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# Experimental investigation on Effect of Partial Replacement of Cement with Metakaolin And Sand with Foundry Sand in Self Compacting Concrete

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## ABSTRACT

Self-Compacting Concrete (SCC) is a significant advancement in concrete technology, offering several advantages over conventional concrete. Designed to flow and solidify by its own weight, SCC does not require any external or internal disturbance, as the name suggests. Quickly and easily filling all formwork corners with SCC is possible thanks to its self-leveling property; this not only eliminates the need to worry about honeycombing but also ensures a high-quality, long-lasting surface.

The experimental hardening properties of SCC were examined in this work by substituting 10% metakaolin by weight for part of the cement and varying the percentages of natural sand used (0, 10, 15, 20, and 25% by weight). To make the mixture more workable, we added 1% Auramix 200, a superplasticizer, and kept the water-to-cement ratio (w/c) at 0.43. At7,14, and 28 days post-curing, mechanical parameters such as compressive and split tensile strengths were measured.

By substituting up to 10% waste foundry sand for natural sand, the strength qualities of SCC were seen to be enhanced in the studies. Due of the wasted sand's coarser surface texture and more angular particles, workability and strength were somewhat diminished as the replacement amount was increased to higher percentages. By increasing its strength and densifying it, metakaolin made concrete less porous and more resistant to breaking. The findings suggest that by mixing 10% waste foundry sand with 10% metakaolin, a sustainable, high-performance SCC suitable for structural applications may be produced. Together, they lessen our effect on the environment and increase our efficiency with the resources we have.

## Introduction:

Concrete, one of the most widely used man-made materials in the world, is the bedrock of modern construction. Nevertheless, its widespread use gives rise to a slew of problems with its design, production, cost-effectiveness, and sustainability. To meet economic and environmental concerns, concrete manufacturing must use readily available raw materials while adhering to both short-term and long-term performance criteria. The material's aesthetic fit with its intended applications should also be considered.

The versatility of concrete's performance in many architectural settings, the accessibility and affordability of its raw materials, and the efficiency of its production methods all contribute to its widespread popularity. Over the last few decades, concrete technology has steadily evolved with the main aims of improving mechanical characteristics, durability, and workability. Superplasticizers and additives that reduce water content without sacrificing workability have been the subject of increasing amounts of study. As a direct outcome of these advancements, high-performance concrete was created. This material offers outstanding longevity and durability, meeting all of society's increasing demands.

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SCC Study and Progress

The Japanese came up with the concept of Self-Compacting Concrete (SCC) in the 1980s because they were worried about the durability of concrete buildings. Trained laborers have traditionally been necessary for thorough compaction, which is crucial for concrete's durability. However, as the number of competent construction workers continued to decline, it became increasingly challenging to maintain high-quality building standards.

This limitation was overcome by developing SCC, a flowable concrete that can completely fill formwork with its own weight. This eliminates the need for vibration while simultaneously compacting all corners of the mold consistently. Professor Hajime Okamura first proposed the notion in 1986, and researchers Ozawa and Maekawa from the University of Tokyo did groundbreaking work on the workability of concrete.

The Japanese developed SCC by combining typical superplasticizers, which make the concrete extremely fluid, with viscosity-modifying agents (VMA), which make the concrete extremely plastic and prevent segregation even at extremely high flow rates. A new era in concrete technology was born in 1988 with the successful construction of the first prototype of SCC using commercially available materials. This technique could achieve three goals at once: simplicity of installation, durability, and quality consistency.

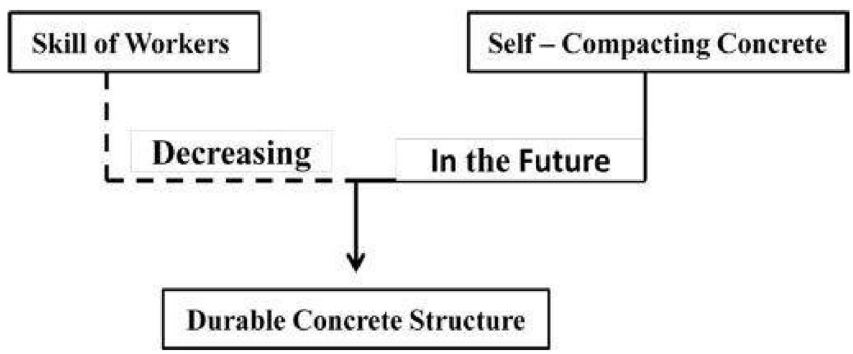


**Fig1.1: Necessity of SCC (OuchiandHibino,2000)**

**Properties of Self-Compacting Concrete (SCC)**

In order to operate well when placed and finished, fresh SCC must have certain workability qualities:

One important property of SCC is its filling ability, which means it can easily fill in all the gaps and corners of the formwork without the need for vibration, just by flowing and spreading under its own weight.

SCC's passing ability refers to its capacity to traverse tight places, such as the spaces between closely spaced reinforcing bars, without becoming stuck or interfering with the flow.

SCC must keep its consistent composition throughout transportation, handling, and placement to avoid bleeding or segregation and to keep fine and coarse particles well-suspended in the mixture.

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**Self Compacting Concrete**

**Advantages of Self-Compacting Concrete (SCC)**

Many modern construction projects choose for self-compacting concrete over normal concrete due to its many advantages. Refraining from utilizing vibration while applying fresh SCC will help you save time and energy. Due to its flowability, it may be readily inserted into complex formworks and heavily reinforced portions. Reducing energy consumption and total construction time via speedier installation is possible with the elimination of mechanical vibration. Even in densely populated areas, SCC ensures a strong relationship with reinforcement, decreases the number of workers required, and creates a high-quality, smooth surface finish. Because less labor and equipment is needed, the construction project may be finished faster and at a cheaper total cost. In addition to improving structural performance over time, SCC improves mechanical properties including compressive and tensile strength.

This Study's Significance

A great alternative to conventional concrete in contemporary construction, SCC enhances efficiency, quality, and sustainability. The desire to minimize expenses and boost performance is driving the usage of this technology. Owners, manufacturers, and contractors are always up against the difficulty of producing high-quality buildings while keeping costs down across the board. In order to accomplish these goals, SCC assists in three ways: by reducing the intensity of work, by shortening the building time, and by increasing the design flexibility. It also improves safety while decreasing energy usage on-site. Prohibiting SCC's broad acceptance is the lack of published research, set criteria, and practical experience with the technology. As more is learned and experienced, and as local needs for using materials from different regions exposed to different types of environmental stresses emerge, the viability of SCC adoption will increase. There needs to be further research on SCC so that its usage and effectiveness may be maximized.

Chapter 1.3: Manufacturing Foundry Sand Abroad, Including India

Foundry sand is an undesirable by-product of the casting industries that produce ferrous and non-ferrous metals. After it has been used several times in foundries, it is called waste foundry sand (WFS). Regional variations in WFS output are attributable to differences in foundry size. The Metakaolin Reaction Process (1.6)

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When metakaolin combines pozzolanicly with calcium hydroxide ($Ca(OH)_2$), a byproduct of cement hydration, it forms additional calcium silicate hydrate (C-S-H) gel, which reinforces the concrete matrix. The calcination of kaolinite is the $Al_2Si_2O_5(OH)_4 \rightarrow Al_2Si_2O_7 + 2\ H_2O$ reaction. Hydrated cement is formed through the chemical reaction Cement + Water → C-S-H gel + $Ca(OH)_2$. Metakaolin increases the speed of this reaction, improves the concentration of C-S-H, enhances the microstructure, decreases porosity, and creates high-performance concrete with a long lifespan by adding its tiny particles and high silica-alumina content.

**Metakaolin + Ca $(OH)_2$ → CSHGEL**

**Metakaolin**

## LITERATURE REVIEW

### Metakaolin (MK)

In order to determine the effects of metakaolin on mortar properties, Luc Courard (2003) compared it to ordinary Portland cement. From five percent to twenty percent of the cement's bulk was replaced with metakaolin. Over the course of over a hundred days, the study used sulfate immersion and chloride diffusion experiments to investigate chemical behavior and transport properties. Metakaolin effectively reduced chloride penetration and sulfate-induced degradation, and the greatest inhibitory activity was seen within an optimal replacement range of 10-15%.

Using both high-purity kaolin that is commercially accessible and low-quality kaolin that is found in Greece, E. Badogiannis et al. (2005) explored the possibility of producing metakaolin. Researchers looked at how different calcination temperatures and times affected the samples using DTA-TG and XRD analysis. The pozzolanic activity and strength development of the cement-metakaolin combination were evaluated. While high-alunite kaolins required heating to 850°C to remove the undesirable $SO_3$, low-quality kaolins were heated to 650°C for 3 hours to produce the very reactive metakaolin. Transforming even low-quality kaolins into highly reactive metakaolin is an economically beneficial process for the concrete production industry, according to this study.

The feasibility of using metakaolin in place of cement in mortar and concrete has been extensively studied (Rafat Siddique et al., 2009). In the research, metakaolin was shown to have a negative impact on slump values, setting durations, and workability when employed as a substitute for cement. In contrast, metakaolin improved mechanical properties early on and maintained high compressive strength and durability over time. It reduced permeability by pore structure refinement and capillary action reduction, and it increased resistance to harmful ion diffusion. According to the study, adding 10-15% metakaolin to concrete significantly improved its durability and resistance to

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sulfate assault.

In their 2010 study, M. Shekarchi et al. focused on the transport properties of metakaolin-modified concrete. Despite a somewhat reduced initial setting time, the data demonstrated that metakaolin had no effect on the final setting time. The compressive strength was enhanced by about 20% when metakaolin was substituted for 15% cement. Metakaolin greatly enhanced the microstructure and durability of concrete. Here are the improvements: Half for penetrating water, one third for gas permeability, one quarter for absorbing water, four hundred and fifty percent for electrical resistivity, and almost half for ionic diffusion.
Sadaqat Ullah Khan et al. (2014) investigated how various mineral admixtures affected the properties of both wet and dry concrete. Fly ash (FA), metakaolin (MK), ground granulated blast furnace slag (GGBS), and rice husk ash (RHA) were among the admixtures that were used. Different types of microfiller (FA, GGBS, RHA) and chemically active mineral admixtures (MK, SF) were characterized in the study. Microfiller admixtures improved hydration heat and reactivity whereas chemically active admixtures increased setting time and decreased workability. Superplasticizers were necessary for the workability of thick, impermeable concrete built with additives with tiny particle sizes, as MK. The following is the sequence of reactivity: MK > SF > FA > GGBS.

## SCOPEANDRATIONALEOFTHESTUDY

### Scope of the Study

The focal point of this experimental study is Self-Compacting Concrete (SCC) created from various industrial by-products and recyclable materials. Using a constant 10% weight ratio of Metakaolin (MK) to cement and varying weight ratios of 10%, 15%, 20%, and 25% for waste foundry sand to natural sand, the experiments aim to determine the optimal combination of these two materials to enhance concrete performance. Multiple mechanical characteristics, including as compressive strength, split tensile strength, and flexural strength, are measured for each mix %. Additionally, non-replaced standard SCC specimens are cast for use as control samples. In order to identify potential improvement areas, we compare the modified mixes to the control specimens in terms of strength, durability, and workability. After the mix is optimized, it may be recommended for use in actual construction projects, demonstrating a sustainable way to produce high-quality concrete from industrial waste.
The 3.2 goal of the research
The purpose of this research is to evaluate the mechanical properties of Self-Compacting Concrete (SCC) by checking how different amounts of natural sand and partial cement substitution with Metakaolin (MK) affect the material. This study's overarching objective is to:

• Determine the effect of these alternatives on the compressive, split tensile, and flexural strengths of SCC at different ages of curing.
Determine the optimal proportions of MK and WFS alternatives so that the material achieves the desired properties (high strength, extended lifespan, and manageable workability).
• Evaluate the benefits of using MK and WFS as eco-friendly substitutes by comparing the efficiency of SCC blends with that of conventional mixes.
Provide a practical recommendation for building applications, highlighting the potential of SCC with MK and WFS as a cost-effective and environmentally conscious choice for HPC buildings.

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## MATERIALSANDRESEARCHMETHODOLOGY

Our primary goal in doing this research was to analyze the properties of the materials that were used in the experimental investigation of Self-Compacting Concrete (SCC). Water, Aurum Mix 200, Metakaolin, Ordinary Portland Cement, Coarse and fine aggregates, and that's pretty much it. Additionally, water and sand from a previous foundry are also used. The effects of these components on the mechanical and fresh properties of the concrete are ascertained by extensive testing.
Appendices 4.2
4.2.1 Portland cement

Ordinary Portland Cement (OPC) is the main binder of concrete, providing the material with its strength and cohesiveness when combined with water. A thorough analysis of the chemical and physical properties of cement is necessary for the correct mix design. Specific gravity, uniformity, fineness, and setting times are some of the parameters we measure. Hydration behavior is also studied after curing in order to evaluate strength increase. This experiment makes use of OPC 43 grade cement. Compressive strength at3,7, and 28 days, specific gravity, consistency, starting and ending setup times, and other metrics are laid forth in Table 4.1.
According to Table4.1, these are the characteristics of OPC 43 grade cement.

**4.2.2 Aggregates**
The workability, durability, and strength of concrete are significantly impacted by the aggregates that make up the bulk of the material. To ensure density and stability, the concrete mix uses the appropriate ratio of fine to coarse particles. The combination of coarse and fine particles in a matrix improves the material's workability and consistency. Clean, hard, angular aggregates that are appropriately graded will avoid segregation and provide excellent bonding with the cement paste. The experiment used coarse material that could not exceed 10 mm in size. It is standard practice to wash and dry all aggregates thoroughly before using them.

| S. No. | Characteristic | Experimentally Obtained Value | IS 8112:1989 Specification |
|---|---|---|---|
| 1 | Fineness (retained on 90 µm sieve) | 4.5 g | <10% of 300 g |
| 2 | Normal Consistency | 29.5% | - |
| 3 | Initial Setting Time | 47 minutes | ≥ 30 minutes |
| 4 | Final Setting Time | 278 minutes | ≤ 600 minutes |
| 5 | Soundness | 3 mm | <10 mm |
| 6 | Specific Gravity | 3.15 | - |

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**Table 4.2 Physical Properties of Fine Aggregates**

| Characteristic | Description |
|---|---|
| Color | Grey |
| Shape | Angular |
| Maximum Size | 10 mm |
| Specific Gravity (coarse aggregates) | 2.71 |

**Table 4.3 Sieve Analysis of Coarse Aggregate (10 mm)**

| S. No. | IS Sieve (mm) | Weight Retained (g) | % Retained | % Passing | Cumulative % Retained |
|---|---|---|---|---|---|
| 1 | 100 | 0 | 0 | 100 | 0 |
| 2 | 80 | 0 | 0 | 100 | 0 |
| 3 | 40 | 0 | 0 | 100 | 0 |
| 4 | 20 | 0 | 0 | 100 | 0 |
| 5 | 10 | 2012 | 67.07 | 32.93 | 0 |
| 6 | 4.75 | 958 | 31.93 | 1 | 67.07 |
| 7 | Pan | 30 | 1 | 0 | 99 |
| **Total** | - | 3000 | - | - | - |
| **FM** | - | - | - | - | 6.66 |

### 4.2.3 Fine Aggregates

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If an aggregate can pass through an IS sieve with a size of 4.75 mm, we say that it is fine. Zone I is the coarsest while Zone IV is the finest when it comes to fine aggregates, as per IS 383-1970. The stone dust used in this investigation was sourced from Jalandhar, which is categorized as Zone II. Coarse and light brown in hue, this sand has been screened to eliminate any extra large particles using a 4.75 mm sieve. In accordance with IS 383-1970, physical characteristics and sieve analysis were carried out. Fine aggregates have a specific gravity of 2.49. 4.2.4 The liquid

The concrete was mixed and cured using high-quality potable water that was free of dangerous impurities. All criteria for the safe and efficient hydration of concrete are satisfied by the water.

4.2.5.1 Combinations

For better workability and uniformity, add Auramix 200, a high-performance superplasticizer. Consistent concrete quality at the desired dose is ensured by the creation of SCC with excellent flowability without segregation.

4.3.1 Evaluation Procedures

Three main fresh-state properties—filling ability, passing ability, and resistance to segregation—define self-compacting concrete. Since no one test can adequately quantify these elements, many test techniques are used to assess these features. In Table 4.4, you can see the suggested limits for SCC mixtures.

Table 4.4: SCC Property Limits Suggested

| S. No. | Property | Recommended Range |
|---|---|---|
| 1 | Slump Flow Diameter | 500–700 mm |
| 2 | T50 cm (time to reach 500 mm flow) | 2–5 sec |
| 3 | L-Box Ratio (H2/H1) | ≥ 0.8 |

**4.3.1 Slump Flow Test**

Slump flow testing determines how SCC behaves when subjected to horizontal pressure and free of impediments. When the slump cone containing concrete is lifted, the material spreads out horizontally. The filling ability is shown by the average diameter of the resultant circle, and the secondary indication of flowability is T50 cm, which measures the time (in seconds) necessary for the concrete to reach a 500 mm diameter.

The L-Box Assay

To determine how well SCC can traverse narrow openings, such reinforcing gaps, the L-box test is

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used. After the vertical part of the L-box has been filled with concrete, the gate is raised to let the flow into the horizontal part. To determine passing ability, take the height of the concrete at the end of the horizontal part (H2) and divide it by the height in the vertical section (H1). It is okay to have a ratio of 0.8 or higher.

Concrete's Compressive Strength

Cube specimens of 150 mm × 150 mm × 150 mm are used to measure compressive strength. These specimens are examined at 7, 14, and 28 days. After the specimens have been taken out of the curing tank and any excess water has been wiped off, they are set up in the testing machine with their castings oriented perpendicular to the load. Applying a steady load at a rate of 5.1 kN/sec until failure, the formula is used to compute compressive stress:

$$\text{Compressive Strength (C)} = \frac{P}{A}$$

Where $P$ is the applied load and $A$ is the cross-sectional area of the cube.

**Compressive Strength test of Cube**


**4.1.1 Split Tensile Strength of Concrete**

Using cylindrical specimens of 100 mm × 200 mm, the split tensile strength of concrete is ascertained. To guarantee even loading, the cylinders are meticulously put in the testing device. At7,14, and 28 days post-moisture curing, specimens are taken out of the curing tank and any surface water is cleaned off before testing. A compression testing machine is used to apply a load progressively at a rate of 2.1 kN/sec throughout the test.

The formula for the tensile stress that develops along the applied load's path is:

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$$T = \frac{0.637\,P}{D \cdot L}$$

Where:

T = Split tensile strength of concrete (MPa)

P = Applied load at failure (N)

D = Diameter of the cylinder (mm)

L = Length of the cylinder (mm)

An accurate assessment of the concrete's fracture resistance and overall structural performance relies on its tensile strength, which may be reliably measured using this approach.

**Fig4.2SplitTensileStrengthtestofcylinder**


**RESULTS AND DISCUSSION**

Extensive testing was carried out on the materials used to make Self-Compacting Concrete (SCC), and the results are presented in this chapter. The experimental program was to explore the effects of Metakaolin (MK) and Foundry Sand (FS) on the mechanical characteristics of SCC, namely its

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compressive strength, split tensile strength, and flexural strength, in order to evaluate its possible use in construction. We poured and dried samples of both the regular (control) concrete mix and SCC mixes with different proportions of Metakaolin and Foundry Sand, and different curing durations, to see how the results would change.

5.2 Strength under Compression One of the main reasons why concrete is so widely used in construction is its compressive strength. When a plain concrete component fails in an axial compression test, microcracks form and spread along the member's vertical axis due to lateral tensile stresses. These fractures often manifest in diagonal planes.

For this study, specimens of 150 mm × 150 mm × 150 mm were cast to determine the compressive strength after 7, 14, and 28 days of curing. A variety of control and SCC mixtures were evaluated, each with varying amounts of Foundry Sand added to the fine aggregate. A 10% cement replacement with Metakaolin was a constant in the SCC mixes, whereas the fine aggregate percentages ranged from 20% to 25% to 10%. Three examples were made for each combination and curing age, for a total of nine cubes per mix. After the stipulated curing intervals, the specimens were tested for compressive strength and the average results were recorded. The main results are shown in Table 5.1.

**Table 5.1 Compressive Strength of cubes**

| Compressive Strength (MPa) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Curing age (days) | 0% MK 0% FS | | 10% MK 10% FS | | 10% MK 15% FS | | 10% MK 20% FS | | 10% MK 25% FS | |
| 7 | 23.1 | 24.86 | 36.18 | 36.40 | 33.67 | 35.98 | 33.34 | 34.43 | 30.21 | 32.60 |
| | 26.49 | | 35.76 | | 35.99 | | 35.84 | | 35.1 | |
| | 24.99 | | 37.28 | | 38.28 | | 34.12 | | 32.51 | |
| 14 | 26.56 | 29.72 | 39.75 | 39.78 | 37.12 | 38.92 | 32.39 | 35.23 | 36.77 | 34.71 |
| | 30.8 | | 41.69 | | 39.45 | | 38.42 | | 34.45 | |
| | 31.79 | | 37.9 | | 40.19 | | 34.88 | | 32.9 | |
| 28 | 35.39 | 37.37 | 45.91 | 45.60 | 42.99 | 43.18 | 39.37 | 41.8 | 40.12 | 38.73 |
| | 38.23 | | 44.29 | | 44.67 | | 42.34 | | 37.76 | |
| | 38.5 | | 46.78 | | 41.89 | | 43.7 | | 38.32 | |

**Variation in the Compressive Strength with the increase in curing age**

If CM=Control mix

Metakaolin and 10% foundry sand make up M1. The formula M2 is 10% metakaolin and 15% foundrysand. M3, which is composed of 10% metakaolin and 20% foundrysand, 10 percent metakaolin and 25 percent foundrysand make up M4.

The compressive strength was measured for various percentages of FS with sand replacement (by weight), specifically for0%,10%,15%,20%, and 25%. After 28 days of testing, the compressive strength for 10% replacement (M1) was 22% higher than the control mix. At a water-cement ratio of 0.43, the compressive strength of the concrete cubes increases when the proportion of foundry sand is increased by substituting it with sand, as shown in the graph of compressive strength. In order to get the cubes' maximal compressive strength, one must substitute

10 percent cement, 10 percent makaolin, and 10 percent foundry sand. Cubes' compressive strength drops, nevertheless, when more sand is added.

5. Partition Tensile Strength

After7,14, and 28 days, the 200 mm x 100 mm cylinders were subjected to split tensile strength tests. Various percentages of foundry sand have been substituted for sand in the control mix (0%, 10%, 15%, 20%, and 25%), and metakaolin has been replaced with cement (set at 10%). For each %, a total of three samples were cast: one each for seven, fourteen, and twenty-eight days. After7,14, and 28 days, we tested a range of FS replacement amounts in concrete mixtures to find their split tensile strengths.

**Table5.2SplitTensilestrengthofcylinders**

| SplitTensileStrength(MPa) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Curing age (days) | 0%MK 0%FS | | 10%MK 10%FS | | 10%MK 15%FS | | 10%MK 20%FS | | 10%MK 25%FS | |
| 7 | 2.98 | 2.99 | 3.75 | 3.74 | 3.99 | 3.30 | 3.55 | 3.19 | 2.81 | 3.09 |
| | 3 | | 3.89 | | 3.21 | | 2.89 | | 3.12 | |
| | 2.99 | | 3.59 | | 2.71 | | 3.15 | | 3.33 | |
| 14 | 3.37 | 3.39 | 3.97 | 4.06 | 4.12 | 3.85 | 3.45 | 3.35 | 2.92 | 3.14 |
| | 3.39 | | 4.45 | | 3.8 | | 3.32 | | 3.12 | |
| 28 | 3.81 | 3.86 | 4.24 | 4.26 | 4.2 | 4.09 | 3.36 | 3.59 | 2.9 | 3.24 |
| | 3.91 | | 4.59 | | 3.88 | | 3.4 | | 3.26 | |
| | 3.86 | | 3.95 | | 4.18 | | 4.01 | | 3.57 | |

**here:**

"CM" stands for "Control Mix"
M1 is composed of 10% foundry sand and 10% metakaolin.
M2 is composed of 30% foundry sand and 10% metakaolin.

Metakaolin (10%) and Foundry Sand (20%) make up M3.
The formula M4 is 10% Metakaolin with 25% Foundry Sand.
The picture displays the results of the split tensile strength tests conducted on each of the concrete mixtures. The findings show that when 10% Foundry Sand is used instead of natural sand, the split tensile strength goes up. As compared to the control mix, M1's split tensile strength rose by 10.36% after 28 days of curing. At a Foundry Sand replacement level of 10%, the split tensile strength was higher than the control mix. At levels of 20% and 25% replacement, in particular, the strength starts to drop beyond this point. To get the best results in terms of split tensile strength, it is recommended to use a 10% replacement. Since there is only a little decrease in strength after 28 days, a 20% replacement is also appropriate for practical and cost-effective reasons.
Dynamic Rigidity
Flexural strains are typical for concrete pavements, including airways and roads. When concrete is bent under load, it undergoes a variety of stresses, including shear, tensile, compressive, and direct

## CONCLUSION

**6.1 Analysis of Compressive Strength**
The compressive strength findings show that at a water-cement ratio of 0.43, the compressive strength of concrete cubes increases first as the percentage of sand replaced by Foundry Sand increases, with a constant 10% substitution of cement by Metakaolin. Using Foundry Sand as a 10% replacement for sand produces the maximum compressive strength. The compressive strength gradually decreases after this degree of replacement if additional substitution is made.
Section 6.2: Split Tensile Strength Analysis
Just like compressive strength, divided tensile strength tends to follow a certain pattern. At a 10% sand-to-foundry-sand replacement ratio, the split tensile strength is at its maximum. A 20% replacement is still appropriate for practical applications since there is only a modest drop in tensile strength after 28 days, which also helps to cost efficiency. This is despite the fact that larger replacement levels lower strength.

6.3 Flexural Strength Analysis
Results for flexural strength follow a pattern similar to those of compressive and split tensile strengths. The flexural strength of concrete shows an increase with sand substitution by Foundry

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