# EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF CEMENT WITH RECYCLED AMORPHOUS SILICATE

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**ABSTRACT**

Concrete is one of the most widely used construction materials due to its high compressive strength, durability, and versatility. However, the extensive use of cement contributes significantly to environmental pollution, particularly through carbon dioxide emissions during cement production. This necessitates the adoption of sustainable alternative materials that can partially replace cement without compromising the performance of concrete.

This study presents an experimental investigation on the partial replacement of cement using recycled amorphous silicate (RAS) in M25 grade concrete prepared with Portland Pozzolana Cement (PPC). Amorphous silicate, being a highly reactive pozzolanic material rich in silica content, reacts with calcium hydroxide released during cement hydration to form additional calcium silicate hydrate (C–S–H) gel. This secondary hydration process contributes to improved microstructure, reduced porosity, and enhanced interfacial bonding within the concrete matrix.

The primary objective of this study is to evaluate the influence of RAS on the fresh and hardened properties of concrete. Different replacement levels of cement with RAS (such as 5%, 10%, 15%, and 20%) were considered to determine the optimum percentage. A plasticizer dosage of 0.5% by weight of cement was incorporated to achieve approximately 15% reduction in water content while maintaining adequate workability and consistency.

The concrete mix design was carried out as per IS 10262:2019 guidelines using PPC, M-Sand as fine aggregate, crushed coarse aggregate, potable water, amorphous silicate, and chemical admixture. Standard cube specimens of size 150 mm × 150 mm × 150 mm were cast, compacted, and cured under controlled conditions. Fresh concrete properties were evaluated using slump test, flow table test, and setting time measurements to assess workability and consistency.

Hardened concrete properties were determined through compressive strength tests at 7 and 28 days of curing. Additionally, durability aspects such as water absorption, permeability, and resistance to microcracking were considered to evaluate the long-term performance of the modified concrete. The incorporation of RAS was found to refine pore structure and reduce capillary voids, thereby enhancing durability characteristics.

The experimental results indicate that the inclusion of amorphous silicate significantly improves compressive strength up to an optimum replacement level, beyond which strength reduction may occur due to dilution effect. The use of plasticizer effectively compensates for the reduced workability caused by the fine particle size of RAS, enabling better compaction and finishing. Furthermore, the improved particle packing and pozzolanic reaction contribute to higher density and reduced permeability of concrete.

**Keywords:** Recycled Amorphous Silicate (RAS), Portland Pozzolana Cement (PPC), M25 Grade Concrete, Partial Cement Replacement, Pozzolanic Activity, Compressive Strength, Workability, Plasticizer, Sustainable Concrete, Durability, Microstructure, Eco-friendly Construction

## INTRODUCTION

### 1.1 General:

Concrete is one of the most widely used construction materials in the world due to its strength, durability, and versatility. In recent years, there has been increasing emphasis on improving concrete properties while reducing the environmental impact associated with cement production.

One of the effective approaches to achieve sustainable concrete is the partial replacement of cement with supplementary cementitious materials. Amorphous silicate, a pozzolanic material rich in reactive silica, plays a significant role in enhancing the properties of concrete. It reacts with calcium hydroxide released during cement hydration to form additional calcium silicate hydrate (C-S-H) gel, which improves the strength, durability, and microstructure of concrete.

However, the incorporation of such materials may influence the workability of concrete. To overcome this, chemical admixtures like plasticizers are used. Plasticizers help in reducing the water–cement ratio while maintaining the required workability of fresh concrete. A lower water–cement ratio results in improved strength and durability. In this study, a plasticizer dosage of 0.5% by weight of cement is used to achieve approximately 15% reduction in water content.

This study focuses on M25 grade concrete prepared using Portland Pozzolana Cement (PPC), where cement is partially replaced with amorphous silicate. The project aims to evaluate the combined effect of amorphous silicate and plasticizer on the workability and strength characteristics of concrete. Fresh concrete properties such as slump and setting time are studied, along with compressive strength evaluation.

### 1.2 Concrete:

Concrete is a composite construction material made from a mixture of cement, fine aggregate (sand), coarse aggregate (gravel or crushed stone), water, and sometimes chemical admixtures. When these materials are mixed in suitable proportions, a plastic mass is formed which can be easily placed and molded into desired shapes. Over time, through the process of hydration, the mixture hardens and gains strength.

In this project, Ordinary Portland Cement (OPC 53 Grade) is used as the binding material. M-Sand (Manufactured Sand) is used as fine aggregate, and crushed stone is used as coarse aggregate. A plasticizer is added to improve workability and reduce water content. Partial replacement of conventional coarse aggregate with RASis also carried out to study its influence on the fresh properties of concrete.

Concrete is valued for its high compressive strength, durability, fire resistance, and adaptability. Because of these properties, it remains one of the most important materials in modern construction.

### 1.3 Historical Details:

The history of concrete dates back thousands of years. Early forms of concrete were used by ancient civilizations such as the Egyptians, who used mixtures of lime and gypsum as binding materials in construction. Around 2600 BC, the Egyptians used these materials in the construction of massive structures such as the pyramids.

The Romans made significant advancements in concrete technology by developing a mixture of lime, volcanic ash, and aggregates. This material, known as Roman concrete, was used to construct remarkable structures such as the Pantheon and the Colosseum, many of which still stand today.

After the fall of the Roman Empire, the knowledge of advanced concrete construction gradually declined. However, interest in concrete revived during the 18th and 19th centuries with the development of Portland cement, which became the primary binding material in modern concrete. Today, concrete technology continues to evolve with the introduction of chemical admixtures, improved mix design methods, and advanced materials, enabling better strength, durability, and sustainability in construction

**1.4 Propertiesof Concrete:**

Concrete has several important properties that make it suitable for construction applications. One of the most significant properties is compressive strength, which allows concrete to withstand heavy loads. This strength results from the binding action of cement and the rigid framework formed by aggregates.

Another important property is workability, which refers to the ease with which concrete can be mixed, transported, placed, and compacted without segregation. The use of plasticizers helps improve workability while maintaining a lower water–cement ratio.

**LITERATURE REVIEW**

**Salem et al. (2016)** studied the effect of superplasticizer dosage on concrete properties and reported that increasing dosage significantly improved workability and compressive strength at a constant water–cement ratio. The study showed enhanced dispersion of cement particles, which reduced internal friction and improved flow characteristics. It also accelerated hydration, contributing to higher early-age strength. Improved uniformity in the mix resulted in better overall performance. However, excessive dosage beyond the optimum level led to segregation and reduced stability of the concrete mix.

**Tareque et al. (2023)** investigated ready-mix concrete with different superplasticizers and found that they enhanced slump retention and increased compressive strength at both early and later ages. The study highlighted reduced water demand without compromising workability. Improved consistency during transportation made the mix more suitable for practical applications. The use of admixtures also reduced bleeding and improved surface finish. Overall, the study confirmed better performance of ready-mix concrete with proper admixture dosage.

**Teymouri et al. (2024)** reviewed modern superplasticizers and concluded that polycarboxylate-based admixtures effectively reduce water demand while maintaining high workability and strength. These admixtures provided extended slump retention compared to conventional types. The study emphasized improved compatibility with supplementary cementitious materials. Reduced shrinkage and cracking were also observed in hardened concrete. The findings support their use in high-performance and sustainable concrete applications.

**Neville (2011)** observed that chemical admixtures improve the dispersion of cement particles, resulting in better hydration and increased workability. The study noted a significant reduction in segregation and bleeding. Improved microstructure led to enhanced compressive strength. Lower permeability contributed to increased durability of concrete. The research established the importance of admixtures in modern concrete technology.

**Aïtcin (2004)** reported that the use of superplasticizers in high-performance concrete reduces porosity and enhances durability and strength. The study highlighted the production of high-strength concrete with low water–cement ratios. Improved resistance to aggressive environmental conditions was observed. Reduced capillary pores enhanced long-term performance. The findings supported the development of advanced concrete materials.

**Shetty (2013)** explained that plasticizers improve flowability and reduce water content, thereby increasing strength and durability. The study emphasized ease of placement and compaction in concrete works. Reduced honeycombing improved structural integrity. Better cohesion minimized segregation issues. Overall, plasticizers were found essential for achieving workable and durable concrete.

**Malhotra and Mehta (2006)** concluded that superplasticizers enhance both fresh and hardened properties of concrete by improving particle dispersion. The study highlighted improved rheological behavior of fresh concrete. Enhanced durability and long-term strength were observed. Reduced need for vibration improved construction efficiency. The research emphasized the role of admixtures in sustainable construction.

**Ramachandran (1995)** explained that superplasticizers act through electrostatic repulsion, reducing flocculation and improving hydration efficiency. The study showed improved cement utilization and reduced water requirement. Uniform microstructure formation enhanced strength characteristics. Reduced water film thickness improved bonding. The findings explained the fundamental mechanism of superplasticizer action.

**Mehta and Monteiro (2014)** highlighted that proper aggregate gradation improves packing density and reduces voids, resulting in better strength and durability. Optimized particle distribution reduced the need for excess cement paste. Improved resistance to shrinkage and cracking was observed. Better interlocking enhanced load transfer. The study emphasized the importance of mix design optimization.

**Sharma and Gupta (2018)** found that the inclusion of smaller aggregates improves compressive strength due to better packing and reduced void spaces. Improved interlocking between particles enhanced load-bearing capacity. Reduced void ratio contributed to higher density. The study also noted better bonding between aggregates and cement paste. Overall, strength improvement was significant with proper grading.

**Reddy and Kumar (2017)** reported that partial replacement with smaller aggregates increases strength up to an optimum level by improving density. Enhanced bonding between aggregate and cement paste improved structural performance. Reduced voids contributed to higher compressive strength. Improved crack resistance was observed. However, excessive replacement reduced workability.

**Singh and Patel (2019)** observed improved compaction and higher strength in concrete containing smaller aggregates. Better particle arrangement reduced permeability. Improved density enhanced durability. The study also highlighted better finishing characteristics. Overall, optimized aggregate size improved concrete performance.

**Kumar and Rao (2015)** concluded that excessive replacement with smaller aggregates may reduce workability and strength. Increased fines raised water demand in the mix. Reduced cohesion affected compaction efficiency. Poor workability led to lower strength development. The study emphasized the need for optimum replacement levels.

**Kannan et al. (2019)** studied partial replacement of coarse aggregates with 6 mm aggregates and found that optimum replacement levels significantly increased compressive strength. Improved packing density reduced void content. Enhanced bonding between aggregate and cement paste contributed to strength gain. The study also observed better uniformity in the mix. However, excess replacement affected workability.

**Ekundayo et al. (2018)** reported that smaller aggregate sizes increase compressive strength but may reduce workability. Increased surface area required more cement paste. Improved strength-to-weight ratio was observed. The study emphasized careful proportioning of materials. Proper mix design was necessary to balance strength and workability.

**Pandurangan et al. (2014)** found that smaller aggregate sizes improve flowability and strength due to enhanced packing density. Reduced voids improved compactness. Better cohesiveness improved mix stability. The study also noted improved finishing quality. Overall, optimized aggregate size enhanced concrete performance.

**Rao and Arun (2015)** showed that the use of superplasticizers in concrete with modified aggregates helps achieve target strength and workability. Reduced water–cement ratio improved strength. Improved compatibility enhanced mix performance. Better flowability facilitated placement. The study emphasized the combined effect of aggregates and admixtures.

**Malhotra (2002)** highlighted that pozzolanic materials improve long-term strength and durability by reacting with calcium hydroxide to form additional C-S-H gel. Reduced heat of hydration minimized thermal cracking. Improved resistance to sulfate attack enhanced durability. Reduced permeability improved service life. The study supported sustainable concrete practices.

**Mehta (1987)** emphasized that pozzolanic reactions refine pore structure, reduce permeability, and enhance durability of concrete. Reduced calcium hydroxide improved chemical resistance. Formation of secondary C-S-H increased strength. Improved microstructure enhanced long-term performance. The study established the importance of pozzolanic materials.

**Sharma and Singh (2020)** studied the use of silica-rich materials and reported that they significantly improve compressive strength and resistance to chemical attack. Reduced porosity improved durability. Enhanced resistance to aggressive environments was observed. Improved microstructure increased density. The study confirmed the benefits of silica-based materials.

**Reddy et al. (2019)** investigated partial replacement of cement with silica-based materials and found improved strength and durability due to pozzolanic activity. Enhanced microstructural densification improved performance. Reduced shrinkage cracks increased stability. Improved resistance to environmental degradation was observed. The study supported eco-friendly materials.

**Kumar et al. (2021)** reported that amorphous silica materials enhance the microstructure of concrete and improve compressive strength by reducing voids and increasing density. Improved interfacial transition zone strengthened bonding. Reduced microcracks enhanced durability. Increased structural integrity was achieved. The study emphasized the importance of silica-rich materials.

**Patel and Shah (2018)** observed that partial replacement of cement with pozzolanic materials improves long-term strength and reduces environmental impact. Reduced carbon emissions supported sustainability. Improved durability enhanced service life. Better utilization of waste materials was achieved. The study highlighted eco-friendly construction practices.

**Mindess et al. (2003)** studied the role of admixtures and supplementary materials in concrete and reported that they significantly improve both fresh and hardened properties. The study highlighted improved workability and reduced water demand. Enhanced durability and resistance to environmental exposure were observed. The use of mineral admixtures improved long-term strength. The research emphasized the importance of material selection in modern concrete design.

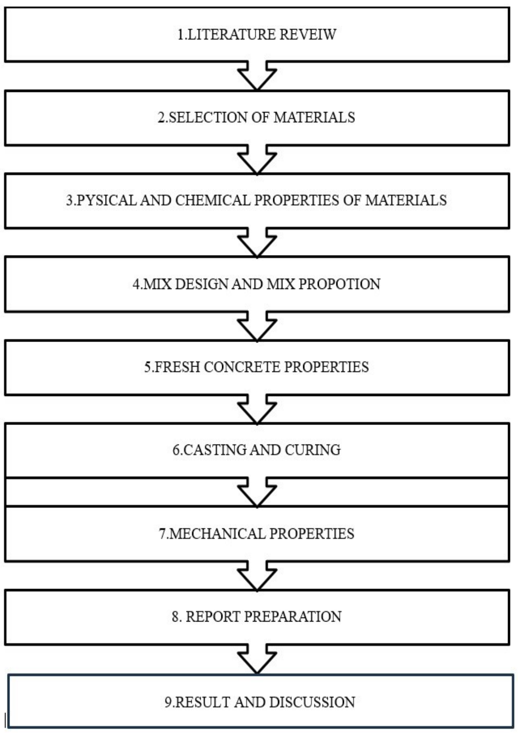
**Neville and Brooks (2010)** examined advanced concrete technology and found that chemical admixtures play a vital role in improving performance. Improved dispersion of cement particles enhanced hydration efficiency. Reduced permeability increased durability. Better control over setting time improved construction practices. The study confirmed the importance of admixtures in high-performance concrete.

**Gambhir (2013)** reported that proper mix design and use of admixtures improve the strength and durability of concrete. The study emphasized reduction in water–cement ratio for higher strength. Improved workability ensured better compaction. Reduced voids increased density and durability. The findings supported efficient and economical concrete production.

## METHODOLY

### 3.1 GENERAL:

The methodology adopted for this study provides a systematic approach to investigate the effects of incorporating steel scrap into concrete cubes The methodology follows standard guidelines and IS codes to maintain reliability and reproducibility of results. The overall process involves material acquisition, mix design formulation, concrete casting, curing, mechanical testing, and performance analysis. Each stage is executed with precision to evaluate the feasibility and structural benefits of utilizing steel scrap as a sustainable additive in concrete production.




**MATERIAL**

**4.1 General**

The selection of suitable materials plays a vital role in determining the strength, durability, and workability of concrete. The overall performance of concrete primarily depends on the quality and characteristics of its constituent materials. In this study, conventional materials such as Portland Pozzolana Cement (PPC), fine aggregate (M-Sand), coarse aggregate, and potable water were used along with amorphous silicate as a partial replacement for cement and a chemical admixture in the form of a plasticizer.

The incorporation of amorphous silicate in the concrete mix is aimed at enhancing the strength and durability properties through its pozzolanic action. Being rich in reactive silica, amorphous silicate reacts with calcium hydroxide released during hydration to form additional calcium silicate hydrate (C-S-H) gel, which improves the microstructure of concrete. However, the inclusion of such supplementary materials may affect the workability of concrete.

**4.2 Materials Used**

The materials used in this investigation include cement, fine aggregate, coarse aggregate, plasticizer, and water. These materials were selected based on their availability, quality, and suitability for concrete production. Each material plays an important role in determining the strength, workability, and durability of concrete.

- Cement
- Amorphous Silicate
- Fine Aggregate
- Coarse Aggregate
- Water

**4.2.1 Cement**

Pozzolanic Portland Cement (PPC) of was used in the preparation of concrete. The cement used in this study conforms to IS 12269 specifications and acts as the primary binding material in the concrete mix.

**4.2.1.1 Type:** Pozzolanic Portland Cement (PPC)
**4.2.1.2 Specific Gravity:** 3.15
**4.2.1.3 Standard Consistency:** 32%
**4.2.1.4 Initial Setting Time (Observed in Project):** 35 min
**4.2.1.5 Final Setting Time (Observed in Project):** 600 min

Fig 4.1 Cement

**4.2.1.5 Reason for Variation:**

- Use of Amorphous silicate
- Partial replacement Cement
- Change in workability and hydration behavior

**TABLE 1.0 : MATERIAL TESTING RESULTS FOR CEMENT**

| S. No. | Test Name | IS Code | Observed Result | Permissible Limit (IS) | Remarks |
|---|---|---|---|---|---|
| 1 | Specific Gravity | IS 4031 (Part 11):1988 | 3.15 | 3.10 – 3.15 | Satisfactory |
| 2 | Initial Setting Time | IS 4031 (Part 5):1988 | 35 minutes | ≥ 30 minutes | Satisfactory |
| 3 | Final Setting Time | IS 4031 (Part 5):1988 | 600 minutes | ≤ 600 minutes | Satisfactory |
| 4 | Fineness Test (90 µm sieve) | IS 4031 (Part 1):1996 | 6 % | ≤ 10 % | Satisfactory |

### 4.2.2 Fine Aggregate

Fine aggregate used in this study consists of Manufactured Sand (M-Sand) obtained from crushed granite stone. The sand conforms to Zone II grading as per IS 383 specifications and is used to fill the voids between coarse aggregates and improve workability.

**4.2.2.1 Type:** Manufactured Sand (M-Sand)

**4.2.2.2 Source:** Crushed granite stone

**4.2.2.3 Zone:** Zone II (as per IS 383)

**4.2.2.4 Specific Gravity:** 2.60 – 2.70

**4.2.2.5 Water Absorption:** 1% – 2%

**4.2.2.6 Maximum Particle Size:** 4.75 mm


Fig 4.3 Fine aggregate (M Sand)

**TABLE 2.0 : MATERIAL TESTING RESULTS FOR FINE AGGEREGATE**

| S. No. | Test Name | IS Code | Observed Result | Permissible Limit (IS) | Remarks |
|---|---|---|---|---|---|
| 1 | Specific Gravity | IS 2386 (Part 3):1963 | 2.60 | 2.5 – 3.0 | Satisfactory |
| 2 | Water Absorption | IS 2386 (Part 3):1963 | 1.2 % | ≤ 2 % | Satisfactory |

**TABLE 2.1: SIEVE ANALYSIS FOR FINE AGGREGATE (M-SAND)**

| Sieve Size (mm) | Weight Retained (g) | % Retained | % Passing |
|---|---|---|---|
| 4.75 | 80 | 4.0 | 96.0 |
| 2.36 | 120 | 6.0 | 90.0 |
| 1.18 | 160 | 8.0 | 82.0 |
| 0.6 | 260 | 13.0 | 69.0 |
| Pan | 1380 | 69.0 | 0 |

### 4.2.3 Coarse Aggregate

Crushed stone aggregates with a nominal maximum size of 20 mm were used as coarse aggregates in the concrete mix. In addition to conventional aggregates, partial replacement was carried out using 6 mm aggregates in different percentages to study their influence on workability and performance of concrete.

**4.2.3.1 Type:** Crushed Stone Aggregate

**4.2.3.2 Source:** Granite / locally available rock

**4.2.3.3 Size:**20 mm (Nominal)

**4.2.3.4 Specific Gravity:** 2.65 – 2.85

**4.2.3.7 Maximum Particle Size:** 20 mm

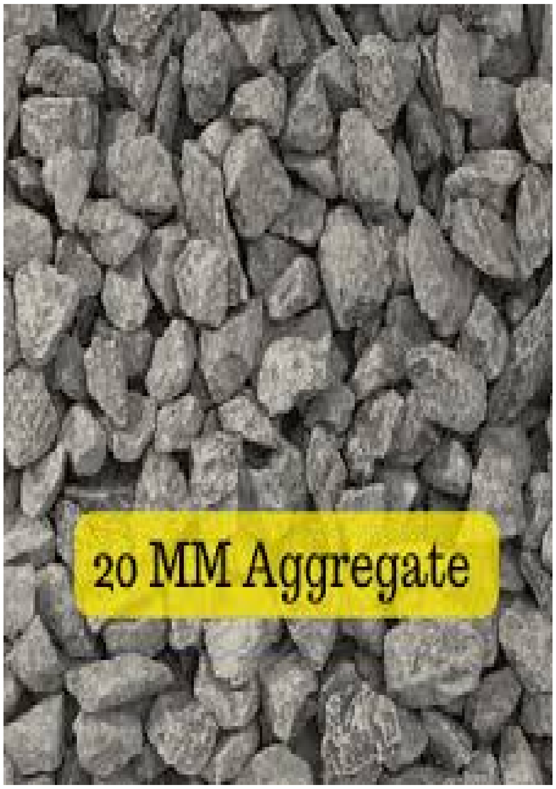



Fig 4.3 Coarse aggregate

**4.2.3.8 Reason for Selection:**

• Provides structural strength and stability to concrete

• Reduces voids and improves workability

**TABLE 3.0 : MATERIAL TESTING RESULTS FOR COARSE AGGREGATE (20mm)**

| S.No. | Test Name | IS Code | Observed Result | Permissible Limit (IS) | Remarks |
|---|---|---|---|---|---|
| 1 | Specific Gravity | IS 2386 (Part 3):1963 | 2.72 | 2.5 – 3.0 | Satisfactory |
| 2 | Water Absorption | IS 2386 (Part 3):1963 | 0.6 % | ≤ 2 % | Satisfactory |

**TABLE 3.1 : MATERIAL TESTING RESULTS FOR RECYCLED AMORPHOUS SILICATE**

| S. No. | Test Name | IS Code | Observed Result | Permissible Limit (IS) | Remarks |
|---|---|---|---|---|---|
| 1 | Specific Gravity | IS 2386 (Part 3):1963 | 2.72 | 2.5 – 3.0 | Satisfactory |
| 2 | Water Absorption | IS 2386 (Part 3):1963 | 0.6 % | ≤ 2 % | Satisfactory |
| 3 | Fineness (90μ Sieve Passing) | IS 4031 (Part 1): 1996 | 92 % | ≥ 90 % | Satisfactory |
| 4 | Bulk Density | IS 2386 (Part 3): 1963 | 1380 kg/m³ | 1200 – 1800 kg/m³ | Satisfactory |
| 5 | Pozzolanic Activity Index | IS 1727: 1967 | 75 % | ≥ 70 % | Satisfactory |

**4.2.4 RAS**

Recycled Amorphous Silicate was used as a supplementary cementitious material in the concrete mix to partially replace cement. It acts as a pozzolanic material and contributes to strength development by reacting with calcium hydroxide released during cement hydration. The inclusion of RAS helps improve the microstructure of concrete and reduces the overall cement content, making the mix more sustainable.

**4.2.4.1 Type:** Pozzolanic material (Supplementary Cementitious Material)

**4.2.4.2 Product Used:** Obtained from processed silica-rich waste material (e.g., recycled glass/silicate material)

**4.2.4.3 Company:**Fosroc

**4.2.4.4 Dosage Used:** Partially replaced with cement at varying percentages (e.g., 5%, 10%, 15%,20%)

**4.2.4.5 Purpose:**

• To partially replace cement and reduce environmental impact
• To utilize pozzolanic properties for strength

enhancement

• To improve durability and microstructure of concrete

**4.2.4.6 Advantages:**

• Enhances compressive strength due to pozzolanic reaction

• Improves durability and resistance to permeability

• Reduces cement consumption and $CO_2$ emissions

• Refines pore structure and reduces voids

Fig 4.4 Recycled Amorphous Silicate

**4.2.5 Water**

Potable water free from harmful substances such as oils, acids, and salts was used for mixing and curing the concrete. The water used satisfies the requirements specified in IS 456:2000 for concrete production.

**4.3 Scope of the Project**

• The main scope of this study is to evaluate the influence of partial replacement of cement using recycled amorphous silicate (RAS) on the workability and overall performance of concrete. The use of pozzolanic materials like RAS helps in improving the properties of concrete while reducing cement consumption and environmental impact.

• Another important aspect of this study is the preparation of a control mix and several modified mixes by partially replacing Portland Pozzolana Cement (PPC) with RAS at different replacement levels (such as 5%, 10%, and 15%). This helps in understanding the effect of RAS on the strength and behavior of M25 grade concrete.

• The study also focuses on the use of a plasticizer to improve the workability of concrete. A dosage of 0.5% by weight of cement is used to achieve approximately 15% reduction in water content while maintaining the desired consistency.

• Another scope of the study is to assess the compressive strength of concrete by casting and testing standard cube specimens at different curing periods (7 days and 28 days). This helps in analyzing the strength development due to the pozzolanic reaction of RAS.

**4.4 Objectives**

• To study the effect of partial replacement of cement with recycled amorphous silicate (RAS) in concrete mixtures and analyze how it improves strength and durability through pozzolanic reaction.

• To investigate the influence of replacing Portland Pozzolana Cement (PPC) with RAS at different percentages and examine its impact on the overall performance of concrete.

• To evaluate the mechanical properties of concrete, such as compressive strength and durability, when RAS is incorporated into the concrete mix.

• To analyze the behavior of fresh concrete by studying parameters like slump value, consistency, and ease of placement when plasticizer is used along with RAS.

• To study the combined effect of RAS and plasticizer in reducing the water–cement ratio while maintaining the required workability of concrete.

• To understand the influence of amorphous silicate on the microstructure of concrete, particularly its role in reducing voids and improving density through pozzolanic activity.

• To compare the performance of conventional concrete (without RAS) and modified concrete containing different percentages of RAS.

• To develop an improved concrete mix design that provides better workability, higher strength, and sustainable material utilization by incorporating RAS and plasticizer.

**CUBE MIX DESIGN**

**5.1 MIXING PROCEDURE**

The mixing procedure for preparing concrete cubes with plasticizer involves several steps to ensure a uniform and well-mixed concrete. Proper mixing helps in achieving good workability, strength, and durability of the concrete mix.

### 5.1.1 Materials

• Cement
• Recycled Amorphous Silicate
• Fine Aggregate (Sand)
• Coarse Aggregate
• Water

### 5.1.2 Equipment

• Concrete mixer
• Weighing scale
• Mixing trays or buckets
• Trowel or mixing tool
• Cube moulds (150 mm × 150 mm × 150 mm)
• Vibrating table or tamping rod

## 5.2 CASTING OF CONCRETE CUBES

The concrete mix was prepared by thoroughly mixing cement, fine aggregates, coarse aggregates, water, and plasticizer. The following procedure was followed.

### 5.2.1 Batching

All materials were measured by weight according to the designed mix proportion to ensure accuracy and consistency in the concrete mix.

### 5.2.2 Mixing

First, the dry materials such as cement, fine aggregate, and coarse aggregate were mixed thoroughly until a uniform colour was obtained. After that, water mixed with plasticizer was gradually added and mixed properly to achieve a homogeneous concrete mix.

Fig 5.1 Mixing

### 5.2.3 Casting

The prepared concrete was poured into standard cube moulds of size 150 mm × 150 mm × 150 mm in three layers. Each layer was compacted properly using a vibrator or tamping rod to remove entrapped air and ensure proper compaction.

Fig 5.2 Casting

### 5.2.4 Curing

After 24 hours, the cubes were removed from the moulds and placed in a water curing tank. The specimens were cured for 7 days and 28 days at room temperature to allow proper hydration and strength development.

Fig 5.3 Curing

**5.2.5 Mix Design Calculation**
M25 MIX DESIGN CALCULATION

**Codes Referred**
**IS 10262:2019 : Concrete Mix Proportioning**
**IS 456:2000 : Plain and Reinforced Concrete**

**5.2.5.1 Target Mean Strength**
Given :
Target Mean Strength = fck + 1.65 × S
Where:
fck = 25 MPa
S = Standard deviation (4 MPa for M25)
Target Mean Strength = 25 + (1.65 × 4)
= 25 + 6.6
= **31.6 MPa**
**Calculation :**
Selection of Water-Cement Ratio
Adopt w/c ratio = 0.45
Check durability condition:
Maximum w/c ratio for Moderate Exposure = 0.45
Reference:
IS 10262:2019 Clause 6.3
IS 456:2000 Table 5
Water Content :
From IS 10262:2019 Table 4
Water content for 20 mm aggregate = 186 litres
Assume reduction due to plasticizer ≈ 15%
Water = 186 − (0.15 × 186)
= 186 − 27.9
= 160 litres
Adopt Water = 160 L **IS 456:2000 Table 5**

**5.2.5.3 Water Content**
Water content for 20 mm aggregate : 186 litres
**(Source : IS 10262:2019 Table 4)**

**5.2.5.4 Water calculation :**
Water : 186 − (0.15 × 186)
Water : 186 − 27.9
Water : 160 litres
Adopt Water : 160 L

**5.2.5.5 Cement Content**
Formula:
Cement = Water / (w/c ratio)
= 186 / 0.45
= **413 kg/m³**
Check minimum cement content (IS 456 Table 5)
Minimum required = 300 kg/m³
Provided = 413 kg/m³ (OK)

**5.2.5.6 Absolute Volume Method**
Specific Gravity:
Cement = 3.15
Fine Aggregate = 2.65
Coarse Aggregate = 2.70
RAS= 2.5

**5.2.5.7 Volume of Cement**
= 320 / (3.15 × 1000)
= 320 / 3150
= 0.1016 m³
Volume of Water
= 160 / 1000
= 0.16 m³

**5.2.5.8 Volume of Water**
Volume of Water : Water / 1000
Volume of Water : 160 / 1000
Volume of Water : 0.16 m³

**5.2.5.9RAS**
Cement = 392 kg
WGP = 21 kg
Fine Aggregate = 686 kg
Coarse Aggregate = 1159 kg
Water = 186 kg

**5.2.5.11 Total Volume of Cement + Water + Plasticizer**
Total Volume : 0.1016 + 0.16 + 0.00213
Total Volume : 0.26373 m³

**5.2.5.12 Volume of Aggregates**
=1 – (0.131 + 0.186)
= 1 – 0.317
= 0.683 m³

**5.2.5.13 Aggregate Distribution**
From IS 10262:2019 Table 5
Volume of Coarse Aggregate : 0.62
Volume of Fine Aggregate : 0.38

**5.2.5.14 Coarse Aggregate Calculation**
= 0.683 × 0.62
= 0.423 m³
Mass = 0.423 × 2.74 × 1000
= **1159 kg**

**5.2.5.15 Fine Aggregate Calculation**
= 0.683 × 0.38
= 0.259 m³

**5.2.5.16 Mass of Fine Aggregate :**
Mass = 0.259 × 2.65 × 1000
= **686 kg**

**5.2.5.17 Final Mix Proportion (per 1 m³)**
Cement = 413 kg
Water = 160 litres
Fine Aggregate = 686 kg
Coarse Aggregate = 1159 kg
RAS = 81kg
**5.2.5.18 Mix Ratio :**
Cement : Fine Aggregate : Coarse Aggregate
**1 :1.66 : 2.80**
Water-Cement Ratio = 0.45

**TABLE: 5.1 MIX PROPORTION RATIOS (PER 1m$^3$)**

| Material | Mass (kg/m³) | Ratio |
|---|---|---|
| Cement | 413 | 1 |
| Fine Aggregate | 686 | 1.66 |
| Coarse Aggregate | 1159 | 2.80 |
| Water | 160 Litres | 0.45 (w/c) |
| RAS | 81 | 20% of Cement |

**5.3MIXING PROPORTION**
Material Quantities per Cube – M25 Mix (RAS REPLACEMENT OF CEMENT)

| S.No | Mix | Cement (kg/m³) | Cement (%) | Cement (kg/m³) | Fine Aggregate (kg/m³) | Coarse Aggregate 20mm (kg/m³) | RAS (%) | RAS (kg/m³) | W/C Ratio |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Mix | 413 | 0% | 413 | 686 | 1159 | - | - | 0.45 |
| 2 | mix1 | 413 | 5% | 397 | 686 | 1159 | 5% | 21 | 0.45 |
| 3 | mix2 | 413 | 10% | 371 | 686 | 1159 | 10% | 41 | 0.45 |
| 4 | mix3 | 413 | 15% | 352 | 686 | 1159 | 15% | 61 | 0.45 |
| 5 | mix4 | 413 | 20% | 330 | 686 | 1159 | 20% | 81 | 0.45 |

5%, 10%, 15% and 20% of coarse aggregate weight (1159kg) is replaced with RAS. 15% of Coarse Aggregate = 0.15 × 1159 = **173.8 kg**

**TEST ON FRESH CONCRETE**

**General:**

To evaluate the workability and consistency of concrete containing partial replacement of 20 mm aggregate with RASand the addition of plasticizer, fresh concrete tests such as the slump cone test and flow test were conducted.

**6.1 Slump Cone Test**

**6.1.1 Objective:**

To determine the workability of fresh concrete mixes with 0%, 15%, 20%, 25%, and 30% replacement of 20 mm coarse aggregate by 6 mm aggregate.

**6.1.2 Apparatus Used:**

- Slump Cone
- Tamping Rod
- Base Plate
- Scale for measuring slump

**6.1.3 Procedure:**

1. The slump cone was placed on a clean, flat, and non-absorbent surface.
2. Fresh concrete was filled into the cone in three equal layers.
3. Each layer was tamped 25 times using a tamping rod.
4. The top surface was levelled and the cone was lifted vertically.
5. The decrease in height of the concrete was measured as the slump value.

**6.1.4 Observation:**

| Mix Type | Replacement of RAS (%) | Slump (mm) |
|---|---|---|
| Control Mix | 0% | 79 |
| Mix A | 5% | 81 |
| Mix B | 10% | 84 |
| Mix C | 15% | 89 |
| Mix D | 20% | 92 |

Concrete mixes with higher percentages of RASshowed slightly increased slump values, indicating improved workability due to better particle packing and the use of plasticizer.

**6.2 Flow Test**

**6.2.1 Objective:**

To determine the flowability of fresh concrete mixes with 0%, 15%, 20%, 25%, and 30% replacement of 20 mm coarse aggregate by 6 mm aggregate, and with the addition of plasticizer.

**6.2.2 Apparatus Used:**

• Flow Table

• Tamping Rod

• Funnel (if required)

• Measuring Scale

**6.2.3 Procedure:**

1. The flow table was placed on a clean, horizontal surface.
2. Fresh concrete was filled into the mold on the flow table.
3. The concrete was tamped lightly to remove air voids.
4. The flow table was lifted and dropped 15 times using the standard handle.
5. The final diameter of the spread concrete was measured in two perpendicular directions, and the average value was recorded as the flow diameter.
6. The flow percentage was calculated as:

**6.2.4 Observation:**

| MixType | RAS(%) | Flow (%) | Flow Diameter (mm) |
|---|---|---|---|
| ControlMix | 0% | 78 | 400 |
| MixA | 5% | 76 | 390 |
| MixB | 10% | 74 | 380 |
| MixC | 15% | 72 | 370 |
| MixD | 20% | 70 | 360 |

The gradual increase in flow percentage and diameter indicates that the inclusion of RAS enhances the workability of concrete. This improvement may be due to the finer particle size and smooth texture of RAS, which reduces internal friction and improves the flow characteristics. The highest workability is achieved at **20% replacement**, but further tests (such as strength and durability) are necessary to determine the optimum replacement level for practical applications.

**TEST ON HARDENED CONCRETE**

**GENERAL**

To assess the strength and internal quality of concrete containing partial replacement of coarse aggregate with 6 mm aggregate, two important tests were conducted: the **compressive strength test** and the **fresh concrete property tests**.

**7.1 Compressive Strength Test**

**7.1.1 Objective:**

To determine the compressive strength of concrete cubes with 0%, 15%, 20%, 25%, and 30% coarse aggregate replacement using RAS and 0.5% plasticizer incorporated to improve performance.

**7.1.2 Apparatus Used:**

- Compression Testing Machine
- Concrete cube moulds (150 mm × 150 mm × 150 mm)

**7.1.3 Procedure:**

1. Concrete cubes were cast and cured for 7 and 28 days.
2. After curing, the cubes were taken out and surface water was removed.
3. Each cube was placed in the compression testing machine.
4. Load was applied gradually until the specimen failed.

5. The maximum load was noted and the compressive strength was calculated using the formula:

**7.1.4 Observation:**

| S.NO | MixType | Compressive Strength at 7Days (MPa) |
|---|---|---|
| 1 | Control | 18.5 |
| 2 | Mix1 | 19.2 |
| 3 | Mix2 | 20.1 |
| 4 | Mix3 | 21.3 |
| 5 | Mix4 | 17.0 |

| S.NO | MixType | Compressive Strength at 28 Days (MPa) |
|---|---|---|
| 1 | Control | 27.8 |
| 2 | Mix1 | 29.2 |
| 3 | Mix2 | 31.0 |
| 4 | Mix3 | 31.7 |

| MixType | Split TensileStrength at7Days (MPa) |
|---|---|
| Control | 1.85 |
| Mix1 | 1.95 |
| Mix2 | 2.10 |
| Mix3 | 2.70 |
| Mix4 | 2.00 |

| MixType | Split Tensile Strength at Days(MPa) |
|---|---|
| Control | 2.75 |
| Mix1 | 2.90 |
| Mix2 | 3.10 |
| Mix3 | 3.50 |
| Mix4 | 3.00 |

Cubes with 15% to 30% replacement of RAS showed an increase in compressive strength compared to the normal mix. The 30% replacement gave the highest strength due to improved packing density and reduced voids in the concrete matrix.

**7.1 Split Tensile Strength Test**

**7.1.1 Objective:**

To determine the split tensile strength of cylindrical concrete specimens with 0%, 5%, 10%, 15%, and 20% coarse aggregate replacement using 6 mm aggregate.

**7.1.2 ApparatusUsed:**

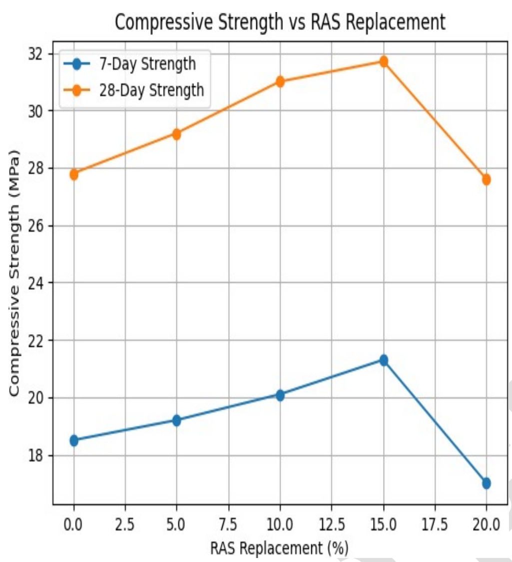
- Compression Testing Machine: Capable of applying a
- Cylindrical Moulds: Standard size of 150mm diameter rand 300 mm length.
- Packing Strips: Plywood or similar material to distribute the load.

**7.1.3 Procedure:**

1. Cylindrical specimens were cast for eachmixproportion and cured for 7 and 28 days.
2. Aftercuring,thespecimenswerewipeddryandthediameterandlengthwere measured.
3. The specimen was placed horizontally between the loading surfaces of thecompression testing machine.
4. Plywood strips were placed between the specimen and the plates to ensureuniform load distribution.
5. Load was applied continuously without shock until the specimen failed bysplitting.
6. The split tensile strength was calculated using the formula:

**7.1.4 Observation:**

- Splittensilestrength**increasesupto15% RASreplacement**
- Maximumvalueobservedat**15%RAS(optimumlevel)**
- Strength slightly decreases beyond 15% but remains higher than control mix
- Improvement is due to **better bonding and denser micro structure**




**RESULTS**

## 8.0 RESULTS AND OBSERVATIONS

The following sections detail the experimental results for both fresh and hardened concrete properties. These results evaluate the performance of the control mix against modified mixes containing 6 mm aggregate replacement and 0.5% plasticizer.

### 8.1 Fresh Concrete Property Tests (Workability)

#### 8.1.1 Objective:

To evaluate the fresh concrete properties, specifically workability and consistency, through slump and flow characteristics.

#### 8.1.2 Apparatus Used:

- Slump cone and tamping rod.
- Flow table, mold, and calipers.

#### 8.1.3 Procedure:

1. The slump test was conducted by filling the slump coneinlayersand measuring the subsidence of the concrete after the cone was removed.
2. The flow test was performed by placing concrete in a mold on a flow table, jolting the table, and measuring the resulting spread diameter.

#### 8.1.4 Observation:

| MixType | Replacementof RAS (%) | Slump(mm) | Flow(%) | Flow Diameter (mm) |
|---|---|---|---|---|
| ControlMix | 0% | 82 | 78 | 400 |
| MixA | 5% | 80 | 76 | 390 |
| MixB | 10% | 78 | 74 | 380 |
| MixC | 15% | 75 | 72 | 370 |
| MixD | 20% | 72 | 70 | 360 |

### 8.2 Setting Time Tests

#### 8.2.1 Objective:

To determine the initial and final setting times of the concrete mixes to analyze the effect of aggregate replacement and reduced water content.

#### 8.2.2 ApparatusUsed:

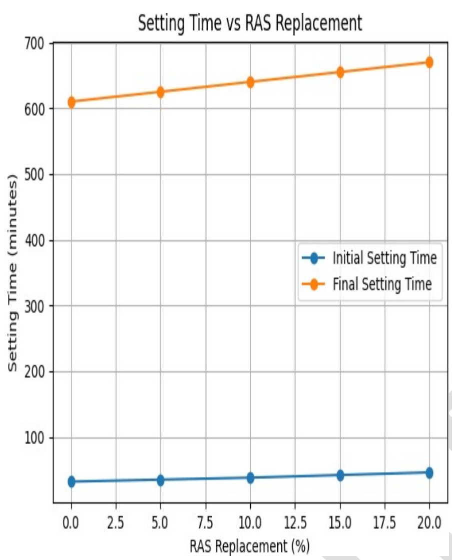
- Vicatapparatuswithinitialandfinalsettingneedles.

#### 8.2.3 Procedure:

1. The initial setting time was recorded when theneedle ceased to penetrate the block to a certain depth.
2. The final setting time was recorded when the needle made an impression but the attachment failed to do so.

#### 8.2.4 Observation:

| MixType | Coarse Replacement (%) | Initial Set (min) | Final Set(min) |
|---|---|---|---|
| ControlMix | 0% | 32 | 610 |
| Mix1 | 5% | 35 | 625 |
| Mix2 | 10% | 38 | 640 |
| Mix3 | 15% | 42 | 655 |
| Mix4 | 20% | 46 | 670 |




**Compressive Strength Test**

**8.2.5 Objective:**

Todeterminethecompressivestrength ofconcretecubestoevaluatetheload-bearing capacity of modified mixes.

**8.2.6 ApparatusUsed:**

- CompressionTestingMachine(CTM).
- Concretecubemoulds(150mmx150mmx 150mm)

**8.2.7 Procedure:**

1. Concretecubeswerecastandcuredfor7and28days.
2. Loadwasappliedgraduallyuntilthespecimenfailed,andthe maximumload was noted.

**8.2.8 Observation:**

| Mix Type | Coarse Replacement (%) | 7-Day Strength (MPa) | 28-Day Strength (MPa) |
|---|---|---|---|
| Control | 0% | 18.5 | 27.8 |
| Mix1 | 5% | 19.2 | 29.2 |
| Mix2 | 10% | 20.1 | 31.0 |
| Mix3 | 15% | 21.3 | 31.7 |
| Mix4 | 20% | 17.0 | 27.6 |

**8.3 SplitTensileStrengthTest**

**8.3.1 Objective:**

To evaluate the resistance of concrete specimens to longitude in al cracking under indirect tension.

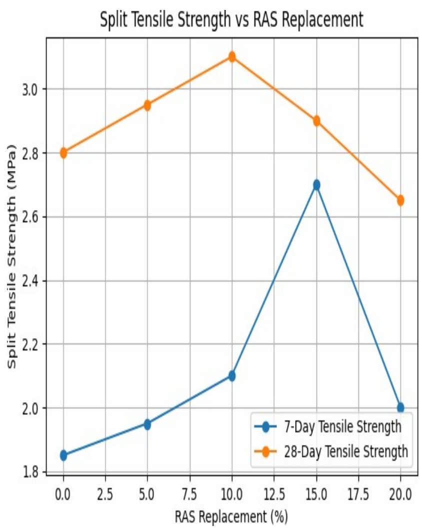
**8.3.2** ApparatusUsed:

- CompressionTestingMachine.
- Cylindricalmoulds(150mmx300mm).

**8.3.3 Observation:**

| MixType | Coarse Replacement (%) | Split Tensile Strengthat7 Days (MPa) | 28-DayTensile Strength (MPa) |
|---|---|---|---|
| Control Mix | 0% | 1.85 | 2.80 |
| ModifiedMix 1 | 5% | 1.95 | 2.95 |

| | | | |
|---|---|---|---|
| **ModifiedMix 2** | 10% | 2.10 | 3.10 |
| **ModifiedMix 3** | 15% | 2.70 | 2.90 |
| **ModifiedMix 4** | 20% | 2.00 | 2.65 |




## CONCLUSION

### 9.1 GENERAL

### 9.1 CONCLUSION

This experimental study was carried out to investigate the performance of M25 grade concrete prepared using Portland Pozzolana Cement (PPC) with partial replacement of cement by recycled amorphous silicate (RAS). The main objective was to evaluate the effect of RAS on the workability, strength, and overall performance of concrete. A plasticizer dosage of 0.5% by weight of cement was used to achieve approximately 15% reduction in water content while maintaining the required workability. The study aimed to determine whether RAS can be effectively utilized as a sustainable alternative material without compromising the structural performance of concrete.

### 9.2 SUMMARY OF STUDY

The project focused on the combined effect of pozzolanic material (RAS) and chemical admixture (plasticizer) in producing high-performance concrete. The experimental program involved:

• Preparation of a control mix and modified mixes with different percentages of RAS replacement (such as 5%, 10%, and 15%) based on IS 10262:2019 guidelines.
• Conducting fresh concrete tests such as slump test and setting time test to evaluate workability and consistency.
• Evaluating hardened properties by testing compressive strength of concrete cubes at 7 days and 28 days.
• Studying the influence of amorphous silicate on the microstructure and density of concrete due to pozzolanic reaction.

### 9.3 TEST FINDINGS

The results obtained from the experimental investigation revealed the following key observations:

• **Workability:** The addition of plasticizer improved the workability of concrete even at reduced water–cement ratio. However, the inclusion of RAS slightly reduced workability due to its fine particles, which was effectively compensated by the plasticizer.

• **Setting Characteristics:** The initial and final setting times showed a marginal increase with the increase in RAS content due to slower pozzolanic reaction, which is beneficial for better handling and placement.

• **Compressive Strength:** The compressive strength of concrete increased with the addition of RAS up to an optimum replacement level. The improved strength is attributed to the formation of additional C-S-H gel due to pozzolanic reaction. Beyond the optimum level, strength showed a slight reduction.

• **Microstructural Improvement:** The incorporation of RAS refined the pore structure and reduced voids in the concrete matrix, resulting in a denser and more homogeneous structure.

• **Overall Performance:** The combination of RAS and plasticizer resulted in improved strength, better durability characteristics, and efficient utilization of materials.

## 9.4 MATERIAL SUSTAINABILITY AND SCOPE

The findings of this study highlight several advantages for sustainable construction practices:

• **Cement Reduction:** Partial replacement of cement with RAS reduces cement consumption, thereby lowering carbon emissions and environmental impact.

• **Waste Utilization:** The use of recycled amorphous silicate promotes the effective utilization of waste materials in construction.

• **Water Conservation:** The use of plasticizer enables reduction in water content without affecting workability, contributing to efficient resource usage.

• **Improved Performance:** The study demonstrates that M25 grade concrete with PPC can achieve better strength and durability with the incorporation of RAS.

• **Future Scope:** Further research can be carried out on long-term durability aspects such as resistance to chemical attack, permeability, and performance in reinforced concrete structures.

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