve at the aggregate surface. ASR gel is created around the aggregates as a result of the released silica's reaction with the available alkali. When moisture enters the gel, it expands; if the pressure exceeds the tensile strength of the concrete, cracking occurs. The durability and permeability of the concrete may be compromised if the ASR gel penetrates further into these cracks and results in more surface deterioration and cracking.

Although it can take several years for ASR-related damage to concrete structures to become apparent, in some instances, such as in Texas, it has been noted in shorter time. Due to the high alkali pore solution's need to attack and degrade the aggregates' silica-rich surface, the creation of the ASR gel requires time. Additional moisture may enter the system once the gel begins to split from water absorption, which would result in further ASR expansion. This highlights the absence of early warning indications prior to significant damage.

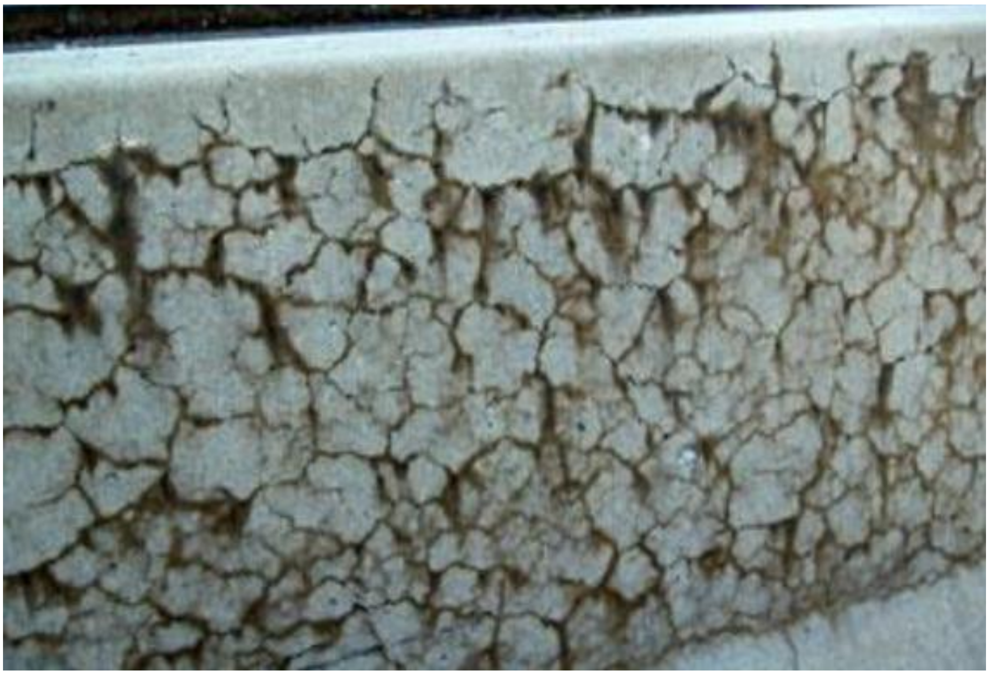


Fig 5: Shows maps cracking pattern and surface staining

In the USA, concrete bridge constructions have been exhibiting an extremely high incidence of early concrete deterioration brought on by ASR, according to a recent paper by Williams et al. The distinctive damage included broad map cracking with discoloration on concrete surfaces, longitudinal cracking at the bottom flange of the beam ends of prestressed girders, and cracking in unreinforced sections of cast-in-place concrete. For instance, four concrete bridges along the toll road system in Harris County, Texas, have developed obvious cracks over the past two years that will cost millions to repair.

As a result, the existence of ASR has a negative impact on transportation infrastructure costs, the lifespan of roadway infrastructure, and highway safety. This is a problem that affects the entire world, and it needs to be solved easily, cheaply, and without affecting the other attributes of the concrete. A very practical way to stop ASR and prevent spending millions on transportation infrastructure is to target the problematic aggregate with surface treatments to create construction materials resistant to ASR.

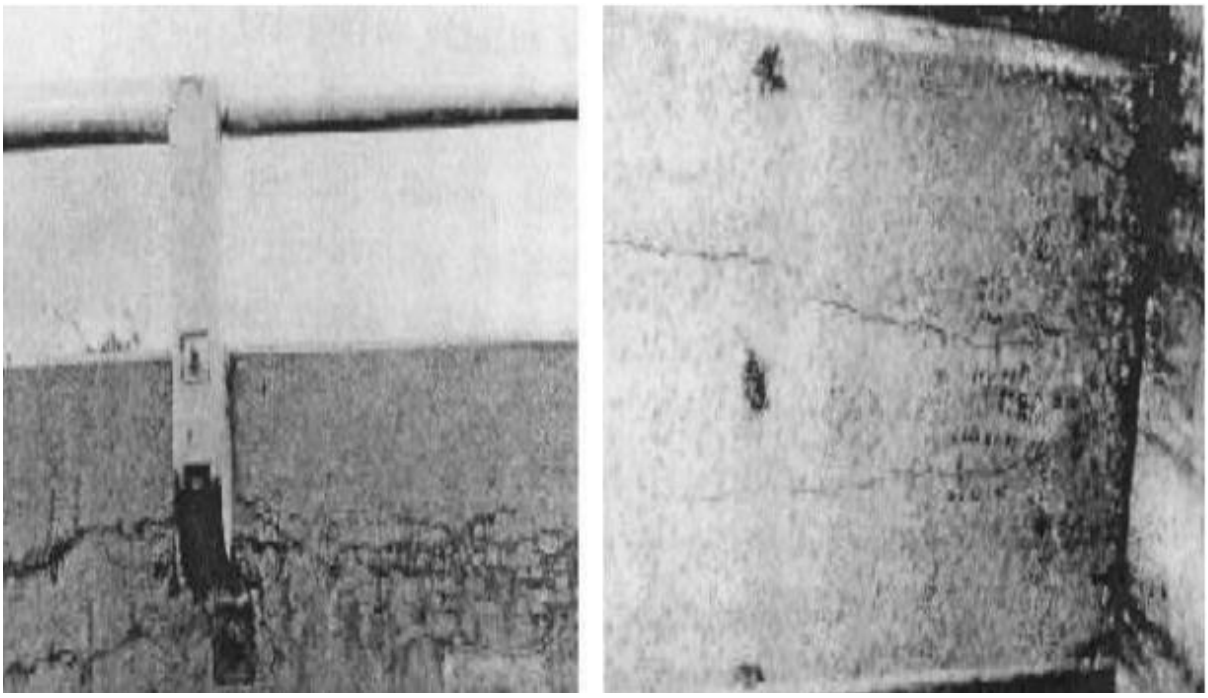


Fig 6: Shows severe Cracking Caused by ASR on the Susan River Bridge

Many methods and technologies have been suggested to address the difficulties caused by ASR. These include mitigation techniques used after construction as well as preventative measures used in the design and construction of concrete mixtures.

1. Aggregate Selection: ASR can be mitigated by choosing non-reactive aggregates. Reactive silica minerals can be identified in aggregates through chemical and petrographic analysis. Aggregate reactivity can be greatly decreased by using low reactivity aggregates.
2. Selection of Cement: The development of ASR is greatly influenced by the alkali content of cement. The availability of alkalis for the reaction can be reduced by using low-alkali cement, such as those that conform to Indian standards.
3. Supplementary Cementitious Materials (SCMs): Adding SCMs to concrete mixtures, including fly ash or slag, can assist lower the alkali level and lessen ASR. These substances react with alkalis, which reduces their usefulness in silica mineral reactions.

4. Chemical Admixtures: The efficiency of chemical admixtures in reducing ASR has been studied, including lithium compounds. Concrete cracking can be prevented by lithium ions because they prevent ASR gel from expanding.
5. Surface treatments: A variety of surface treatments, such as sealers and coatings, can function as a barrier to the penetration of moisture, so lowering the amount of moisture that is available for the ASR reaction.

3.7 CONCRETE

The concrete mix design is done accordance with IS 10262(1982). Well graded recycled concrete aggregate (RCA) and waste glass was used as coarse and fine aggregate respectively. The maximum size of 20mm coarse aggregate was used and maximum size of 4.75 mm as fine aggregate. A sieve analysis conforming to IS: 383-1970 was carried out for aggregates. Concrete can be manufactured into a dense mass that resembles artificial rock and then treated with chemicals to make it waterproof, or it can be made porous and highly permeable for uses like filter beds. Normally, the full hardening period of concrete is at least 7 days. The gradual increase in strength is due to the hydration of the tri calcium aluminates and silicates.

4 TESTS ON CONCRETE

4.1 INTRODUCTION

For the testing program, a series of standard compressive tests were conducted with variable amounts of recycled concrete aggregate as coarse aggregate and waste glass as fine aggregate with a water cement ratio of 0.45. The reference samples for comparison were also caste with natural aggregate and river sand. All tests were conducted at 7days and 28days compressive strength accompanied with slump tests for each case of sample. Tables 3.5 and 3.6 summarize the entire testing plan conducted within this research, and note that each group in this list comprises of four samples for conducting the compressive strength and the slump tests.

The major purpose of separating each testing group into four samples is to ensure that the output data points have the highest level of credibility possible and that the samples meet the minimum three-sample requirement specified by the Indian standards.

After evaluating the testing cases from the perspectives of data quality and completeness, a total of 75 testing data points were selected. The following are the reasons for excluding some of the data points:

- Samples with improper treating and/or testing procedures.
- Tests with very abnormal outcomes.

4.2 MIX DESIGN

The process of choosing the ratios of cement, aggregates, water, and admixtures to produce the required qualities of the concrete mixture is known as mix design in the construction industry. To give concrete the proper strength, workability, and durability, it is necessary to choose the right components, establish their quantities, figure out the water-cement ratio and making concrete as economical as possible. The purpose of designing can be seen from the above definitions, as two-fold. The first objective is to achieve the stipulated minimum strength and durability. The second objective is to make the concrete in the most economical manner. The grades of concrete used in present investigation are ordinary grade concrete and standard grade concrete. The mix proportions ordinary grade and standard grade are designed as per IS:

10262-1982. The mix we used in this study is the nominal mix M25 with the general mix proportion of 1:1:2.

4.3 MIXING OF CONCRETE

The mixing of concrete was done using electric mixer. The materials were placed in uniform layers one over the another in the order – coarse aggregate, fine aggregate and cementitious material. Dry mixing was done get uniform colour. After the dry mixing water was added to the materials to make concrete. Mixing was done for about 20min and then the samples were casted and left for 24hrs. Soon after mixing slump test and compaction factor apparatus were used to test the workability of fresh concrete in accordance with IS :10510-1983.

4.4 CASTING AND CURING

The concrete made was according to mix design and then the cubes of size 150mm x 150mm x 150mm were casted in accordance to IS : 516-1999. After the casting was complete the samples were demoulded after 24 hrs and then placed in temperature-controlled curing tank containing clean fresh water. After curing is done for 7 days cubes are placed under shade.

4.4.1 CASTING

The cube mould plates should be disassembled, cleaned thoroughly, and all bolts should be securely fastened. Then, all of the mould's faces should be covered in a thin layer of oil. The cube's side faces must be parallel, which is crucial.

After mixing the samples the casting should be done as soon as possible. The concrete should be placed into the cubes in layers of approximately 5cm deep. To achieve a symmetrical distribution of the concrete inside the mould, each scoopful of concrete must be placed while being moved around the top edge of the mould as the concrete slides from it. Each layer must be compacted, either by hand or vibrator, as explained below.

COMPACTION BY HAND

The compaction of concrete in the mould is done in layers and each layer should be compacted by not less than 35 strokes by tamping rod. The bottom layer must be rodded through to its depth and the strokes must reach the underlying layer. The sides of the mould should be tapped to fill any voids left by the tamping bar.

COMPACTION BY VIBERATOR

When compacting concrete by vibration, each layer should be vibrated until the desired condition is reached using an electric or pneumatic hammer, a vibrator, or a suitable vibrating table. By removing air gaps and assuring greater consolidation of the concrete mixture, vibration is used to improve the compaction process.

4.4.2 CURING

After casting is complete the cubes should be stored in shade at a place free from vibration at normal temperature for 24 hrs covered in wet straw or gunny bags. After 24hrs the cubes are demoulded and are placed in temperature-controlled curing tank containing fresh clean water at temperature of 27±2 ℃ till 7 days or 28days of testing. The cubes should be tested in the saturated and surface dried condition.

Extra cubes must be cast, stored, and cured in conditions identical to those of the structure in order to accurately represent the strength of the concrete in that structure. They must then be tested at the requisite age.

Fig 7. curing tank with concrete cubes

4.5 PROPERTIES OF FRESH CONCRETE

4.5.1 WORKABILITY

Concrete's "workability" refers to the amount of internal effort needed to complete compaction without running into common issues. The energy required to reduce friction between individual concrete particles is referred to as the "internal work." Practically speaking, however, more power is also needed to overcome the friction that exists between the concrete and the formwork or reinforcement. In practise, it can be difficult to assess the precise workability as described above; instead, the workability applicable to the particular method in use is usually measured. Concretes with a higher workability are typically easier to handle and install, but adding more water to a mix can increase workability at the expense of strength and durability. When designing a concrete mix, it's important to strike a balance between workability and other qualities like strength and durability. High workability is preferred for ease of building, but it's crucial to achieve it without sacrificing the concrete's long-term performance. The water-cement ratio, aggregate grading, usage of admixtures, and proper construction methods must all be carefully taken into account.

4.6 Cohesion and Segregation

In order to achieve complete compaction and a uniform distribution of components within the mixture, concrete cohesion and the prevention of segregation are essential. In a heterogeneous mixture, segregation is the separation of the particles, which causes an uneven distribution of the constituent parts. The main source of segregation is disparities in size between the components of concrete, however it can be prevented by using adequate grading and cautious handling.

Segregation comes in two different kinds. The first happens when coarser particles break apart because they move farther or settle more slowly than finer particles. In dry mixes, this kind of segregation is more probable. The second type of segregation, which takes place in wet mixtures, involves separating cement paste from the other components of the mixture.

The handling and positioning techniques employed determine how segregation is implemented. Segregation danger is decreased by directly moving concrete from a skip or wheelbarrow to the final place in the formwork. Concrete should not be discharged against an obstruction, dropped from a height, or passed via a chute with changes in direction since these situations can promote segregation.

Techniques for handling, moving, and arranging objects correctly greatly limit the possibility of segregation. Concrete must be poured precisely where it is to go, not allowed to flow or be worked along the form. Although vibrators are useful for compaction, incorrect vibrator use, such as using them for an extended period of time, might raise the chance of segregation. In rare circumstances, inappropriate vibration can lead to the separation of cement paste at the top and coarser aggregates at the bottom of the form, weakening the concrete and increasing surface moisture.

Entrainment of air reduces the possibility of segregation in the mixture. On the other hand, segregation can be exacerbated by the use of coarser material that has a much greater specific gravity than the fine aggregate. Segregation is difficult to quantify, yet it is simple to notice when handling concrete on the construction site.

Overall, attaining consistent compaction and guaranteeing the quality and durability of the hardened concrete structure depend on preventing segregation and maintaining cohesiveness in fresh concrete. The dangers of segregation are reduced and a more dependable and homogeneous concrete mixture is created by using proper grading, handling methods, and adherence to suggested laying practises.

4.7 BLEEDING OF CONCRETE

When some of the water in a concrete mix rises to the surface after it has been freshly laid, the process is known as bleeding, sometimes known as water gain. This occurs because as the mix settles downhill, the solid components are unable to hold onto all the water used in the mixing process. By calculating the decline in concrete height per unit height, bleeding can be quantified. Bleeding stops once the cement paste has hardened. Bleeding can result in a number of problems. When water is retained by concrete on top of the top layer of each concrete lift, it may become overly moist, creating a porous and fragile layer. A weak wearing surface may result from the finishing process's remixing of the bleeding water. It is crucial to wait until the bleeding water has evaporated before completing, to use wood floats, and to avoid overworking the surface in order to prevent this. However, if the rate of evaporation from the concrete surface is greater than the rate of bleeding, it may result in plastic breaking due to shrinkage. Some of the rising water may not only collect at the surface but may also become trapped behind big aggregate particles or reinforcement, leading to weak bond zones. The voids that are left behind by the trapped water make the concrete more permeable in a horizontal plane. In thin slabs, such as roadways, where frost offers a significant risk, bleeding is frequently more noticeable.

Even though bleeding is not always bad, it can nonetheless be detrimental. It can decrease the effective water/cement ratio and raise strength if left undisturbed and allowed to evaporate. However, the formation of a layer known as laitance may result if the rising water contains a considerable amount of fine cement particles. Laitance at the slab's top can lead to a porous surface that is permanently dusty and has insufficient bonding with the subsequent layer. Laitance should therefore be removed by brushing and washing. The amount of water in the mixture and the characteristics of the cement affect bleeding propensity. Finer cements often have less bleeding, although other chemical parameters can also have an impact. Adding calcium chloride or increasing the cement's C3A (tricalcium aluminate) content, for instance, can lessen bleeding. For concrete constructions to be long-lasting and of the highest calibre, proper bleeding management and awareness are essential.

4.8 FRESH CONCRETE TESTS

In order to evaluate the qualities and characteristics of concrete as soon as it is mixed and before it sets or hardens, fresh concrete tests are carried out. To make sure that the concrete mixture satisfies the specified specifications, workability, and performance requirements, these tests are crucial. Batching, mixing, transporting, putting, compacting, and surface finishing are all included in concrete operations. Then, 6–10 hours after casting (placing), in-place concrete begins to cure, and the first several days of hardening are important.

Concrete's fresh state characteristics have a considerable impact on its hardened state characteristics for a variety of reasons.

- Strength and Compaction: The potential strength and durability of the hardened concrete are strongly influenced by the degree of compaction during the fresh condition. When concrete is properly compacted, it is devoid of voids and air pockets, which increases density and boosts strength.
- Early Age Performance: The first 48 hours following placement are crucial for the early age qualities of concrete to develop. The final strength, stiffness (elastic modulus), and other mechanical properties of the hardened concrete are affected during this time by processes including hydration and setting.
- Long-Term Behaviour: The characteristics of freshly laid concrete, including compaction, air content, and curing, have a big impact on the concrete's long-term behaviour. The quality and state of the concrete when it is still fresh has an impact on variables including compressive strength (f'c), elastic modulus (Ec), creep, and durability.

Key Properties of Fresh Concrete:

- Fluidity or Consistency: The ability of the concrete mix to flow and be handled readily during mixing, transporting, putting, and compacting is referred to as its fluidity or consistency. When concrete can fill the formwork and flow around reinforcement with the aid of compacting equipment, it is measured using tests like the slump test or flow table test.
- Compatibility: To release any trapped air, new concrete should easily compact. Vibration is one efficient form of effective compaction that guarantees appropriate consolidation of the mix, improving strength, reducing porosity, and improving durability.
- Cohesiveness or Stability: New concrete should be homogeneous and uniform, with no segregation of the cement paste from the particles. To stop the cementitious materials from settling or separating during handling and placement, it should keep its cohesion.

To produce a hardened concrete structure of superior quality, it is essential to guarantee the appropriate fresh state qualities of concrete. To achieve the desired fresh state properties and, subsequently, the desired hardened state properties of the concrete, proper mix design, appropriate water-cement ratio, control of aggregate grading, use of suitable admixtures, adherence to proper construction practises, and quality control measures are all necessary.

4.9 WORKABILITY

After being poured while still wet, concrete dries to a stage that is considered "workable" and allows for shaping, smoothing, and towelling. Timing is really important. When trowelled too quickly, the material is still too wet, won't maintain its shape, and may separate the water from the particles, giving the finish a terrible appearance. It becomes excessively stiff and impossible to shape or smooth if towelled too late. The term "workability of concrete" refers to how well it performs throughout the crucial period, and it does depend on elements like water content and additives. The numerous tests that were conducted to evaluate workability include

4.9.1 SLUMP TEST

Slump test is used to determine the workability of fresh concrete. Slump test is done as per IS 1199-1959. The apparatus used for performing this test is slump cone and tamping rod.

Procedure for this test is below

1. Prepare clean, flat and moisture free surface for conducting the test.
2. The inside of cone is cleaned and a tin film of oil is applied.
3. The mould is filled in three layers. Each layer is almost one third of cone.
4. Use a standard tamping rod to compact each layer with 25 strokes uniformly distributed over the cross section.
5. After compacting the final layer strike off the excess concrete from the top of cone with the help of tamping rod. Ensure that the surface is smooth and level.
6. Make sure there are no lateral or twisting movements as you lift the cone vertically in a continuous motion. Without any jerks, elevate the cone vertically in a single fluid motion.
7. Keep an eye on how the concrete slump changes in height. Calculate the difference between the cone's starting height and the highest point at which the concrete has sunk. The slump value is represented by this variation.
8. Record the slump value in millimetre.

TYPES OF SLUMP

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as;

True Slump: The concrete subsides uniformly and retains its symmetrical shape in a true slump. Without any indications of shearing or significant moisture loss, the concrete simply settles. This kind of slump signifies a coherent, evenly distributed, and workable mixture.

Shear Slump: In a shear slump, the concrete maintains its sloping shape while sliding and shearing off to one side of the slump cone. If a shear or collapse slump is achieved, a fresh sample should be taken and the test is repeated. If the shear slump persists, as may the case with harsh mixes, this suggests a mixture with too much water and insufficient cohesiveness. It hints at a lack of productivity and perhaps segregation.

Collapse Slump: A collapse slump is characterised by a considerable loss of concrete cohesiveness that causes the mass of concrete to collapse. Concrete entirely loses its shape and slumps, which is a sign that the mix contains too much water. Such a fall hints at low employability and possible segregation.

Zero Slump: In a zero slump, the concrete does not slump at all and maintains its original shape. The concrete is unworkable and hard. It is frequently connected to mixtures that contain a lot of aggregates or have a very low water to cement ratio.

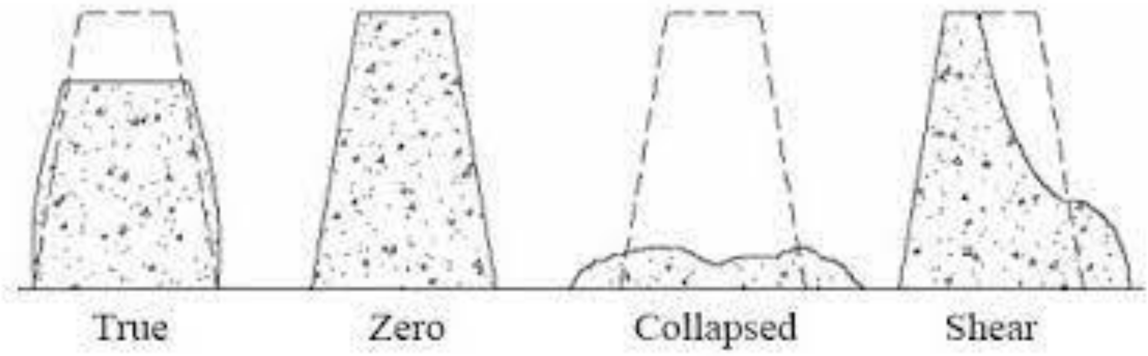


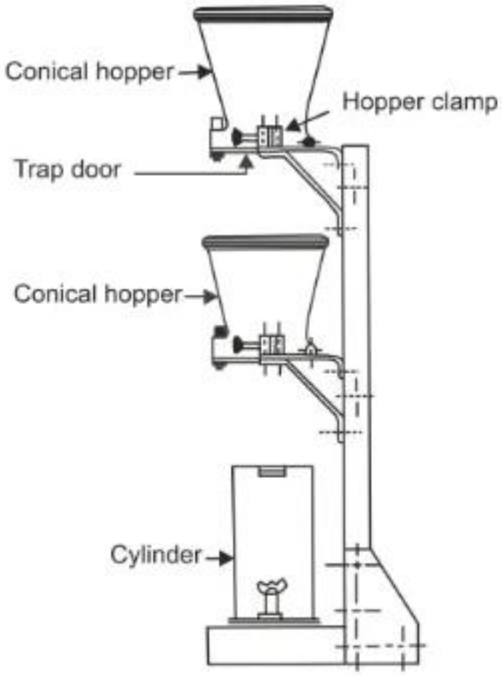
Fig 8: Shows types of slump

4.9.2 COMPACTION FACTOR TEST

Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS: 1199 – 1959. The apparatus used is Compacting factor apparatus. Procedure to determine workability of fresh concrete by compacting factor test.

1. Gently place the concrete sample in the upper hopper of the compaction factor apparatus.
2. Load the upper hopper with concrete until it reaches the top, then open the hinged door to allow the concrete to fall into the lower hopper.
3. If there is any clogging in the hoppers, gently push the rod into the concrete from above to remove the obstruction.
4. Use trowels to cover the cylinder during the entire process.
5. Uncover the cylinder and open the trapdoor of the bottom hopper, allowing the concrete to fall into the cylinder immediately after it has settled.
6. Cut away any excess concrete that remains above the top of the cylinder.
7. Calculate the weight of partially compacted concrete by rounding the weight of the concrete in the cylinder to the nearest 10 g.
8. Replace the cylinder with concrete from the same sample, adding it in 50 mm layers.
9. Vigorously ram or vibrate each layer to achieve complete compaction.
10. Carefully strike off the top surface of the fully compacted concrete level with the top of the cylinder.
11. Calculate the compacting factor by dividing the weight of partially compacted concrete by the weight of fully compacted concrete.
12. The compacting factor is usually expressed to the second decimal place and typically ranges from 0.78 to 0.95. Concrete with higher fluidity tends to have a greater compaction factor.

Compacting factor = (Weight of partially compacted concrete)/ (Weight of fully compacted concrete)



compaction factor test apparatus

Fig 9: Shows Compaction factor apparatus

4.10 HARDNED CONCRETE TEST

Hardened concrete: it is a stage in the chemical reaction between cement and water when the concrete hardens and gains sufficient strength to support its own weight and construction load.

4.10.1 SRINKAGE

Shrinkage in concrete refers to the decrease in volume that occurs during the drying and curing process. It is primarily caused by three factors: settlement of solids, chemical reactions, and drying.

1. Plastic Shrinkage: During the initial plastic state of concrete, water tends to evaporate from the mixture, causing a decrease in volume. This is known as plastic shrinkage. It occurs due to factors such as high temperatures, low humidity, and wind velocity. Plastic shrinkage can lead to surface cracking and can be minimized by taking measures like using shading or windbreaks, misting the surface with water, or using plastic sheeting to retain moisture.
2. Autogenous Shrinkage: Autogenous shrinkage is caused by the chemical reaction between cement and water, known as hydration. As the cement hydrates and forms a solid structure, it undergoes a volume reduction. This autogenous shrinkage is typically minimal and occurs within the first few days of concrete placement.
3. Drying Shrinkage: After the initial curing period, concrete continues to lose moisture as it dries. The loss of water leads to a decrease in volume, known as drying shrinkage. This is a common type of shrinkage and can result in cracks or deformations in the concrete if not properly controlled. The extent of drying shrinkage depends on factors such as the mix design, ambient humidity, temperature, and the drying conditions.

To minimize shrinkage in concrete, several measures can be taken:

- Proper mix design: Using appropriate proportions of cement, aggregates, and water can help reduce shrinkage potential.
- Control of water content: Optimal water-cement ratio should be maintained to minimize shrinkage while ensuring adequate hydration.
- Use of supplementary cementitious materials: Incorporating materials like fly ash, slag, or silica fume can help reduce shrinkage by improving the cementitious paste structure.
- Curing methods: Adequate curing, such as moist curing or the use of curing compounds, helps maintain moisture levels in the concrete, reducing drying shrinkage.
- Joint placement: Control joints or expansion joints are introduced to accommodate the anticipated shrinkage and prevent cracking.

Fig 10: Plastic or fresh concrete

Fig 11: Plastic shrinkage crack

Fig 12: Drying shrinkage cracks

4.10.2 DURABILITY

Concrete's durability is defined as its capacity to withstand various types of deterioration and preserve the intended service life under particular environmental circumstances. Concrete constructions must possess this quality since a lack of durability can cause premature deterioration, diminished structural integrity, and higher maintenance and repair costs.

Several factors can affect the durability of concrete:

1. Exposure to strong chemicals, moisture, and other environmental factors all have the potential to penetrate concrete and trigger chemical reactions. Through processes including the alkali-silica reaction (ASR), sulphate attack, carbonation, and chloride ingress, these reactions can cause concrete to deteriorate.
2. Freeze-Thaw Cycles: Concrete can fracture and spall when water inside of it freezes and expands, creating internal pressure. This is crucial in regions that experience freezing and thawing cycles. To prevent freeze-thaw damage, concrete should be built with sufficient air entrainment and low permeability.
3. Concrete cracking, spalling, and decreased structural strength can result from corrosion of the embedded steel reinforcement, which is caused by the presence of moisture, oxygen, and chloride ions. Prevention of reinforcement corrosion requires proper concrete covering, the use of corrosion inhibitors, and protection from chloride penetration.
4. Abrasion and Wear: Concrete surfaces may degrade and lose their durability when they are exposed to high traffic or abrasion, such as on industrial floors or in transportation infrastructure. Enhancing abrasion resistance and extending longevity can be accomplished by using the right concrete mix designs, surface treatments, and protective coatings.
5. Cracking and structural movements: Concrete constructions may experience cracking due to shrinkage, temperature changes, or differential settling. In order to reduce the possibility of moisture and chemical intrusion through cracks and maintain durability, proper joint design and crack management procedures are required.

To ensure the durability of concrete, various measures can be taken:

Proper mix design can improve the durability properties of concrete by using high-quality components in the right quantities and by adding extra cementitious elements.

Adequate Concrete Cover: Giving reinforcement enough concrete cover helps prevent corrosion and acts as a barrier against moisture and chemical infiltration.

Effective Waterproofing and Surface Protection: Concrete surfaces can be protected from chemical attacks and moisture penetration by implementing the proper waterproofing methods and coatings.

Correct Construction Techniques: Utilising sound building methods, such as appropriate curing, compaction, and consolidation processes, contributes to the maintenance of concrete's quality and integrity while lowering the likelihood of durability problems.

Regular Maintenance: Concrete structures can benefit from periodic inspections, maintenance, and repairs to identify and address any durability concerns early on, preventing further deterioration.

4.10.3 STRENGTH OF CONCRETE

Concrete's strength, often known as its compressive strength, is determined by a number of different elements. The following three significant elements have an impact on concrete's strength:

Paste Strength

The cementitious paste's strength, which is a key factor in establishing the total strength of concrete, is very important.

The aggregates are bound together by the paste, which provides cohesion, to form a dense mass.

Higher bonding strength in the paste will lead to improved adhesion and interlocking of the particles, which will increase the strength of the concrete.

Interfacial Bonding

The connection between the paste and the aggregate particles is referred to as interfacial bonding.

To achieve high concrete strength, the paste and particles must form a solid and long-lasting link.

The bonding between the paste and aggregates can be hampered by clay or other impurities on the surface of the aggregates.

To achieve a stronger bonding contact, it is crucial to adequately wash and clean the aggregate

Aggregate Strength:

Concrete's strength is greatly enhanced by aggregates, particularly coarse particles.

Similar to the body's bones, coarse particles serve as the concrete's skeleton or framework.

The overall strength of the concrete is influenced by the strength and characteristics of the coarse particles.

Aggregates that are rough and angular offer greater interlocking and bonding with the paste, increasing concrete strength.

It is worth noting that the overall strength of concrete is also influenced by other factors such as water-cement ratio, curing conditions, compaction, and the quality of materials used. Proper mix design, adequate compaction, and appropriate curing techniques are crucial to optimize the strength of concrete.

4.10.4 COMPRESSIVE STRENGTH

The strength of concrete refers to its ability to withstand compressive forces without breaking. It is a critical property of hardened concrete and is often considered in the design of concrete mixtures. The measurement of concrete strength is typically performed using a universal testing machine.

Concrete compressive strength tests typically use cylindrical or cube-shaped examples. These specimens' sizes can vary, but typically, cylinder examples have 7.5, 10, and 15 cm in diameter, and cube specimens have 5, 10, or 15 cm on each side.

It is crucial to remember that a number of variables, such as the atmosphere and curing processes, can affect the compressive strength of concrete. As a result, the concrete's real strength in a structure may not match the strength found in laboratory specimens.

Using a standardised approach, fresh concrete is poured into empty moulds to assess the strength of the concrete. The specimens are taken out of the moulds after 24 hours and moist-cured for 28 days. The specimens are examined to evaluate their compressive strength at the conclusion of the curing period.

COMPRESSIVE STRENGTH TEST

The compression testing machine shall be as per IS: 14858-2000. The machine shall be capable of applying the load at the specified rate, uniformly without shock using manual or automatic control. The percentage of error shall not exceed ±1.0 percent of the indicated load.

The procedure for compression test is below

1. Remove the specimen from water after specified curing time and wife out excess water.
2. Take the dimensions the specimen to nearest 0.2m
3. Clean the bearing surface of the testing machine.
4. Place the specimen in the machine such that the load should be uniformly applied to the opposite side of the cube casted.
5. Align the specimen centrally on the base plate of the machine.
6. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
7. Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails.
8. Record the maximum load and note any unusual features in the type of failure.

It should be noted that if strength of any specimen varies by more than 15 per cent of average strength, results of such specimen should be rejected.as per IS average of minimum three specimens give the crushing strength of concrete.

CALCULATIONS

Size of cube = 15 cm x 15 cm x 15 cm

Area of specimen (calculated from the mean size of specimen) =225 cm^2

Compressive strength = (failure load in N / area in $mm^{2)}$

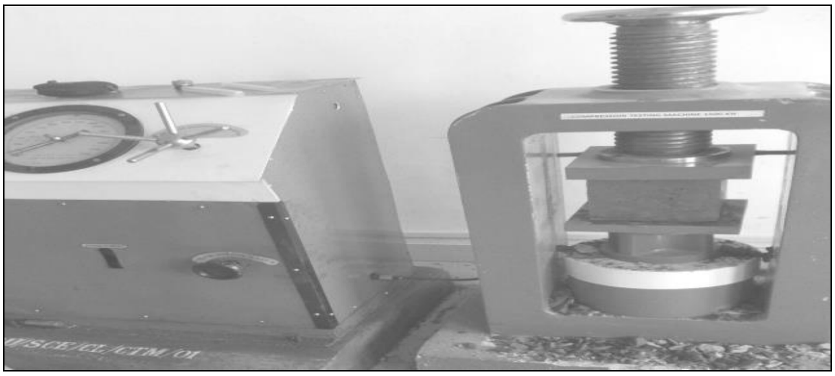


Fig 13. Compressive testing machine

4.10.5 TENSILE STRENGTH

Another crucial characteristic of concrete is its Tensile strength, which gauges how well the substance can withstand tensile pressures and prevent cracking. This is especially important to do in order to combat shrinkage and temperature variations.

There are two common methods used to determine the tensile strength of concrete:
Direct Tensile Strength: In this technique, a concrete specimen is directly subjected to a tensile force. However, because to the difficulties in holding the specimen and the possibility of having uneven fracture patterns, measuring the direct tensile strength is difficult and not usually done.
Splitting Tensile Strength: To determine the tensile strength of concrete, the splitting tensile strength test is frequently performed. A cylindrical specimen (or occasionally a cube-shaped specimen) is horizontally positioned in this test, with its axis parallel to the applied load. The specimen then splits apart after being evenly dispersed with a line load along its length**.**

The splitting tensile strength test provides a reliable estimate of the tensile strength of concrete, and the results can be used to evaluate the material's resistance to cracking and its ability to withstand tensile forces.

SPLIT TENSILE TEST

It is a common method for determining the concrete's tensile strength. Concrete that is either cylindrical or cubical is compressed during the test, and the specimen's tensile strength is assessed as the specimen splits along a plane perpendicular to the compressed force.

The procedure for split tensile test is below

- Coming up with actual cylindrical examples. The standard size for cylindrical specimens is 150 mm by 300 mm, while the standard size for cubic specimens is 150 mm by 150 mm by 150 mm. The samples should be cured and preserved in a controlled environment up until the time of testing.
- Place the test cylinder horizontally on the testing machine's lowest platen and verify that the cylinder's axis is perpendicular to the loading platen.
- Adjust the upper platen so that it's centred over the specimen. Align the upper platen's spherical seating with the spherical seating on the lower platen to ensure uniform load
- Apply a constant rate, uniform, axial, and compressive load to the specimen. For normal tests, the rate is typically 2.5 kN/min. Load the specimen until it breaks into two parts. Measure and note the applied load during the test.
- As per IS-456,
  Split Tensile Strength of Concrete= 0.7fck
  The split tensile strength can also be calculated by using the formula= $2P/\Pi dl$
  Where,
  P= Splitting load
  D= Diameter of specimen
  L= Length of specimen

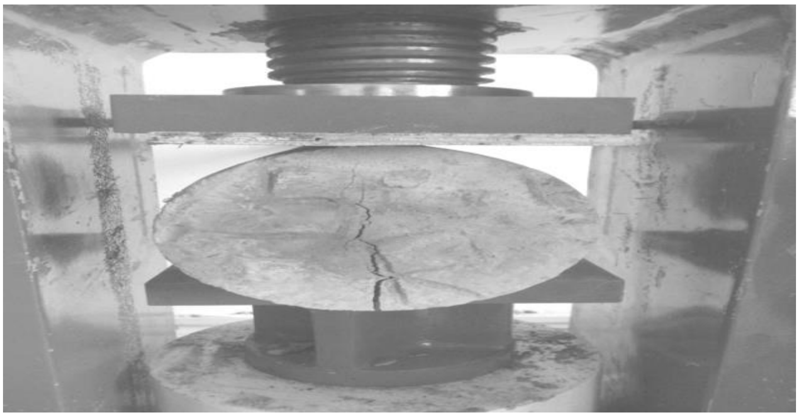

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Fig 14. Split Tensile Strength Test

4.10.6 WATER ABSORPTION

High-quality concrete must have the ability to absorb water if it is to be durable and resistant to freezing and thawing. Concrete with a low permeability is more resistant to the destructive effects of freezing and thawing cycles because it is less prone to water penetration. Water can seep into the aggregate and through the pores in the cement paste. Therefore, concrete must have low absorption, low permeability, and high density in order to endure freeze-thaw temperatures.

Cube specimens are used to evaluate the concrete's water absorption properties. These specimens are originally weighed after being taken out of the moulds to determine their average dry weight. The specimens are then immersed in water for curing and allowed to soak for 28 days. The average specimen weight is now once more determined. The proportion of water absorption can be estimated by comparing the weight before and after immersion in water. The concrete's durability can be inferred indirectly from this measurement.

5 RESULTS AND DISCUSSION

The main goals of this chapter are to assess the fresh concrete's workability and figure out the hardened concrete's compressive strength. These factors are essential for analysing and evaluating the success of adding discarded glass elements and recycled concrete aggregate to concrete mixtures. Addressing uncertainties and potential sources of error during the data analysis process is crucial for ensuring the correctness and dependability of the results.

For accurate output results, it is essential to comprehend the causes of errors. Uncertainties in the measurements can be caused by variables in the material qualities, testing methods, and environmental conditions. These causes of error can be located and taken into account so that the data analysis process can be properly handled and more precise results can be reached.

It is possible to find out a lot about the acceptability of waste glass and recycled concrete aggregate elements in the concrete mix by assessing the workability of fresh concrete, including its flowability, cohesiveness, and ability to be compacted. The overall strength and durability of the concrete using waste glass and recycled concrete aggregate can also be determined by calculating the compressive strength of hardened concrete.

This chapter strives to create a thorough understanding of the performance and viability of employing waste glass materials and recycled concrete aggregate in concrete by taking into account workability and compressive strength. The potential advantages and drawbacks of using waste glass and recycled concrete aggregate can be successfully assessed by rigorous data analysis and appropriate handling of uncertainties, advancing sustainable and environmentally friendly concrete construction techniques.

Laboratory experiments were conducted on strength characteristics of concrete made with utilizing recycled concrete aggregate as coarse aggregate and waste glass as fine aggregate. the recycled aggregate was used in proportions of 40% 70% and 100% as replacement of coarse aggregate by weight and waste glass was used as fine aggregate for preparing M25 concrete mix. The nominal mix for M25 is 1:1:2 is used. These mixes are made with the W/C ratio of 0.5 in addition to supress the alkali silica reaction, alkali silica inhibitor was used. a total of 75 test specimen of size 15x 15x 15cm were made and tests were performed on them to determine the compressive strength of each. There is a tendency of the reaction between the alkali in cement and silica in glass known as Alkali-silica reaction. These reaction results in the formation of silica gel which have a tendency of swelling which ultimately exert pressure on concrete results in cracking the concrete. To mitigate the alkali silica reaction, we have used the barium hydroxide as alkali silica reaction suppressant. The specimen was tested for compressive and durability tests at different ages and the strength was compared with normal concrete of same nominal mix. The result concluded using of recycled concrete aggregate as coarse aggregate has no effect on the strength hen the size of aggregate was 12mm.the use of waste glass has effect on workability as it makes the concrete mix harsh. This paper recommends use of recycled concrete aggregate and waste glass can be used for preparing concrete which is both economical as well as it has no or very less effect on strength.

It is crucial to highlight that the focus of this research study is on particular features of waste glass components' inclusion in hardened concrete compressive strength. The scope of this study does not, however, take into account some factors that might have an effect on the compressive strength of concrete, such as different mixes of course and fine recycled aggregate, the effect of different admixtures, and the unique characteristics of waste glass materials. It was chosen specifically to exclude these factors in order to keep the research's forecasts and recommendations simple and reliable. The researchers want to offer precise and targeted insights into the potential use of recycled concrete aggregate in concrete mixtures by focusing the study's scope on a few key variables

5.1 AGGREGATE TESTS

5.1.1 COARSE AGGREGATE

Recycled concrete aggregate from local demolition site was collected and crushed in the size of about 20mm According to IS: 383-1970, the aggregates underwent testing. The outcomes are displayed in Table 13 below

Table No. 3: Sieve Analysis of Recycled Concrete Aggregates(20mm).

Weight of sample taken =2000 gm					
S. No	**IS-Sieve (mm)**	**Mass Retained (gm)**	**Cumulative mass retained**	**Cumulative %age mass Retained**	**Cumulative % mass passing through**
1	40	0	0	0	100
2	20	143	143	7.15	92.85

3	10	1730	1873	93.65	6.35
5	4.74	125	1998	99.9	0.1
6	2.36	0	1998	99.9	0.1
7	1.18	0	1998	99.9	0.1
8	600µ	0	1998	99.9	0.1
9	300µ	0	1998	99.9	0.1
10	150 µ	0	1998	99.9	0.1
11	Below150µ	2	2000	100	0
	Total			**Σ800.2**	

Fineness Modulus of Fine Aggregates = 800.2/100

= 8.002

Table No. 4: Physical Properties of RCA Aggregates.

Parameters	**Value**
Type	Crushed
Color	Grey
Shape	Angular
Nominal Size	20 mm
Specific Gravity	2.45
Total Water Absorption	1.5%
Fineness Modulus	8.00

5.1.2 FINE AGGREGATE

Crushed waste glass was used as partial replacement of fine aggregate. Waste glass was crused to a fine powder and then sieve analysis as per Indian Standard Specifications IS: 383-1970 was conducted. the results are displayed in table

Table No. 5: - Sieve Analysis of Fine Aggregates.

Weight of sample taken =1000 gm					
S. No	**IS-Sieve (mm)**	**Mass Retained (gm)**	**Cumulative mas Retained**	**Cumulative % mass Retained**	**Cumulative % passing through**
1	4.75	1	1	0.1	99.9
2	2.36	20	21	2.1	97.7
3	1.18	78	99	9.9	90.1
5	600µ	154	253	25.3	74.7
6	300µ	266	519	51.9	48.1
7	150 µ	423	942	94.2	5.8
8	Below150µ	58	1000	100	0

	Total	1000		**Σ283.5**	

Fineness Modulus of Fine Aggregates = 283.5÷100
= 2.835

Table No 6: Physical Properties of Fine Aggregates

Parameters	**Value**
Type	Waste glass
Specific Gravity	2.54
Water Absorption	0.2%
Fineness Modulus	2.83 (Zone III)
Unit Weight	1850kg/m^3
Surface Moisture	1.5%

5.2 Fresh concrete tests

Two types of fresh concrete were conducted to find workability of concrete

- slump cone
- compaction factor test

The following are some guidelines for conducting the slump cone test and checking the workability depending upon the value of slump, the slump is the decrease in the height of cone type structure formed by placing concrete in three layers in slump cone apparatus and compacting it with 25 blows by means of compacting rod. The decrease in height shows us the values of the slump.

This table under shows the value of slump which we got through our examination

Table no 7 Results of slump test and compaction factor

Percentage of recycled concrete aggregate	Percentage of glass	Slump value mm	Compaction factor
0	0	60	0.86
25	10	63	0.89
50	20	65	0.90
75	30	66	0.91
100	40	70	0.93

Table no 8 Shows the guidelines for slump test and compaction factor

Degree of workability	Slump mm	Compaction factor	Suitable use
Very low	0-25	0-1	Very dry mixes; used in road making. Roads vibrated by power operated machine

Low	25-50	1-2	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by hand operated Machines
Medium	50-100	2-4	Medium workability mixes; manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibrations.
High	100-175	4-7	High workability concrete; for sections with congested reinforcement. Not normally suitable for vibration

Thus, from above test results it is concluded that the concrete we used in our investigation is of medium workability.

5.3 Compressive strength test

The steel mould of size 150cm x 150cm x150 cm is tightened and oiled thoughtly fresh concrete mix is placed and well compacted through rods and after 24 hours they are allowed for curing. In a period of 7 28 days they were tested. After 24 hrs the specimen is taken out from the curing tank and are wiped clean. The dimensions and the weight of specimen are measured precisely and noted down. Then the specimen is placed on ctm and load is applied uniformly until the specimen is failed. The ultimate load at the time of failure is noted down. The following data was recorded when we used 150 x 150 x 150 cm cubes with and without use of recycled concrete aggregate and waste glass having a1.5% of salt by weight of waste glass used. The salt used is Barium Hydroxide this to control the expansion of concrete and cracks which ultimately led to failure of respective structures. The reaction is known as alkali silica reaction taking place between alkalis of cement and silica of aggregate.

The compressive strength of the mix design M25 after partially replacing fine aggregate about 40% with crushed waste glass and fully replacing coarse aggregate with recycled concrete aggregate has adverse effect on the compressive strength. As we can see from the table x and the fig below with replacing fine aggregate and coarse aggregate the strength is lost by little amount.

Table 9: Shows the compressive strength of the test specimens

Percentage of recycled concrete aggregate used (%)	Percentage of glass used %	Test Specimen	Strength after 7 days (N/mm2)	Average strength (N/mm2	Strength after 28 days (N/mm	Average strength (n/mm2)
0	0	1	20.25	19.8	33.25	31.5
		2	20.65		31.62	
		3	19.85		30.65	
		4	18.50		30.85	

25	10	1	19.65	19.0	29.36	28.4
		2	19.20		28.65	
		3	18.65		28.32	
		4	18.75		27.24	
50	20	1	17.62	17.8	26.35	25.9
		2	17.90		26.45	
		3	17.63		25.35	
		4	18.36		25.48	
75	30	1	16.65	16.4	24.35	25.1
		2	15.36		26.34	
		3	17.24		25.36	
		4	16.68		24.64	
100	40	1	14.35	13.8	23.34	24.5
		2	14.10		22.40	
		3	13.65		25.64	
		4	13.20		26.64	

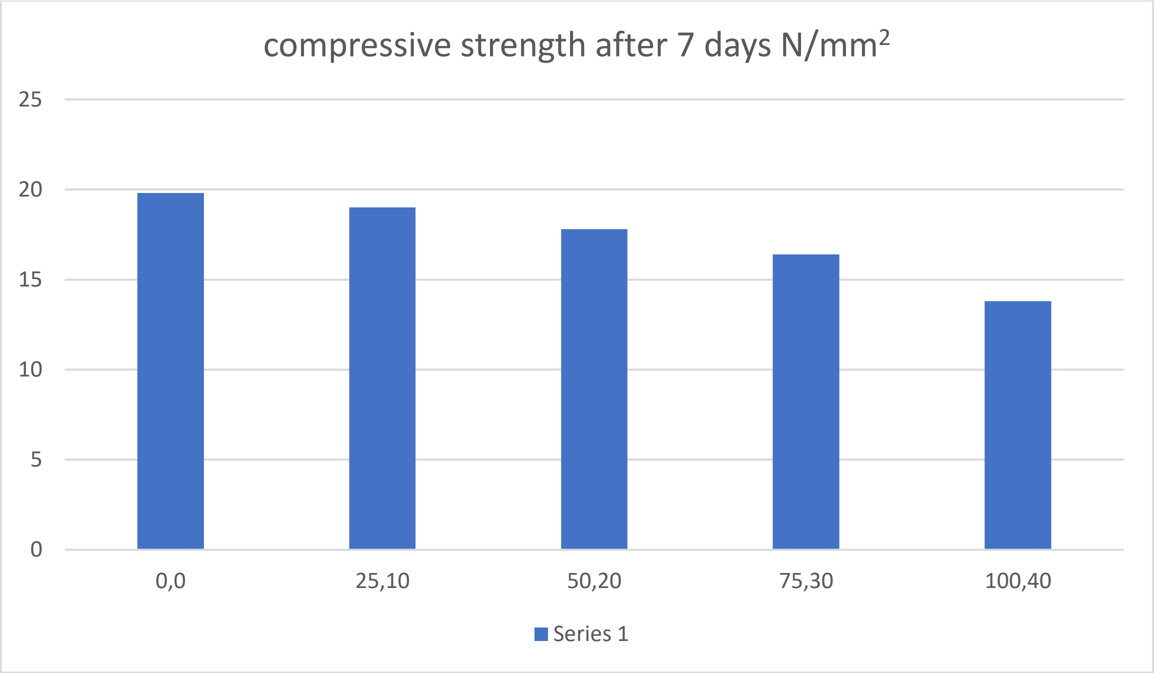

Fig 15 compressive strength after 7 days

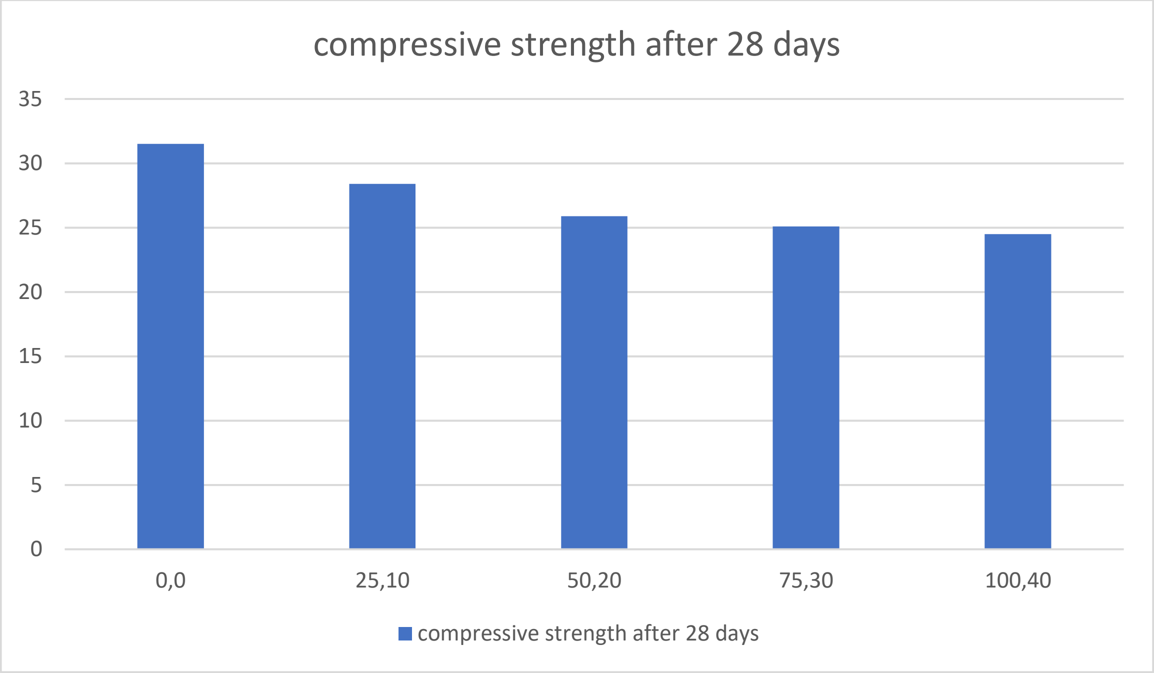

Fig 16 comprssive strength after 28 days

5.4 SPLIT TENSILE STRENGTH

Recycled concrete aggregate	Glass percentage	Avg strength after 7 days N/mm^2	Avg strength after 28 days N/mm^2
0	0	1.98	3.15
25	10	1.72	2.58
50	20	1.62	2.35
75	30	1.49	2.28
100	40	1.25	2.041

Table no 10 shows split tensile strength of specimen

The result shows that concrete mix with more natural aggregate and sand has more tensile strength compared to rest of mixes.as the natural aggregate has more interlocking as compared to recycled concrete aggregate that’s why it has more strength in tensile split test.

5.5 Light mix. Weight character

Studying the average dry weight of cube specimens of each mixture in comparison to the reference mix, it was found that density dropped as waste glass concentration rose. In comparison to the reference mix, the results demonstrated a 5.31% decrease in the dry weight of concrete cube specimens made from a mix containing 40% waste glass. As a result, waste glass concrete is naturally lightweight. Figure 16 shows the dry density of cubes for all combinations, whereas TABLE 8 shows the value of dry density and the percentage change in dry weight relative to the reference

Recycled cocrete aggregate	Glass percentage	Avg dry wt. of cube	Avg dry density of cube	Percentage change in wt. as compared to reference %
0	0	8390	24.86	0
25	10	8330	24.68	-0.724
50	20	8220	24.36	-2.011
75	30	8125	24.07	-3.178
100	40	7946	23.54	-5.309

Table no 11 Shows dry density

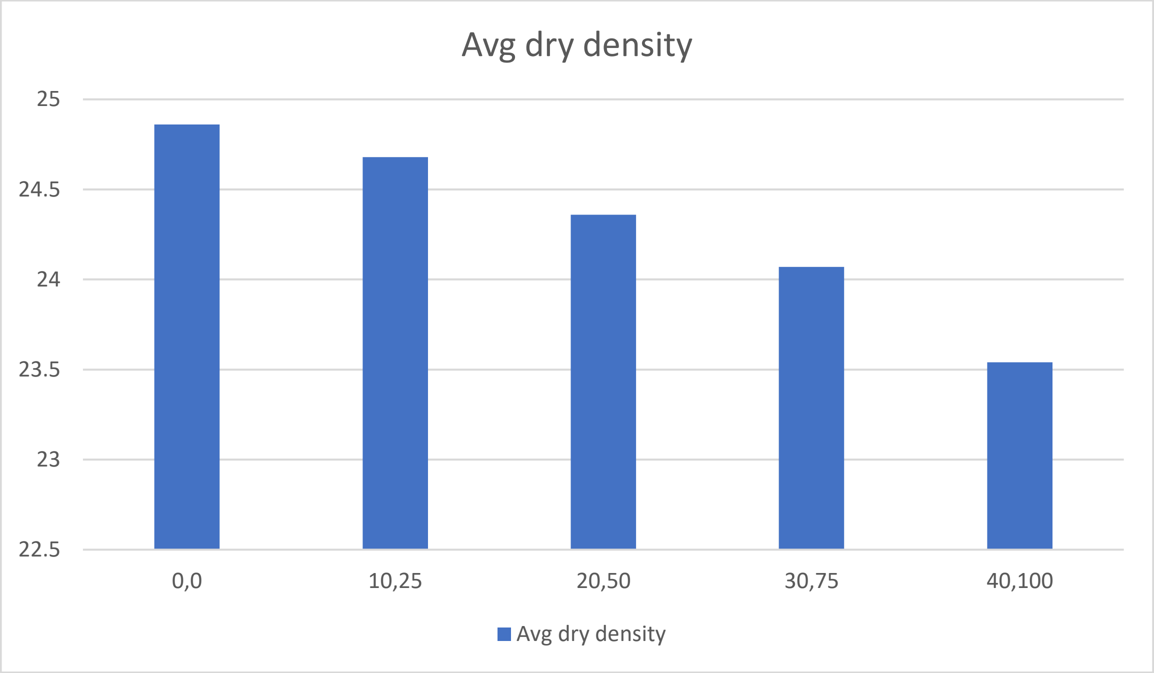

Fig 17 avg dry density

5.6 Water absorption test

Water absorption test was carried out for all mixtures and percentage water absorption was measured. The percentage water absorption decreased with increase in waste glass content. The lowest value of water absorption was found for concrete mix with 40% waste glass content. TABLE 9 depicts the percentage water absorption for all mixtures and Fig. 17 represents percentage water absorption for all mixtures

Recycled concrete aggregate	Glass percentage	Avg dry wt of cube	Avg wet wt of cube	Water absorbed	Percentage water absorbed
0	0	8390	8480	90	1.07
25	10	8330	8410	80	0.96
50	20	8220	8290	70	0.85
75	30	8125	8181	56	0.69
100	40	7946	7990	44	0.55

Table 12 shows percentage water aborbtion

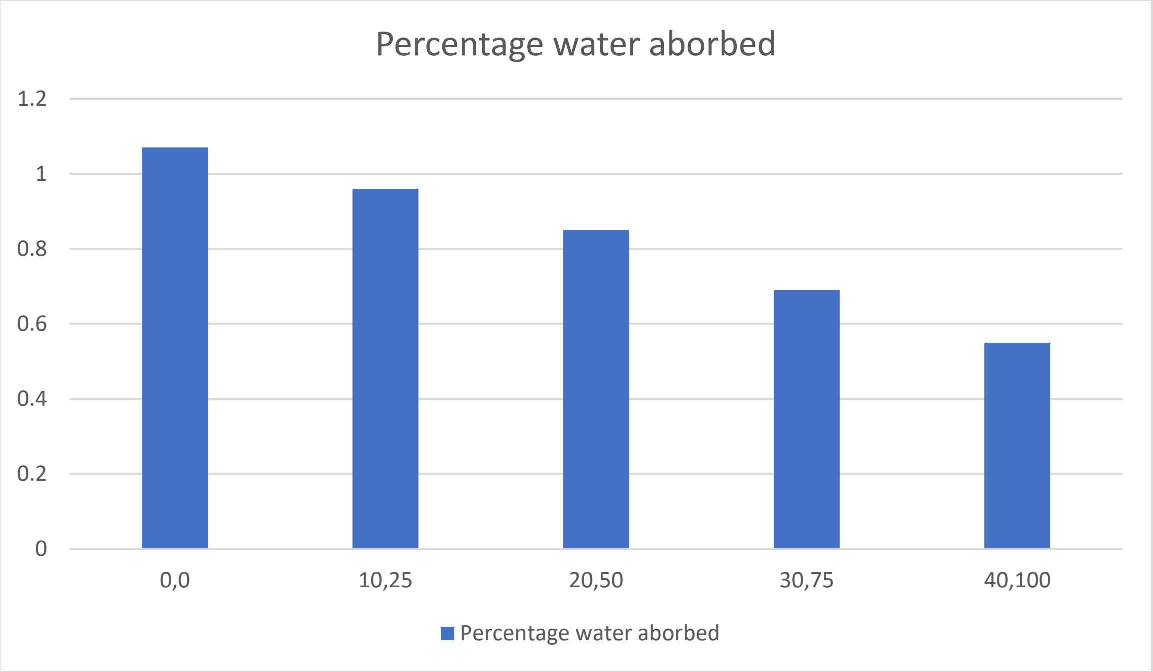

Fig 18 percentage water absorbed

5.7 COST ANALYSIS

Table no 13 cost implications

Cost Implication for 1m^3 of Concrete M25 (1:1:2)				
TYPES OF MIX	**MATERIALS**	**KG**	**RATE/KG**	**AMOUNT**
MIX 1 (0,0)	CEMENT	**360**	7.03	2530
	NCA	**975**	9	8775
	RCA	**---**	5	
	SAND	**362.5**	7.7	2791.25
	WASTE GLASS	**----**	3.7	
	TOTAL			**14096.25**
MIX 2 (10,25)	CEMENT	**360**	**7.03**	**2530**
	NCA	**731.25**	**9**	**6581.25**
	RCA	**250**	**5**	**1250**
	SAND	**326.25**	**7.7**	**2512.125**
	WASTE GLASS	**46.25**	**3.7**	**171.125**
	TOTAL			**13044.5**
MIX 3 (20,50)	CEMENT	**360**	**7.03**	**2530**
	NCA	**487.5**	**9**	**4387.5**
	RCA	**500**	**5**	**2500**
	SAND	**290**	**7.7**	**2233**
	WASTE GLASS	**92.5**	**3.7**	**342.25**
	TOTAL			

				11992.75
MIX 4 (30,75)	CEMENT NCA RCA SAND WASTE GLASS **TOTAL**	**360** **243.75** **750** **253.75** **138.75**	**7.03** **9** **5** **7.7** **3.7**	**2530** **2193.75** **3750** **1953.875** **513.375** **10491.00**
MIX 5 (40,100)	CEMENT NCA RCA SAND WASTE GLASS **TOTAL**	**360** **--** **1000** **217.5** **185**	**7.03** **9** **5** **7.7** **3.7**	**2530** **5000** **1674.75** **684.5** **9889.25**

NOTE: In accordance with the schedule of rates for engineering departments (SOR-2022), these estimates are based on data provided by the Government of Jammu and Kashmir (R&B) Public Works Department. In TABLE the prices of mixes are shown. In MIX 5 the overall cost of mix is reduced by approx. 30%which is good amount.by using recycled concrete aggregate and waste glass the concrete has become economical as well as sustainable as, Recycled aggregates are often more affordable than natural aggregates, making them a cost-effective choice for construction projects. This can lead to significant savings in material cost.

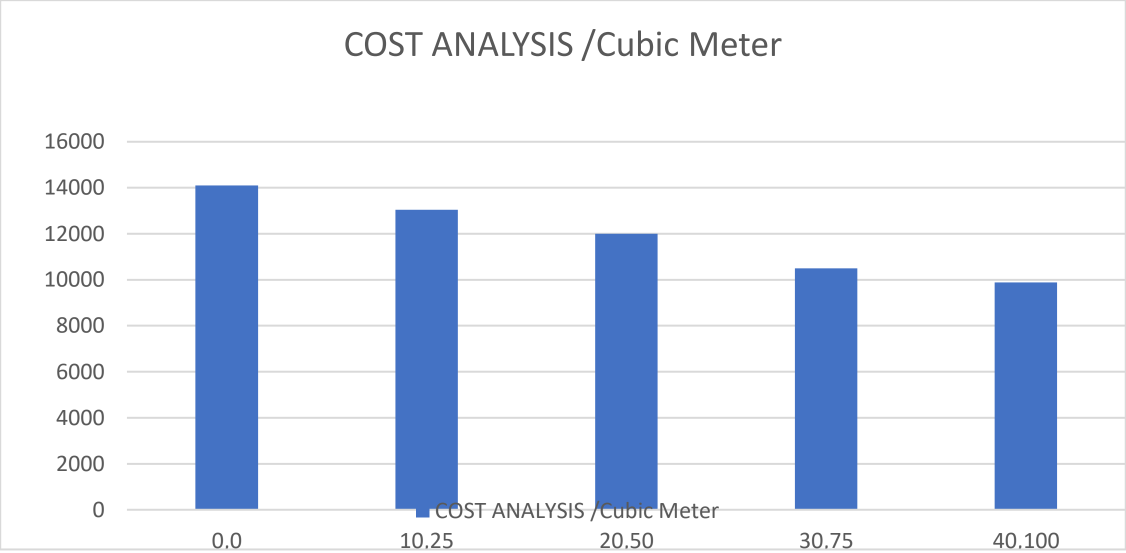

Fig 19 cost implications

6 CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

Investigating alternative materials and methods in the construction business is not only a need but a choice in a world where environmental sustainability is of utmost importance. In order to create sustainable

concrete, waste glass and recycled concrete aggregate (RCA) were used as important ingredients in this thesis. This research has produced important insights that highlight the practicality and variety of advantages of sustainable concrete practises through a thorough investigation.
The following conclusions an be derived from above research.

1. Marginal reduction in strength is observed at replacement of natural aggregate by 75-100% by recycled concrete aggregate and 30-40% replacement of natural sand by waste glass.
2. Recycled concrete aggregate and waste glass can be effectively used as replacement of natural coarse aggregate and sand respectively.
3. Optimum replacement of natural aggregate by RCA by 100% and sand can be effectively replaced by 30%.
4. With increase in RCA the water abortion in concrete decreased.
5. Workability of mix increases with increase with increase of waste glass as coarse aggregate.
6. Use of recycled aggregate can make the concrete more economical as its not a useful product.
7. Use of recycled concrete aggregate can help in replacing natural coarse aggregate which is limited in nature.
8. One of the main conclusions of this study is that using waste glass and RCA in the construction of concrete can significantly reduce its negative environmental effects. This strategy significantly decreases the demand on natural resources by keeping waste from building and demolition out of landfills and by lowering the need for virgin aggregates.

6.2 FUTURE SCOPE

Future studies must continue to address some of the issues that haven't been fully examined in this one as we advance. Among these are the blending ratios and RCA grading optimisations for consistent strength outcomes in a range of applications. Furthermore, more research is necessary to fully understand how various waste glass kinds and their attributes affect the properties of concrete. It is imperative to conduct full life cycle evaluations that evaluate the economic and environmental efficacy of sustainable concrete in comparison to traditional methods.

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