

Performance Comparison of Normal Concrete and Sacred-Ash-Based Partial Replacement Concrete

Mr. Vaibhav S. Poman¹, Prof. Saminabi M. Kazi, and Dr. Vaibhav V. Shelar³

¹Student, Trinity College of Engineering & Research, Pune

²Assistant Professor, Trinity College of Engineering & Research, Pune

³Head of Department (civil Engg.), Trinity College of Engineering & Research, Pune

Abstract: Sustainable construction encourages the use of waste materials to reduce natural resource consumption and environmental impact. This study investigates sacred ash, generated from religious activities, as a partial replacement for cement in concrete. M30 and M40 concrete mixes were prepared with 0%, 2.5%, 5%, 7.5%, 10%, and 12.5% sacred ash replacement levels to evaluate workability, compressive strength, stress–strain response, and failure behavior. Experimental results showed that replacement up to 10% produced improved or comparable compressive strength, while higher replacement levels reduced performance. Due to the water absorption characteristics of sacred ash, adjustments in water–cement ratio and use of finely sieved ash were necessary to maintain workability. The study demonstrates that sacred ash has potential as a supplementary cementitious material for sustainable and eco-friendly concrete production.

IndexTerms - Sacred Ash, Sustainable Concrete, Cement Replacement, Supplementary Cementitious Material.

INTRODUCTION

Rapid industrialization and urban growth have greatly increased the demand for concrete, which is widely used for its strength and durability. However, cement—the key component of concrete—has a high environmental cost, as its production consumes large amounts of energy and releases significant CO₂, contributing to climate change. To make construction more sustainable, researchers are exploring supplementary cementitious materials (SCMs) that can partially replace cement. Many industrial and agricultural wastes, such as fly ash and rice husk ash, have already shown good results due to their pozzolanic properties, which improve concrete performance.

In India, large quantities of sacred ash are generated from religious activities but are often disposed of improperly, causing environmental pollution. Since this ash contains fine particles and mineral compounds, it has the potential to be used as a partial cement substitute. This study examines the use of sacred ash in M30 and M40 concrete by evaluating properties such as workability, strength, and overall behavior, aiming to develop a more eco-friendly construction material.

NEED OF THE STUDY

The construction industry is one of the largest consumers of natural resources, particularly cement, whose production significantly contributes to environmental pollution and carbon dioxide emissions. With the growing demand for infrastructure development, there is an urgent need to adopt sustainable alternatives that reduce dependence on conventional materials.

In India, large quantities of sacred ash are generated daily from religious activities such as hawan rituals and temple practices. This ash is often disposed of in rivers, lakes, or open areas, leading to water pollution and environmental degradation. Despite its abundance, this material remains largely unutilized in engineering applications.

At the same time, the concept of incorporating waste materials into concrete has gained attention as an effective way to achieve sustainability in construction. Utilizing sacred ash as a partial replacement for cement can address two major issues simultaneously—reducing environmental pollution caused by improper ash disposal and decreasing the consumption of cement.

Moreover, limited research has been conducted on the use of sacred ash in concrete, especially for higher-grade mixes such as M30 and M40. There is a need to evaluate its impact on key properties like workability, strength, and durability to determine its practical applicability.

Therefore, this study is essential to explore the potential of sacred ash as a supplementary cementitious material, contributing to eco-friendly construction practices, cost reduction, and sustainable waste management.

1.1 Sacred Ash as a Cementitious Material

Sacred ash is produced from the burning of organic materials such as wood, herbs, ghee, and other substances used in religious rituals. The chemical composition of this ash varies depending on the materials used, but it generally includes:

- Silica (SiO₂)
- Calcium oxide (CaO)
- Alumina (Al₂O₃)
- Carbon and trace elements

The presence of silica and alumina suggests that sacred ash can exhibit pozzolanic behavior similar to other ash-based materials. When combined with cement and water, these components react with calcium hydroxide to produce additional cementitious compounds, which improve the overall strength of concrete.

The fine particle size of sacred ash contributes to better packing within the concrete matrix. It fills micro-voids and enhances density, leading to improved mechanical properties and reduced permeability.

However, certain limitations must also be considered:

- High water absorption capacity
- Inconsistency in chemical composition

- Requirement of proper processing such as grinding and sieving
 To achieve optimal performance, sacred ash must be processed into a fine powder and used in appropriate proportions. Experimental studies are essential to identify the ideal replacement percentage that balances strength and workability.



Fig 1.1 Sacred Ash

Comparison with Other Ash Materials

Sacred ash can be compared with other commonly used supplementary materials:

Material	Source	Key Characteristic	Application
Fly Ash	Power plants	High pozzolanic activity	Widely used
Rice Husk Ash	Agricultural waste	Rich in silica	Strength improvement
Bagasse Ash	Sugar industry	Pozzolanic nature	Partial replacement
Glass Powder	Waste glass	Silica content	Durability enhancement
Sacred Ash	Religious waste	Potential reactivity	Emerging material

Table No. 1.1 Comparison Between Various Supplementary Materials

1.2 Objective of the study

The main objectives of this experimental investigation are:

- To evaluate the suitability of sacred ash as a supplementary cementitious material (SCM) in concrete.
- To determine the optimum percentage of sacred ash that can replace cement without compromising concrete performance.
- To compare the compressive strength of conventional concrete with concrete incorporating sacred ash.
- To analyze the cost differences between traditional concrete and concrete made with sacred ash.
- To study the cost implications of concrete produced with varying levels of cement replacement.

Variables of the study contains dependent and independent variable. The study used pre-specified method for the selection of variables. The study used the Stock returns are as dependent variable. From the share price of the firm the Stock returns are calculated. Rate of a stock salable at stock market is known as stock price.

1.3 Problem Statement

The rapid growth of the construction industry has led to excessive consumption of cement, resulting in increased carbon emissions and depletion of natural resources. At the same time, large amounts of sacred ash generated from religious activities are improperly disposed of, causing environmental pollution, particularly in water bodies. Despite its potential as a mineral-based material, sacred ash remains underutilized in construction applications. There is a lack of systematic research evaluating its suitability as a partial replacement for cement, especially in higher-grade concrete. Hence, the problem addressed in this study is:

“Can sacred ash be effectively utilized as a partial replacement for cement in concrete without compromising strength and performance, while also contributing to environmental sustainability?”

RESEARCH METHODOLOGY

The methodology adopted in this experimental investigation involved using Sacred Ash as a supplementary cementitious material by partially replacing cement in mortar mixes. Initially, the required materials such as cement, Sacred Ash, fine aggregates, and water were collected and proportioned according to the designed mix ratios. Sacred Ash was added in varying percentages as a replacement for cement to study its effect on mortar properties. Water was then added in suitable quantity to obtain proper consistency and workability during mixing. The ingredients were thoroughly mixed to prepare uniform mortar specimens, which

were then cast in moulds and cured for a specified period. After curing, the specimens were tested to evaluate parameters such as strength and performance characteristics, thereby assessing the suitability of Sacred Ash as an alternative construction material.

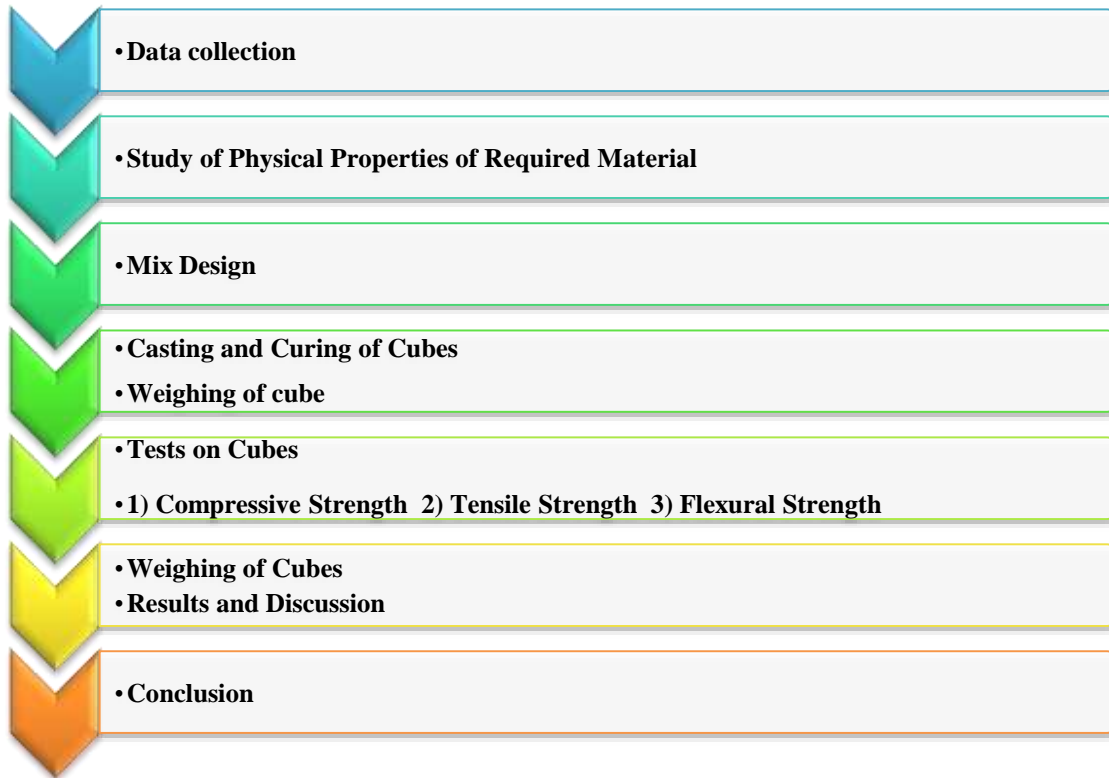


Fig. 2.1 Flowchart

2.1 Material Used

2.1.1 Cement

2.1.1.1 Material Properties of cement

- **Physical Properties of cement**

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of good cement are based on,

- i) Fineness of cement
- ii) Soundness
- iii) Consistency
- iv) Strength
- v) Setting time
- vi) Heat of hydration
- vii) Loss of ignition
- viii) Bulk density
- ix) Specific gravity (Relative density)

- **Chemical Properties of Cement**

The raw materials for cement production are limestone (calcium), sand or clay (silicon), bauxite (aluminum) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. Chemical analysis of cement raw materials provides insight into the chemical properties of cement.

- **Tricalcium aluminate (C3A)**

Low content of C3A makes the cement sulfate-resistant. Gypsum reduces the hydration of C3A, which liberates a lot of heat in the early stages of hydration. C3A does not provide any more than a little amount of strength.

- Type I cement: contains up to 3.5% 503 (in cement having more than 8% C3A)
- Type II cement: contains up to 3% 503 (in cement having less than 8% C3A)

- **Tricalcium silicate (C3S)**

C3S causes rapid hydration as well as hardening and is responsible for the cement's early strength gain an initial setting.

- **Dicalcium silicate (C2S)**

As opposed to tricalcium silicate, which helps early strength gain, dicalcium silicate in cement helps the strength gain after one week.

- **Ferrite (C4AF)**

Ferrite is a fluxing agent. It reduces the melting temperature of the raw materials in the kiln from 3,000°F to 2,600°F. Though it hydrates rapidly, it does not contribute much to the strength of the cement.

- **Magnesia (MgO)**
The manufacturing process of Portland cement uses magnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement unsound and expansive, but a little amount of it can add strength to the cement. Production of MgO-based cement also causes less CO₂ emission. All cement is limited to a content of 6% MgO.
- **Sulphur trioxide**
Sulfur trioxide in excess amount can make cement unsound.
- **Iron oxide/ Ferric oxide**
Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the color of the cement.
- **Alkalis**
The amounts of potassium oxide (K₂O) and sodium oxide (Na₂O) determine the alkali content of the cement. Cement containing large amounts of alkali can cause some difficulty in regulating the setting time of cement. Low alkali cement, when used with calcium chloride in concrete, can cause discoloration. In slag-lime cement, ground granulated blast furnace slag is not hydraulic on its own but is "activated" by addition of alkalis. There is an optional limit in total alkali content of 0.60%, calculated by the equation $Na_2O + 0.658 K_2O$.
- **Free lime**
Free lime, which is sometimes present in cement, may cause expansion.
- **Silica fumes**
Silica fume is added to cement concrete in order to improve a variety of properties, especially compressive strength, abrasion resistance and bond strength. Though setting time is prolonged by the addition of silica fume, it can grant exceptionally high strength. Hence, Portland cement containing 5-20% silica fume is usually produced for Portland cement projects that require high strength.
- **Alumina**
Cement containing high alumina has the ability to withstand frigid temperatures since alumina is chemical-resistant. It also quickens the setting but weakens the cement.

Properties of cement in tabular Form:

Sr.No.	Particulars	Test Results	Requirement of IS: 12269-187	
Chemical requirements				
1	$\frac{CaO - 0.7SO_3}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3}$	0.9	0.90 2.02	Min Max.
2	$\frac{Al_2O_3}{Fe_2O_3}$	2.14	0.88	Min.
3	Insoluble residue (% By mass)	2.91	4.00	Max.
4	Magnesia (% By mass)	0.91	7.00	Max.
5	Sulphuric anhydride	2	3.00	Max.
6	Total loss on ignition	1.38	5.00	Max.
7	Total chlorides	0.017	0.10	Max.
Physical Properties				
1	Specific Gravity	3.20		

Table No. 3.1 Properties of Cement

2.1.1. 2Types of Cement Tests with procedure

Determination Of Initial & Final Setting Times Standard

- IS: 4031 (Part 5) 1988.

Objective

- To determine the initial and final setting times of cement.

Apparatus

- Vicat apparatus conforming to IS: 5513-1976.
- Balance of capacity 1kg and sensitivity 1 gram.
- Gauging trowel conforming to IS: 10086-1982.

Report

- Report the initial setting time and final setting time in minutes.

Precaution

- The time of gauging in any case shall not be less than 3 minutes not more than 5 minutes.

2.1.1.2 Soundness Test of Cement

1. Objective

It is very important that the cement after setting shall not undergo any appreciable change of volume. Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used. The unsoundness in cement is due to the presence of excess of free lime than that could be combined with acidic oxide at the kiln. It is also likely that too high a proportion of magnesium content or calcium sulphate content may cause unsoundness in cement. Soundness of cement may be determined by two methods, namely Le-Chatelier method and autoclave method. In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is speeded up and can be detected. Soundness means the ability to resist volume expansion.

2. Apparatus Required

Le-Chatelier apparatus conforming to IS: 5514-1969

Consist of a small split cylinder of spring brass to other non-corrodible metal of 0.5mm thickness forming a mould of 30mm internal diameter and 30mm high. On either side of the split, two indicators are brazed suitably with pointed ends made of 2mm diameter brass wire in such a way that the distance of these ends to the centre of the cylinder is 165mm. The split cylinder will be kept between two glass plates. The temperature of the moulding room, dry materials and water shall be maintained at 27 \pm 2 $^{\circ}$ C The relative humidity of the laboratory shall be 65 \pm 5 percent. The moist closet or moist room shall be maintained at 27 \pm 2 $^{\circ}$ C and at a relative humidity of not less than 90 percent. Water bath capable of containing immersed Le-Chatelier moulds with specimens and of raising their temperature from 27 \pm 2 $^{\circ}$ C to boiling in 27 \pm 3 minutes. Vernier Calliper should be able to measure up to 30 mm with least count of 0.1 mm On balance in use, the permissible variation at a load of 1000 g shall be 1.0 g. The permissible variation on new balance shall be one-half of this value. The sensibility reciprocal shall be not greater than twice the permissible variation.

2.2 Sand

2.2.1 Properties of sand

Here the different types of physical proprietors of sand are as follows with full detail.

- Grain Size of Sand
- Grain Shape of Sand
- Shape and Distribution of Sand Grains
- Size Distribution of Sand
- **Grain Size of Sand**

The grain shape and scale of the moulding sand determine the overall surface area of the grains found in the unit mass. Total surface area is defined as a particular surface area. A

particular surface provides a rough understanding of the quantity of binder required to coat grains of sand moulding. Grain size and distribution affects many properties of sand, such as permeability, flowability, refractory properties, surface fineness and strength. The finer the grains of sand, the finer the entire sand. Fine grain sands offer a good surface finish but have poor permeability. With the same content of clay, the environmental strength is greater in the context of fine sand than in the context of rough sands. Solid and evenly graded sand has high permeability, decent reactivity as well as high flowability. Usually, foundry sand has grain sizes around 0.1 and 1.0 mm.

- **Grain Shape of Sand**

The shape of the grain is defined in terms of angularity as well as sphericity. The grains of sand range from well rounded, subrounded, angular and also very angular. Inside each angularity unit, grains can be of a high, medium, or low sphericity. The angularity of sand is measured by visual inspection using a low-power microscope. The best foundry sands include grains that have been rounded with medium to high sphericity, offering good flowability and high-intensity permeability at low binder additions. More angular and lower spherical sands require higher binder additions, lower packing density and poorer flowability.

- **Shape and Distribution of Sand Grains**

The texture, size and form of the sand grains are critical for controlling the consistency of the mould. Many of the mould aggregates are mixtures of fresh sand and recycled sand, which comprise not only reclaimed sand but also core sands. In deciding the scale, shape and distribution of sand grains, it is necessary to note that the grain shape corresponds to the amount of sand surface area and that the distribution of grain size influences the permeability of the mould. If the sand surface area increases, the volume of bonding content (usually clay and water) must increase if the sand is to be adequately bonded. As a result, a difference in surface area, possibly due to a change in sand form or the proportion of core sand being retrieved, would result in a related change in the amount of bond required. Rounded grains have a low surface-area-to-volume ratio and are thus favoured for core processing because they need the least amount of binder. However, when recycled into the sand moulding system, their form can be disadvantageous if the moulding system usually uses a high percentage of clay and water to allow quick, automatic moulding. This is because the rounded grains need less sand than the rest of the structure.

- **Size Distribution of Sand**

The size distribution of sand influences the consistency of the casting. Coarse grain sand allows the metal to enter the moulds and cores, giving the castings a weak surface finish. Fine-grained sands produce a better surface finish but need a higher bonding content and

low permeability can cause a gas defects in castings.

2.2.2 Test of sand

Materials Needed:

1. Sand sample
2. Magnifying glass or microscope
3. pH testing kit
4. Sieve set
5. Graduated cylinder
6. Water
7. Glass beakers
8. Scale

Procedure:

1. Visual Inspection:

- Examine the sand sample visually for colour, grain size, and overall texture.
- Use a magnifying glass or microscope to inspect individual grains for shape and surface characteristics

2. Grain Size Distribution:

- Use a sieve set to separate the sand into different size fractions.
- Weigh each fraction and calculate the percentage of the total sample represented by **Grain** size
- **3. Moisture Content:**
- Weigh a sample of sand and record its weight (W1),
- Dry the sample in an oven at a specified temperature until a constant weight it achieved Record the final weight (W2)
- Calculate the moisture content using the formula: Moisture Content (%) $[(W1-W2) / W2] \times 100$
- **4. pH Measurement:**
- Mix a small amount of sand with distilled water to form a slurry.
- Use a pH testing kit to measure the pH of the slurry.
- **5. Density:**
- Measure the volume of a known mass of sand using a graduated cylinder
- Calculate the density using the formula: Density=Mass/Volume
- **6. Sedimentation Test:**
- Mix a sample of sand with water in a glass beaker and stir
- Observe the settling rate of particles to assess the sedimentation characteristics

2.3 Aggregate

2.3.1 Properties of aggregates

- 1. Strength:** Strength is an important factor when it comes to choosing the right materials for your aggregate, especially when making the topmost layers for roads and pavements to withstand stress action due to traffic wheel load, wear and tear and crushing. The aggregate should consist of higher resistance to crushing and withstand higher amounts of stress in order to build high-quality pavements.
- 2. Hardness:** The aggregates used to make surface layers are exposed to constant abrasion and rubbing due to traffic stress. Ideally, the hardness of the aggregate should be enough to withstand the damage caused by moving traffic, especially when it comes to steel tyred vehicles.
- 3. Toughness:** When we say toughness, we refer to the ability of the aggregate surface to withstand impact forces, Ideally, aggregates used in pavements should be able to resist the impact steel tyred heavyweight vehicles have on them on different levels.
- 4. Durability:** Aggregates also have to withstand the cruel forces of nature. The property of an aggregate's ability to withstand adveryc action of weather is called soundness.
- 5. Adhesion:** Adhesion to bitumen is a very essential property to be taken into account when picking the right aggregate.

Sr. No.	Characteristics	Value
1	Specific gravity	3.67
2	Impact value	13.82
3	Crushing strength	28.6
4	Fineness modulus	9.14

Table No. 3.2 Properties of Coarse Aggregate

Sieve No.	Mass retained (kg)	% Retained	% Passing	Cumulative % Reetained
90	0	0	100	0
30	0	0	100	0
30	0.93	18.600	74.400	18.600
16.5	3.91	78.200	22.800	96.800
10	0.132	2.640	98.360	99.440
5.75	0.028	0.560	99.440	100.000
2.40	0	0.000	100.000	100.000
1.18	0	0.000	100.000	100.000
700	0	0	100	100.000

400	0	0	100	100.000
180	0	0	100	100.000
			Total	814.84
Fineness modulus = 814.84/100 = 8.14				

Table No. 3.3 Sieve analysis of 20 mm aggregate

Sr. No.	Characteristics	Value
1	Specific gravity	3.60
2	Absorption %	4.5%
3	Moisture content %	0.90%
4	Fineness modulus	2.54

Table No. 3.4 Properties of Fine aggregate

Sr. No.	Sieve No.	Mass retained (kg)	% Retained	% Passing	Cumulative % Retained
1	2.75	0	0	100	0
2	2.36	0.35	17.5	82.5	0.018
3	1.18	0.776	38.8000	61.2	38.318
4	600u	0.59	29.5	70.5	78.318
5	300u	0.28	14	86	92.318
6	150u	0.008	0.4	99.6	92.718
7	Pan	0	0	100	92.718
				Total	394.408
Fineness modulus = 394.408/100 = 3.94					

Table

No. 3.5 Sieve analysis of fine aggregate

2.3.2 Test of aggregates

Aggregates are very essential part when it comes to surficial strength and durability, and are chosen based on the needs of a project. There are various ways to test an aggregate for its properties and how viable of an option it is recanting a project.

- **Crushing test of aggregate**

A pavement is bound to fail under compression of load it cannot handle, which may lead to public disaster and can definitely prove to be hazardous. Therefore, an aggregate crushing test is conducted to ascertain the aggregate's structural soundness and crushing strength. The aggregate crushing value gives a comparative indication of the resistance to crushing under a crushing load that is applied gradually. The recommended value of a crushing test should ideally be 30% for roads and pavements and 45% for other projects.

- **Abrasion test**

The abrasion test focuses primarily on the hardness of the aggregate and helps decide whether a certain aggregate is suitable for use in construction or not. The Los Angeles abrasion test is the most preferred form of abrasion test of aggregates and has been standardised as the test for aggregate hardness in India.

- **Impact test**

The impact test of aggregates helps in determining the resistance of an aggregate to impact forces.

- **Soundness test**

The soundness test is conducted to determine the resistance of aggregates to wear and tear due to weather forces. This is done through a simulation of weather cycles. Porous aggregates that are exposed to freezing and thawing over and over

again are more likely to disintegrate prematurely. To increase the durability of such aggregates, they are exposed to a series of soundness tests in order to select the highest quality aggregate.

- **Shape tests**
 An aggregate, whether naturally occurring or artificially manufactured, has flaky or elongated parts in it. These flaky components help determine the flakiness of the aggregate. Aggregates with a higher number of flakes seem to be detrimental to higher workability and the stability of mixes. This is known as the flakiness index. Another metric that helps determine the stability of an aggregate is the elongation index of an aggregate. The elongation index of an aggregate is defined as the percentage index by weight particles whose greatest dimension is 1.8 times their mean dimension. This test is only applicable to aggregates larger than 6.3mm.
- **Specific gravity and water absorption test**
 The design of concrete and bituminous mixes must take into account an aggregate's specific gravity and water absorption. A solid's specific gravity is determined by how much mass it has in relation to an equivalent amount of distilled water at a given temperature. There is a possibility of the aggregates containing water permeable voids. Hence, to avoid this, two measures of the specific gravity of aggregates are used, which are known as apparent specific gravity and bulk specific gravity. Whereas, apparent specific gravity is calculated on the basis of the net volume of aggregates or the volume of aggregates excluding the water permeable voids. Bulk-specific gravity, on the other hand, is calculated on the basis of the total volume of aggregates, including the water-permeable voids.
- **Bitumen adhesion test**
 Bitumen is a well-known compound that is widely used in construction. When picking the ideal aggregate for a given use case, it's crucial to consider bitumen's adherence in cold and wet conditions. This test is conclusive of the adhesion of aggregate when wet and cold.

2.4. Properties of Concrete

2.4.1. Fresh Concrete Properties

i) Workability:

This is defined as the ease with which concrete can be compacted fully without segregation and bleeding. It can also be seen as the amount of internal work required to fully compact the concrete to optimum density. The workability depends upon the quantity of water, grading, shape and the percentage of the aggregates present in the concrete.

Workability of concrete is measured by;

- i) The slump observed when the frustum of the standard cone filled with concrete is lifted and removed.
 - ii) The compacted factor determined after allowing the concrete to fall through the compaction testing machine.
 - iii) The time taken in seconds for the shape of the concrete to change from cone to cylinder when tested in Vee-Bee consistometer.
- Workability is measured by slump cone method.



Figure No. 3.2 Workability Of Concrete By Slump Cone Method

ii) Segregation:

Segregation is a situation in which the coarse particles separate from the green concrete. It occurs due to lack of sufficient quantity of finer particles in the concrete or due to throwing of the concrete from greater heights at the time of placing the concrete. Because of segregation, the cohesiveness of the concrete is lost and honey combing results. Segregation results in the loss of strength of hardened concrete. Therefore, care should be taken to avoid segregation in fresh concrete.



Figure No. 3.3 Segregation of Concrete

iii) Bleeding:

This is the appearance of water along with cement particles on the surface of the freshly laid concrete. It happens when there is excessive quantity of water in the mix or due to excessive compaction. Bleeding can be avoided by suitably controlling the quantity of water in the concrete and by using finer grading of aggregates.

2.4.2. Hard Concrete Properties

Hard concrete properties refer to the characteristics of concrete after it has set and hardened. These properties determine the strength, durability, and performance of concrete in service conditions. Important hard concrete properties are explained below:

1. Compressive Strength

Compressive strength is the ability of hardened concrete to resist crushing loads. It is considered the most important property of concrete because it indicates the load-carrying capacity of a structure. It is generally measured by testing concrete cubes or cylinders after 7, 14, or 28 days of curing. Higher compressive strength indicates better quality concrete.

3. Tensile Strength

Concrete is strong in compression but weak in tension. Tensile strength represents the resistance of hardened concrete to cracking under pulling forces. It is usually determined by split tensile or direct tension tests. This property is important in controlling cracks in concrete structures.

4. Flexural Strength

Flexural strength, also called modulus of rupture, is the ability of concrete to resist bending stresses. It is significant in pavements, slabs, and beams where bending loads are developed. It is measured by testing concrete beams under loading.

5. Modulus of Elasticity

The modulus of elasticity defines the stiffness of hardened concrete and indicates how much it deforms under stress. Higher modulus values mean lower deformation. This property is essential in the design of structural members subjected to loads.

6. Durability

Durability is the capacity of concrete to withstand environmental effects such as weathering, chemical attack, abrasion, and freeze-thaw action without deterioration. Durable concrete maintains its strength and serviceability for a long period.

6. Permeability

Permeability is the measure of the ease with which water or other fluids can pass through hardened concrete. Low permeability is desirable because it prevents ingress of moisture, chemicals, and corrosive agents, thereby improving durability.

7. Density

Density refers to the mass of hardened concrete per unit volume. It influences strength, dead load, and thermal properties. Depending on materials used, concrete may be lightweight, normal weight, or heavyweight.

8. Shrinkage

Shrinkage is the reduction in volume of concrete due to loss of moisture and chemical reactions during hardening. Excessive shrinkage can lead to cracks, affecting durability and appearance.

9. Creep

Creep is the gradual deformation of hardened concrete under sustained loading over time. It can cause additional deflection in structural members and must be considered in long-term design.

10. Abrasion Resistance

Abrasion resistance is the ability of concrete surfaces to resist wear caused by friction, rubbing, or traffic movement. It is important for industrial floors, roads, and pavements.

11. Water Absorption

Water absorption indicates the amount of water absorbed by hardened concrete. Lower absorption generally reflects denser and more durable concrete.

12. Fire Resistance

Hardened concrete has good resistance to high temperatures and fire. Its fire resistance depends on aggregate type, moisture content, and concrete composition.

2.4.3. Test for Hard Concrete

Tests On Concrete Cubes:

1. Compressive Strength

2. Tensile Strength
3. Flexural Strength

Universal Testing Machine:

The tensile stress and compressive strength of materials are typically evaluated using a universal testing machine. Various common stress and compression tests can be run on materials, components, and structures using this universal testing machine.

1. Compressive Strength:

In a compression test, an object is squeezed between two parallel plates until either a predetermined weight or displacement is reached, or the product fails to pass the test. Maximum force before failure, load at displacement, and displacement at load are common examples of such metrics.



Figure No. 2.2 Compression test on Universal Testing Machine

2. Split Tensile Strength

One single piece of material is secured at both ends and tugged until it snaps; this is called a tensile test. Strength, elongation, and tensile modulus are all evaluated in this way.



Figure No.2.3 Split tensile test on Universal testing Machine

3. Flexural Strength

Flexural strength is measured indirectly because there is no apparatus to evenly distribute tensile force to the sample. The test is performed using either a one point load or two point load.

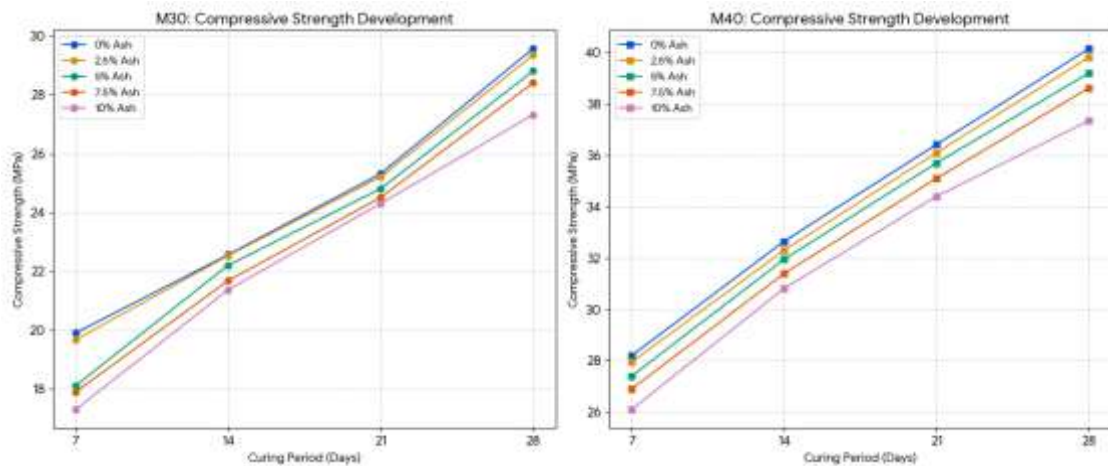


Figure No. 2.4 Flexural Strength test on flexure testing Machine

IV. RESULTS AND DISCUSSION

Sr. No.	Mix Design	Sacred Ash (Cement Replacement) (%)	Tests On Concrete Cubes			
			7 Days (Mpa)	14 Days (Mpa)	21 Days (Mpa)	28 Days (Mpa)
1	M30	0%	19.90	22.56	25.31	29.56
2		2.5%	19.67	22.53	25.20	29.34
3		5%	18.11	22.20	24.80	28.80
4		7.5%	17.90	21.68	24.50	28.40
5		10%	17.30	21.37	24.30	27.31
6	M40	0%	28.20	32.65	36.42	40.15
7		2.5%	27.95	32.30	36.10	39.82
8		5%	27.40	31.95	35.70	39.20
9		7.5%	26.90	31.40	35.10	38.62
10		10%	26.10	30.82	34.40	37.35

Table No. 4.1 Mix Design of M35 and M40 grade concrete with result



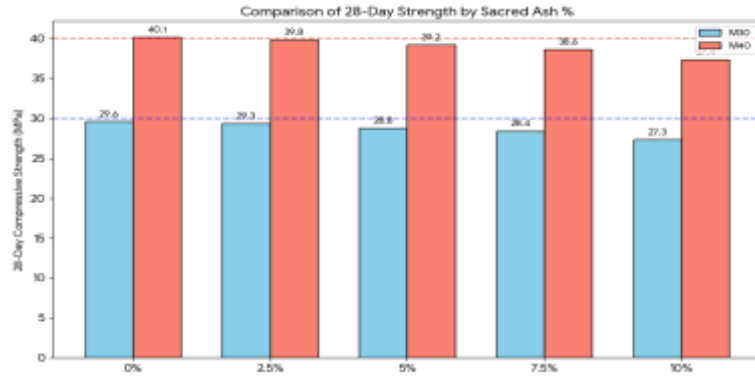


Chart No. 4.1 Compressive strength of concrete in (Mpa)

1. This line graph illustrates how the concrete gains strength over the curing period.

- Observation:** All mixes follow a standard curing curve, but the lines shift downward as the Sacred Ash percentage increases.

- M30 vs M40:** The M40 mix maintains a significantly higher strength profile throughout the 28 days compared to M30, though both show a similar rate of decline as ash content rises.

2. **28-Day Strength Comparison (Performance Benchmark)** This bar chart focuses on the critical 28-day benchmark, which is used to classify the grade of concrete.

- M30 Analysis:** The control (0%) and 2.5% replacement successfully exceed the 30 MPa target. However, at 10% replacement, the strength drops to **27.31 MPa**, failing to meet the M30 design criteria.

- M40 Analysis:** Similar to M30, the 0%, 2.5%, and 5% replacements stay very close to or above the 40 MPa threshold. At 10%, the strength drops to **37.35 MPa**, which is below the M40 design strength.

Based on the charts, a replacement of **2.5% to 5%** is the most sustainable choice that maintains structural integrity near the design target. Replacement levels of 10% result in significant strength loss.

Sr. No.	Mix Design	Sacred Ash (%)	Tests On Concrete Cubes			
			7 Days (Mpa)	14 Days (Mpa)	21 Days (Mpa)	28 Days (Mpa)
1	M30	0%	1.99	2.26	2.53	2.96
2		2.50%	1.97	2.25	2.52	2.93
3		5%	1.81	2.22	2.48	2.88
4		7.50%	1.79	2.17	2.45	2.84
5		10%	1.73	2.14	2.43	2.73
6	M40	0%	2.82	3.26	3.64	4.01
7		2.50%	2.8	3.23	3.61	3.98
8		5%	2.74	3.2	3.57	3.92
9		7.50%	2.69	3.14	3.51	3.86
10		10%	2.61	3.08	3.44	3.74

Table No. 4.2 Mix Design of M35 and M40 grade concrete -Split Tensile Test

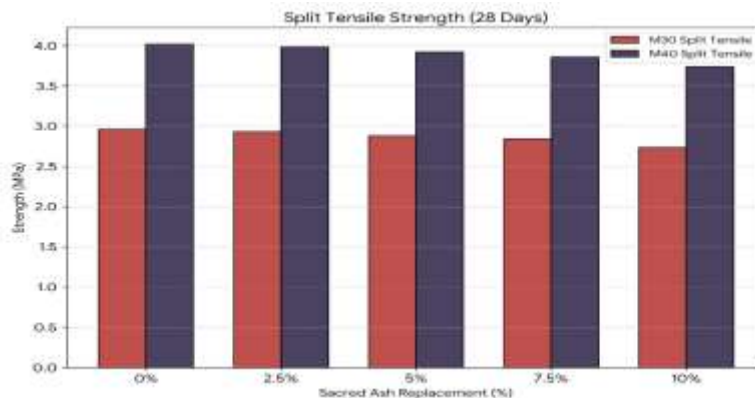


Chart No. 4.2 Tensile strength of concrete in (Mpa)

Sr. No.	Mix Design	Sacred Ash (%)	Tests On Concrete Cubes			
			7 Days (Mpa)	14 Days (Mpa)	21 Days (Mpa)	28 Days (Mpa)
1	M30	0%	3.12	3.32	3.52	3.81
2		2.50%	3.1	3.32	3.51	3.79
3		5%	2.98	3.3	3.49	3.76
4		7.50%	2.96	3.26	3.46	3.73
5		10%	2.91	3.24	3.45	3.66
6	M40	0%	3.72	4	4.22	4.44
7		2.50%	3.7	3.98	4.21	4.42
8		5%	3.66	3.96	4.18	4.38
9		7.50%	3.63	3.92	4.15	4.35
10		10%	3.58	3.89	4.11	4.28

Table No. 4.3 Mix Design of M35 and M40 grade concrete -Flexural Test

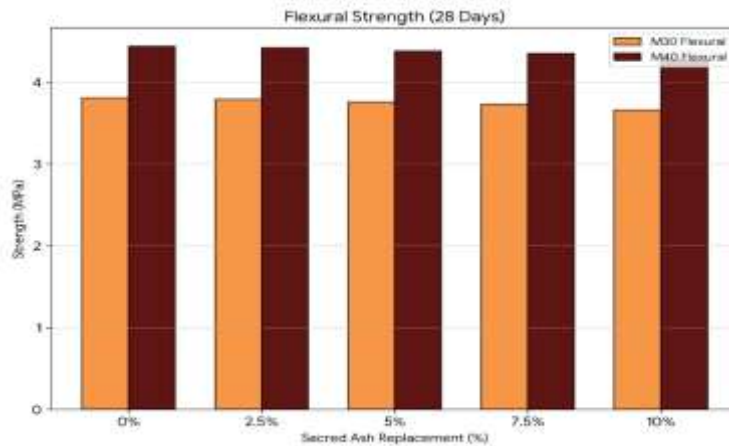


Chart No. 4.3 Flexural Strength of concrete in (Mpa)

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