

A Study on Experimental Investigation on the Properties of M30 Grade Concrete Using Metakaolin and Flyash

Mungara Venkata Naga Sai Bhargav¹; Dr. D. Sreehari Rao²

¹PG Student, Department of Civil Engineering,
Sri Venkateswara University College of Engineering, Tirupati, Andhra Pradesh, India.

²Assistant Professor, Department of Civil Engineering,
Sri Venkateswara University College of Engineering, Tirupati, Andhra Pradesh, India.

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Abstract: Amongst all of the construction substances which are available for construction, we understand that concrete is an extensively used creation fabric for building of various civil engineering structures. Concrete will supply higher durability and also its costs during production in addition to maintenance are very low when in comparison to different production substances. So that it will maintain its properly filling capacity, non-block glide and homogeneity. as a consequence, restrict high cement content which could raise cost as well as cause temperature increase throughout hydration and probably affect other traits like creep and shrinkage, subsequently giant quantities of additives are typically Metakaolin as a partial replacement for cement in concrete, aiming to enhance housing quality and reduce heat generation. Various admixtures are known to improve concrete's strength and workability, with Metakaolin standing out due to its distinct advantages. It significantly improves durability and resistance against chloride and sulphate attacks, freezing-thawing cycles, alkali-silica reactions, and frost damage. Additionally, Metakaolin enhances compressive strength, reduces permeability and bleeding, and strengthens the interfacial transition zone (ITZ), eliminating its typical weaknesses. In this research, concrete mixes incorporating 5%, 10%, 15%, and 20% Metakaolin were evaluated to determine optimal performance. At the optimal level of 15% Metakaolin, further cement replacement was done using fly ash at 10%, 20%, and 30% by weight. The hardened properties of these mixes were tested for compressive strength at 7, 28, 56, and 90 days, while split tensile and flexural strength were measured at 28 days.

Keywords: Concrete, Metakaolin, Fly Ash, Compressive Strength, Split Tensile Strength, Flexural Strength.

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I. INTRODUCTION

Concrete has been utilized in constructing creation because ancient instances, together with Greece and Rome, but the sector is confronted with sustainability issues from immoderate usage of virgin materials and cement's high greenhouse gas emissions. With a growth in construction interest comes extended call for concrete, a ubiquitous aspect in homes, highways, bridges, and lots greater. To address this, novel types of concrete, such as excessive-strength and self-compacting, have emerged to enhance great and sustainability. one of the most promising solutions is the usage of waste materials for partial or overall substitute of conventional aggregates or cement in concrete, those wastes no longer only minimize environmental footprints however also improve the power, durability, and workability of concrete. alternative of cement with supplementary cementing materials (SCMs) has the capacity to notably

lessen CO₂ emissions and enhance concrete characteristics. The growing utility of business via-merchandise in concrete presents a green alternative while minimizing landfill disposal and natural resource consumption. The elevated use of Portland cement in developing international locations bills for a huge proportion of CO₂ emissions, especially due to the burning of fossil fuels throughout cement manufacturing. To counter this, pozzolanas along with Metakaolin are being considered as opportunity substances to update a part of the cement. Metakaolin, that is crafted from thermally activated kaolin clay, reacts with calcium hydroxide during cement hydration to boom power and sturdiness. Its utility no longer simplest decreases cement utilization and CO₂ emissions but additionally prolongs shape life.

Metakaolin's reactive nature and nice particle size render it a successful pozzolan in concrete, enhancing compressive and flexural power, decreasing permeability,

and increasing durability. properly produced Metakaolin possesses meaningful benefits over different substances including silica fume or fly ash, improving completing, and decreasing efflorescence.

Fly Ash is a waste made of coal burning in power flora and is made of round nice debris derived from mineral impurities such as shale and clay. it's far collected the usage of electrostatic precipitators or bag filters and is particularly composed of silica, alumina, iron, and calcium. There are two instructions of Fly Ash for concrete packages: elegance F, which has pozzolanic interest, and class C, which has each cementitious and pozzolanic activity. Fly Ash unearths tremendous application in concrete, commonly making up 15-40% of the cementitious issue.

Fly Ash has some of advantages which includes waste utilization, lower disposal expenses, and environmentally beneficial components like reduced pollution. Its characteristics decorate workability, durability, lengthy-time period strength, and heat of hydration and water call for discount.

II. LITERATURE REVIEW

In this research work concerning the numerous programs and strategies used for checking out the concrete is reviewed. This review provides an in-depth summary of various studies conducted by researchers on the use of Metakaolin and fly ash as partial cement replacements in concrete.

Batham Geeta, Akhtar Saleem, and Rajesh Bhargava (2022) organized ultra-fine fly ash concrete mixes of excessive extent using OPC 53 grade cement for M40, M50, and M60 of higher grades. The control mix began with being prepared using 100% OPC cement. Later 40% of the cement content material became changed through extremely first-class fly ash, and the usage of Alccofine (metakaolin) and sparkling properties have been found. Metakaolin (alccofine) had been applied in 5%, 10%, 15%, and 20% for enhancing the properties of concrete and lowering the content of cement for M40, M50, and M60. In this manner, overall cement content material diminished as much as 60%. Replacement of cement with UFFA and the use of metakaolin produces higher-value and more powerful concrete. Laboratory checks decided the workability, density, and water absorption of concrete produced. UFFA and metakaolin aggregate indicate the use of metakaolin diminishes the workability of concrete and urban density. As compared to the control mix, concrete with fly ash and metakaolin suggests much less segregation, a lower absorption charge of water, and higher cohesion.

Snehl Ghuge, Yuvaraj Patil, Avinash Marathe, and Prof. Yogesh Deore (2018) The test conducted on concrete samples with 0, 6, 12, and 18% cement alternative used metakaolin and fly ash concurrently. Concrete is extremely sturdy in compression but extremely vulnerable in tension. But the tensile and bending electricity of concrete is 10 to 15% of compressive energy, respectively. Using numerous pozzolanic cloths in concrete has greatly improved its

compressive in addition to tensile electricity. Inside the contemporary research, metakaolin and fly ash are included within the mixes of concrete, and compressive takes a look at specimens. Fourteen (4+4) mixes will be prepared by using a one-of-a-kind percentage of metakaolin and fly ash on M40 and M20 grades of concrete mix. The inclusion of fly ash in concrete has been shown to enhance certain properties such as workability, long-term strength development, and specific durability aspects. In this study, concrete mixes with high proportions of fly ash and metakaolin were used as partial substitutes for ordinary Portland cement. M20 and M40 grade concrete mixes were prepared using varying combinations of metakaolin and fly ash to evaluate different performance characteristics and compare them with conventional concrete. Through optimization, a replacement level of 18% cement with a combination of metakaolin and fly ash was found to deliver superior results compared to other mixes

Alvin Harison et al. (2014) completed uncommon research on the usage of materials that could meet the expectancies of the development zone in various regions. In this research cement has been substituted with fly ash in due percentage in the range of zero%, 10%, 20%, 30%, 40%, 50%, and 60% by means of weight of cement for the M25 blend with a 0.46 water-cement ratio. Concrete combos have been organized, tested, and compared primarily based on compressive power. It becomes located that 20% alternative of Portland pozzolana cement with the aid of fly ash increases energy (1.9% to a few.2%) at 28 days and fifty-six days, respectively.

Hussein et al. (2013), In his study, Ordinary Portland Cement (OPC) was partially replaced with fly ash in proportions ranging from 5% to 50%. The results showed that a 10% replacement yielded the highest compressive strength across all curing periods. Additionally, using 15% to 30% fly ash significantly improved compressive strength at 90 and 180 days.

Swaroop et al. (2013) In his study, the focus was on evaluating changes in compressive strength and weight loss across five different M30 grade concrete mixes: conventional aggregate concrete (CAC), concrete with 20% cement replaced by fly ash (FAC1), concrete with 40% fly ash replacement (FAC2), concrete with 20% cement replaced by GGBS (GAC1), and concrete with 40% GGBS replacement (GAC2). To assess the durability of these mixes, concrete cubes were submerged in 1% H₂SO₄ solution and seawater for periods of 7, 28, and 60 days. The resulting changes in compressive strength and weight were measured. The findings indicated that concretes incorporating fly ash and GGBS demonstrated superior strength and durability under aggressive environmental conditions compared to conventional concrete.

Moinul and Saiful (2012) The study investigated the effect of fly ash on the performance of mortar and aimed to determine its optimal usage. Mortar containing fly ash as a partial replacement for cement, up to 50%, showed excellent results in both compressive and tensile strength. The ideal replacement level of fly ash was found to be around 40% of

the cement content.

Vidivelli and Mageswari (2010) executed the investigation on concrete with partial substitution of cement via fly ash. They concluded that compressive electricity, cut-up tensile strength, and flexural energy were more suitable by way of about 10% to 20% alternative of cement by means of fly ash.

Chindaprasirt (2005) The inclusion of fly ash in concrete generally enhances its overall compressive strength. However, when fly ash is used in high proportions (around 50% replacement), a reduction in compressive strength can occur. This influence is largely due to the packing effect of fly ash particles. Physical properties such as particle shape (sphericity), uniformity, and fineness play a key role in this effect. These characteristics allow fly ash particles to fill the voids within the concrete matrix more effectively, increasing its density. Additionally, the pozzolanic reaction further contributes to the improvement in compressive strength.

Jian-Tong Ding et al. (2002) experimental study was carried out to evaluate the effects of metakaolin and silica fume on various properties of concrete. Concrete mixes were prepared with 7.5%, 10%, and 15% replacement of cement by weight using high-reactivity metakaolin or silica fume, maintaining a water-cement ratio of 0.35 and a sand-to-aggregate ratio of 40%. The research examined how these materials influenced workability, mechanical strength, shrinkage behavior, and resistance to chloride penetration.

Results showed that incorporating either metakaolin or silica fume reduced free drying shrinkage and limited the width of shrinkage cracks. Furthermore, both additives significantly lowered the rate of chloride diffusion in concrete, with silica fume demonstrating better overall performance than metakaolin.

Sabir.B.B et al. (2001) Metakaolin as pozzolanic cloth for concrete and mortar and discussed a considerable range of applications of metakaolin in construction. They stated that using metakaolin as pozzolana will assist in the improvement of early strength and positive enhancement in long-term electricity. They stated that metakaolin adjusts the pore structure of cement paste mortar and urban and significantly complements its resistance to water transport and diffusivity of deleterious ions, which causes deterioration of the matrix.

III. CONSTITUENTS

➤ Cement

The experiment made use of regular Portland cement, especially grade 53 JSW cement—which may be observed effectively within the neighborhood marketplace. To keep the test uniform, the identical batch of cement was utilized for all exams. The cement's homes were scrutinized very carefully in opposition to specific parameters targeted in IS 4031-1988, making sure it meets the IS 12269-1987 trend. Table 1 informs the precise bodily homes of the cement.

Table 1 Physical Qualities of Cement

Sl No	Properties	Test Results
1	Normal Consistency	32%
2	Specific Gravity	3.11
3	Initial setting time	90min
4	Final setting time	330min
5	Fineness of Cement	4%

➤ Fine Aggregate

Locally available River sand, which meets Zone II specifications according to IS 383-1970, is used. The

bodily properties of this quality aggregate in info are given in table 2. It is well worth bringing up that the sand incorporates particles whose size is beneath 4.75 mm.

Table 2 Characteristics of Fine Aggregate

S. No	Properties	Test Results
1	Specific gravity	2.48
2	Fineness modulus	3.21

➤ Coarse Aggregate

Coarse aggregate with 20 mm and 12.5 mm maximum sizes was utilized. In step with the requirements

of IS 383-1970 and IS 2386-1983, experimental observation was performed for analyzing the properties of the coarse aggregates. The results are furnished in Table 3.

Table 3 Characteristics of Coarse Aggregate (20mm)

S. No	Properties	Test Results
1	Specific gravity	2.69
2	Fineness modulus	7.08

➤ *Metakaolin*

Metakaolin is a thermal remedy powder that forms while kaolinite undergoes thermal treatment. It forms on thermal treatment between 400 and 500°C; the water content is compelled out of an amorphous aluminosilicate called metakaolin (MK). It's far colorless and is a pozzolanic. The reactivity of the metakaolin also can be prompted by way of grinding to a smaller particle size.

➤ *Fly Ash*

Fly ash is also referred to as "pulverized gasoline ash" inside the United Kingdom. It's fly ash, a high-quality powder that stays after burning pulverized coal in a power plant to generate electricity. It's a form of pozzolana, which includes substances like alumina and silica. Whilst mixed with water, these materials help form cement. In this observation, the fly ash used had a density of 2.4 grams per cubic centimeter. The fly ash used came from a nearby supply in Nellore, Andhra Pradesh.

➤ *Water*

Fresh tap water conforming to IS:456-2000 standards used for the casting of concrete factors within the laboratory. Before the integration, the vital volume of water was carefully measured with a graduated jar and changed and then blended with the dry components.

➤ *Mix Design*

IS 10262-2019, IS 456-2000, and literature had been consulted so as to create specific grades of concrete. Table 4 illustrates the design blend ratio for M30 grade concrete.

Table 4 M30 Grade Design Mix Ratio

S. No	Material	Quantity(kg/m ³)
1	Cement	360
2	Fine Aggregate	699.3
3	Coarse aggregate	1186.4
Design Mix Ratio: 1:1.94:3.29 & W/c is 0.45		

IV. DISCUSSIONS OF TEST OUTCOMES

➤ *Compressive Strength*

Specimens with dimensions of 0.15 × 0.15 × 0.15 meters had been forged and examined in a compression

testing system (CTM) following 7, 28, 56, and 90 days of curing, which corresponded to special mix ratios for concrete. For each blend and curing age, the average strength was determined from 3 samples.

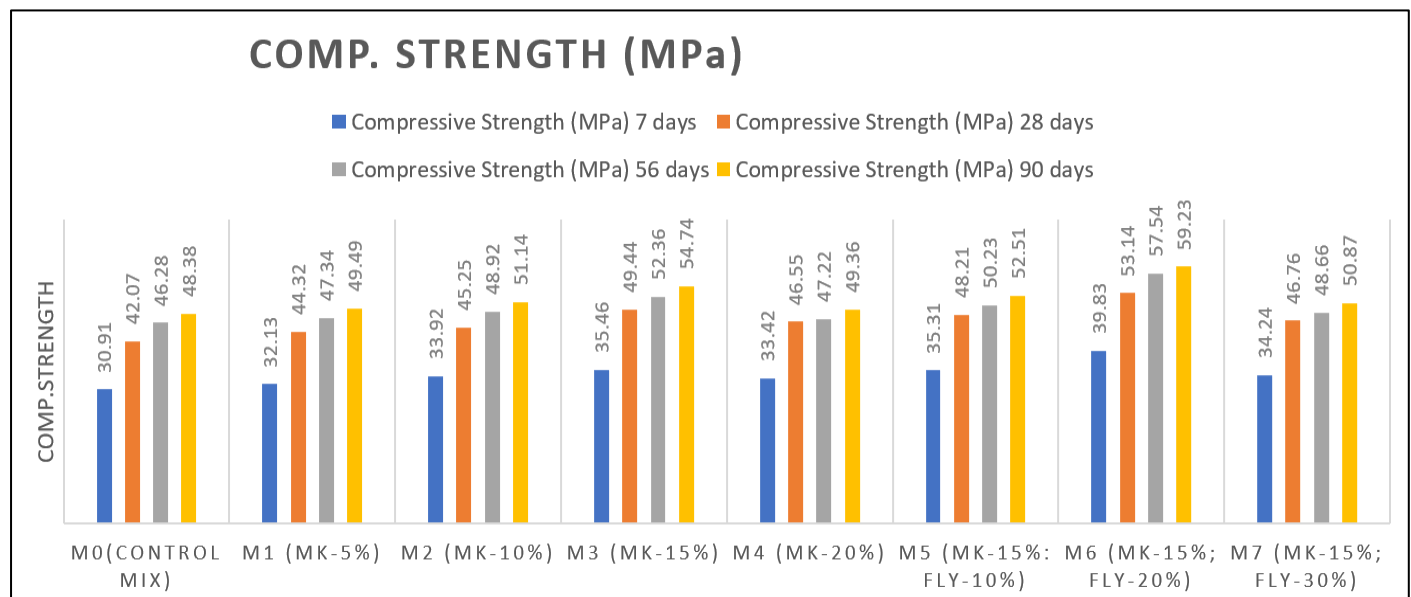


Chart 1 Compressive Strength of Concrete

➤ *Split Tensile Strength*

Tensile strength is a critical property of concrete, as it plays a significant role in determining its cracking behavior. Due to concrete's inherently low tensile strength and brittle nature, it is not typically relied upon to resist direct tension. However, assessing its tensile strength is important to identify

the load at which cracks may begin to form in structural elements. This measurement is typically performed using a Compression Testing Machine (CTM) at a loading rate of 140 kg/cm²/min. The split tensile strength results after 28 days are presented in the accompanying chart.

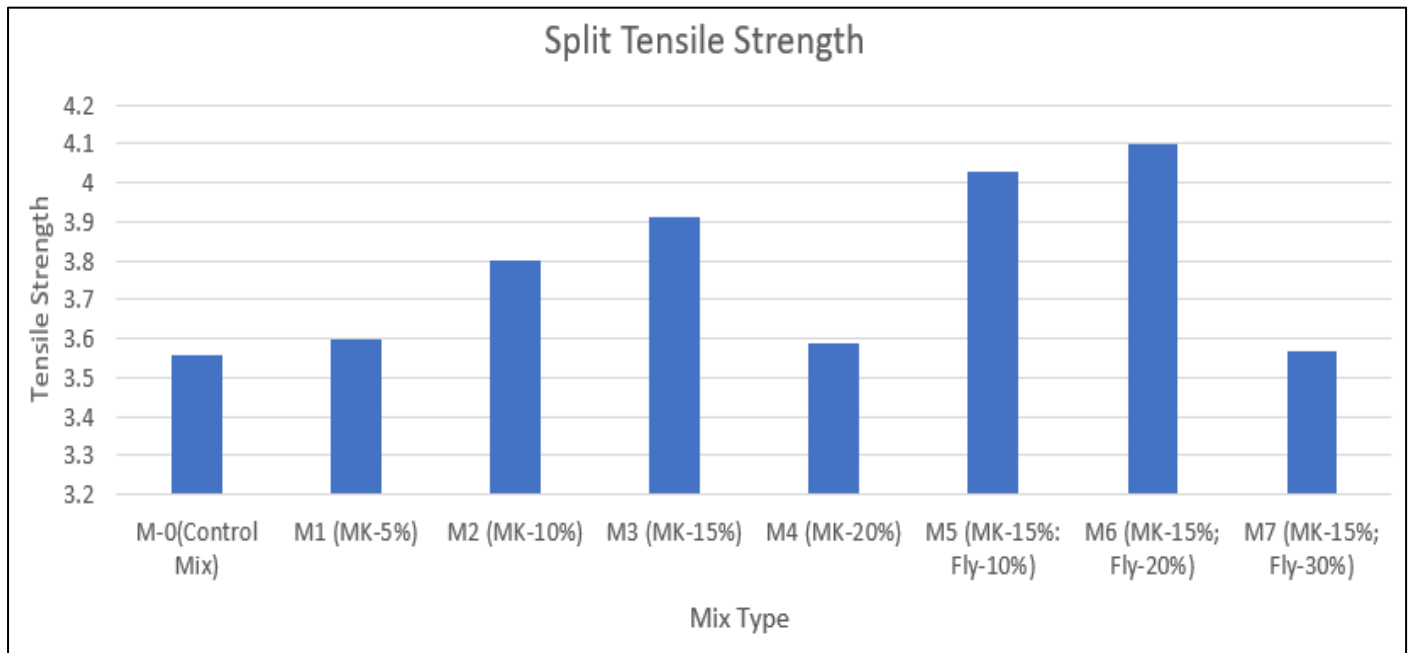


Chart 2 Split Tensile Strength of Concrete

➤ Flexural Strength

Flexural strength or modulus of rupture, and bending strength or fracture strength, are mechanical properties for brittle material and refer to a material's capacity to resist deformation under loading. Transverse bending takes a look

at the maximum typically applied, in which a specimen with either a circular or square cross-segment is flexed until yielding or fracture. Flexural strength is the best strain on the material at its point of failure. Flexural strength at 28 days shown on chart.

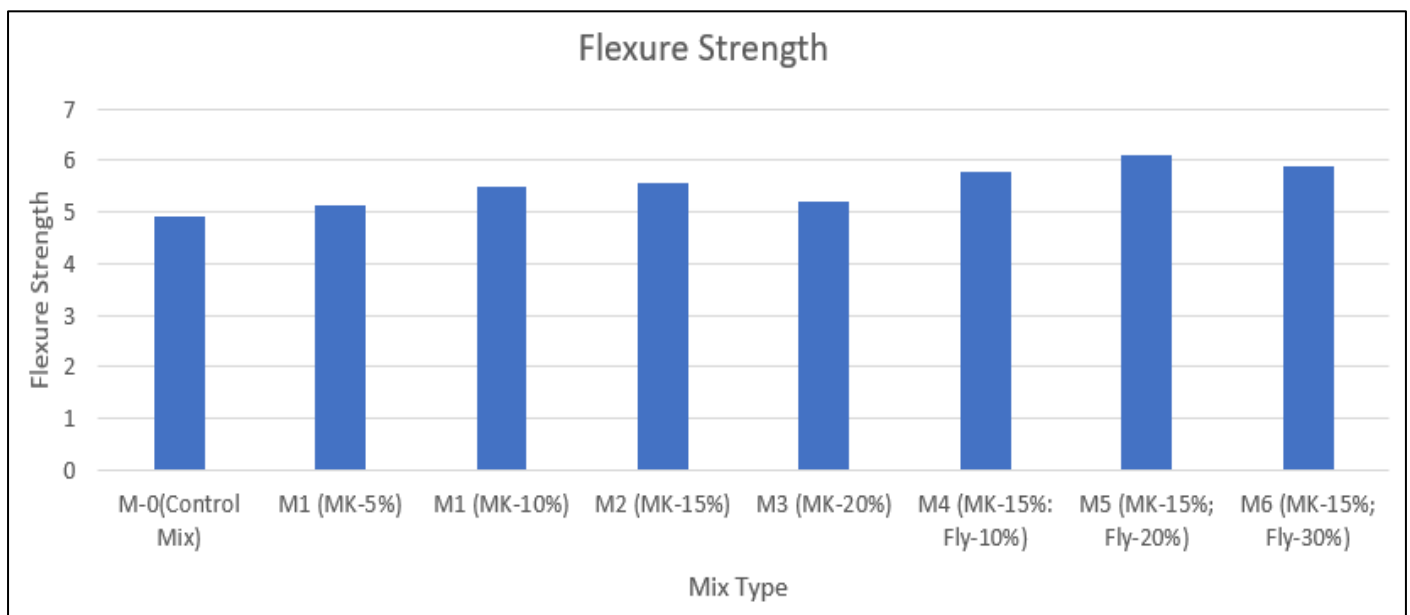


Chart 3 Flexural Strength of Concrete

➤ Concluding Remarks

Plain concrete is a brittle material with relatively low strength. Incorporating Metakaolin and Fly Ash into the concrete mix enhances its strength and durability. The test results from this study lead to the following conclusions.

- Test results show that when 15% Meta kaolin and 20% Fly Ash are used, the compressive strength increases by 22.5% after 90 days.

- The test results show that when 15% Meta kaolin and 20% Fly Ash are used, the compressive strength increases by 27.27% after 56 days.
- The test results show that when 15% Meta kaolin and 20% Fly Ash are used, the compressive strength increases by 26.3% after 28 days.
- The test results show that when 15% Meta kaolin and 20% Fly Ash are used, the compressive strength increases by 28.8% after 7 days.

- The test results show that when 15% Meta kaolin is used, the compressive strength increases by 15.8% after 56 days.
- The test results show that when 15% Meta kaolin is used, the compressive strength increases by 17.5% after 28 days.
- The test results show that when 15% Meta kaolin is used, the compressive strength increases by 14.7% after 7 days.
- The split tensile strength was highest at 4.1 MPa when 15% Meta kaolin and 20% Fly Ash were used, compared to the control concrete, which was 3.56 MPa.
- The split tensile strength increased by 9.8% to 3.91 MPa when 15% Meta kaolin was used, compared to the control concrete, which was 3.56 MPa.
- The flexural strength increased by 13.2% to 5.57 MPa when 15% Meta kaolin was used, compared to the control concrete, which was 4.92 MPa.
- The maximum increase in flexural strength was 24% to 6.1 MPa when 15% Meta kaolin and 20% Fly Ash were used, compared to the control concrete, which was 4.92 MPa.
- Regardless of the type of strength tested, the best results were achieved when cement was replaced with 15% Meta kaolin and 20% Fly Ash. The optimum percentage of Metakaolin and Fly Ash is 15%, 20% respectively

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