

# Research on Concrete that uses M-Sand, Chemical admixture, and Fly ash to partially replace Cement

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**Abstract** - This study focuses on the impact of chemical admixtures, M-sand, and partial cement replacement with fly ash on the characteristics of concrete. An increasing demand for sustainable construction materials has resulted in the usage of alternatives such as manufactured sand (M-sand) and fly ash, both of which help minimize environmental impact and improve concrete quality. The current investigation analyses the mechanical characteristics and durability of concrete by using a chemical additive that increases workability, M-sand as a full replacement for natural sand, and fly ash as a partial replacement for cement. In order to replace cement, concrete samples were prepared with varying percentages of fly ash (10%, 20%, and 30%), for M40 mix and their compressive strength, split tensile strength and workability were evaluated. According to the results, concrete that has been mixed with fly ash and M-sand has more strength and durability than traditional concrete. Chemical admixtures are used to further improve workability and performance, thereby making the modified concrete more suitable for environmentally friendly building methods. The results show that using fly ash and M-sand together can produce high-performance, environmentally friendly concrete while using less natural sand and ordinary cement. This research develops our understanding of sustainable concrete materials and provides useful advice for utilizing them in modern construction.

**Key Words:** Fly ash, Manufactured sand, Natural Sand, High-performance, Workability, Compressive Strength

## 1.INTRODUCTION

In recent years, there has been a rising demand to create sustainable alternatives that limit the use of natural resources in concrete production. This study investigates the use of three important sustainable components in concrete production: M-sand (Manufactured Sand), fly ash, and chemical admixtures. M-sand, created by crushing rocks, is an environmentally beneficial alternative to natural river sand, addressing sand depletion and environmental degradation. Fly ash, a byproduct of coal combustion in power plants, has been extensively researched as a supplemental cementitious material because of its pozzolanic qualities, which contribute to increased concrete strength and durability. By partially substituting cement

with fly ash, cement production's overall environmental effect, especially carbon emissions, can be substantially reduced. Chemical admixtures are also utilized to improve the performance and workability of concrete. These admixtures are a necessary part of contemporary concrete mixes since they improve strength, allow for better handling, and lower water content. This study aims to assess the combined impacts on concrete's durability and mechanical properties of fly ash and chemical admixtures, M-sand, and partial cement replacement. This study seeks to provide information on how these components affect concrete's behavior in order to produce more high-performing and environmentally friendly concrete solutions for the construction industry.

## 2.MATERIALS

The materials that are used are:

- OPC 53 grade Cement
- M-Sand (as fine aggregate)
- Coarse aggregate
- Fly ash
- Chemical admixture



**Fig 1:** Representing Cement, M-sand, Coarse aggregate and Fly ash

### 3.METHODOLOGY

In this Research the materials were selected based on their physical and chemical properties. The most important material for this research is M-Sand which is chosen as a fine aggregate with particle size of up to 4.75mm, and Coarse aggregate with particle size of up to 20mm. The main binder used in the concrete mix is Ordinary Portland Cement of 53 grade to ensure high strength and Durability. Fly ash is used as a mineral admixture, since it is a cementitious material it bind aggregates together and improve the strength and durability of the concrete. So in order to improve the strength of concrete cement is partially replaced with fly ash (I.e. 10%, 20%, 30% of weight of cement). By partially replacing cement with fly ash, the study aims to optimize the mix design to achieve both performance and environmental benefits. The experimental results will guide the proportion of fly ash that delivers the best balance between strength, durability, and cost-effectiveness.

#### 3.1 Mix Design

In this study we are preparing a mix design for M40 grade concrete with M-Sand as fine aggregate, partial replacement of cement by fly ash, and chemical admixtures, it is important to follow the proper methodology. The mix design should achieve the target strength and workability while taking into account the specific materials and replacement levels of cement.

**Table -1:** Mix Proportions

Grade	Cement	M-Sand	Coarse aggregate	Water
M40	1	1.8	3.4	0.4

**Table -2:** Quantities of Materials for M40 mix @1m<sup>3</sup>

Replacement of Cement (%)	0%	10%	20%	30%
Cement (kg/m <sup>3</sup> )	368.78	331.91	324.52	283.96
Fly ash (kg/m <sup>3</sup> )	0	36.88	81.13	121.69
M-Sand (kg/m <sup>3</sup> )	665.39	660.78	631.68	624.47
Coarse aggregate (kg/m <sup>3</sup> )	1261	1252.74	1240.09	1227.34
Chemical admixture (lit)	3.68	3.68	3.68	3.68
Water (lit)	147.51	147.51	147.51	147.51

#### 3.2 Casting Process

After mixing, the ready-made concrete is poured into molds measuring 150 x 150 x 150 mm. For conducting compressive strength tests and other tests as well the concrete must be molded into standard cube forms with these molds. The Casting is done according to the various mix proportions given in table -2 I.e. 0%, 10%, 20%, and 30% replacement levels of cement

To avoid air pockets or voids in the mixture, the concrete is carefully poured into the molds. The concrete-filled molds are vibrated after pouring to remove trapped air and ensure proper compaction. Subsequently, the molds are not disturbed for an entire day in order to ease the concrete's solidification.



**Fig 2:** Concrete Cubes in the molds

#### 3.2 Curing Process

The concrete specimens are removed from the molds after 24 hours. Proper curing is essential to improve the strength and durability of concrete. Curing keeps the concrete at the proper temperature and moisture level. The casted cubes are cured for 28 days to attain maximum strength. The curing process takes at a room temperature of 27°C. The duration and temperature are monitored closely to ensure the concrete's perfect hydration, allowing it to attain its maximum strength and durability. Regular monitoring during the curing process ensures that the concrete remains sufficiently wet and protected, which improves its overall performance and lifetime.



**Fig 3:** Concrete Cubes in the Curing tank

## 4. EXPERIMENTAL TESTS AND RESULTS

### 4.1 Workability Test

Workability refers to the way readily fresh concrete can be mixed, placed, compacted, and finished without segregation or bleeding. The slump test is often used to evaluate workability. In this study, we aim for a 75 mm slump and used superplasticizer in our concrete mix to increase workability while reducing water content. Since we are utilizing M-sand, we need to use superplasticizer. Concrete compositions with M-sand had a slightly lower initial workability than those with natural sand. However, the use of fly ash and chemical admixtures, such as superplasticizers, significantly improved workability. The process involves filling the slump cone with concrete in three separate steps and compacting each layer with a usual tamping rod so as to eliminate air bubbles and make sure uniform compaction. Once the cone has been removed, the loss in concrete height is measured to calculate the slump. A 75 mm slump indicates a medium consistency, which offers the required workability for the concrete mixture.

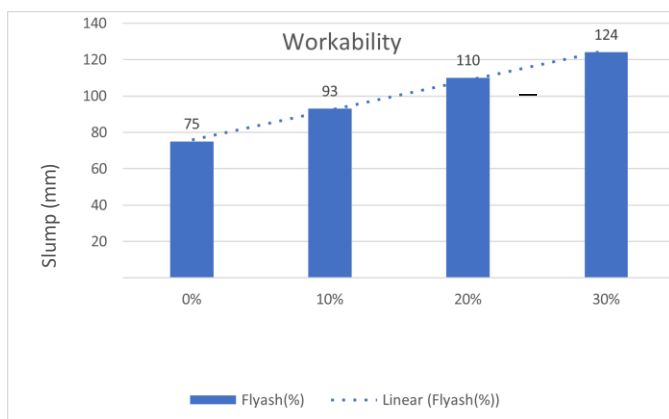


Fig 4: Workability of the Concrete

After performing the slump cone test on the first sample where cement was completely used (i.e., 0% replacement of cement), we obtained the slump value of 75mm, which is true slump and was exactly what we expected. Because during the mix design calculations we have aimed for a slump of 75mm as per IS 10262:2019.

The slump value for the second sample, in which 10% fly ash replaces for cement, is 93 mm. The slump value for the third sample, in which 20% fly ash replaces for cement, is 110 mm. Furthermore, the slump value for the fourth sample, which replaces 30% fly ash for cement, is 124 mm. As the amount of fly ash has increased, we have observed a progressive improvement in workability.

### 4.2 Compressive Strength Test

Compressive strength testing is an important technique to measure concrete's durability and load-bearing capacity. This

test is important for determining if concrete is suitable for structural applications since it analyzes the material's resistance to axial loads.

The compressive strength of a specimen is calculated by dividing its cross-sectional area by the maximum load applied to it. The compressive strength of each specimen is determined and noted. The test needs to be done three times for each blend in order to make sure accurate data and take into consideration any variations in the results.



Fig 5: Performing Compressive Strength Test on a Cube

The average compressive strength is then calculated from these triplicate tests to provide an overall evaluation of the concrete's performance.

$$\sigma = F/A$$

Where

F = Applied Load, A= Area Cross-sectional

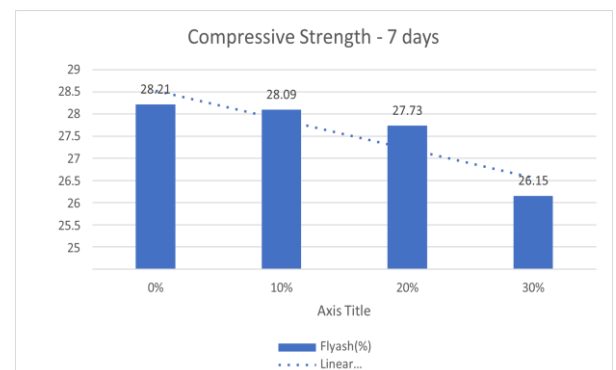


Fig 6: Compressive Strength at 7 days

The 7-day compressive strength is primarily influenced by the hydration of cement. In mixes without or with low fly ash content, the 7-day strength is typically around 60-70% of the 28-day strength. However, as the fly ash content increases, the early strength decreases due to the slower pozzolanic reaction of fly ash. Thus, the 7-day strength in fly ash mixes tends to be lower, especially at higher replacement levels (e.g., 20% and 30%).

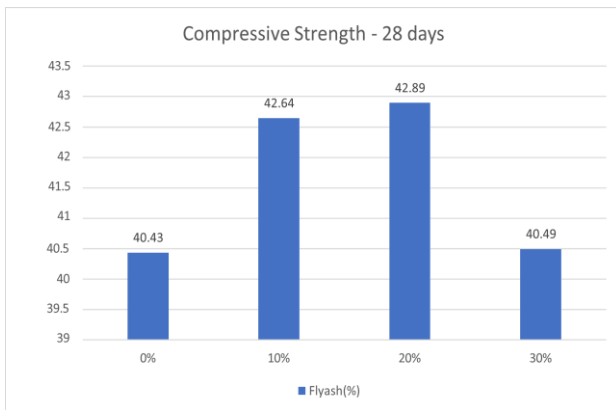


Fig 7: Compressive Strength at 28 Days

By 28 days, the concrete has reached its designed strength (40 MPa for M40 concrete). Fly ash, especially at 10-20% replacement, enhances the compressive strength after 7 days due to its reaction with calcium hydroxide, forming additional C-S-H gel. This leads to denser concrete and improved long-term performance. At 30% fly ash, the strength reaches a point close to the control mix, but the early strength suffers due to the reduced cement content.

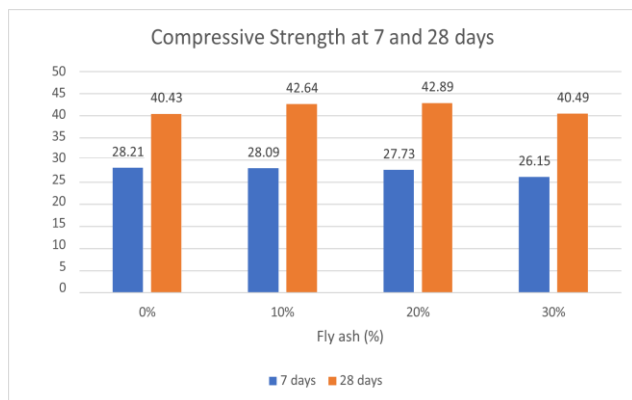


Fig 8: Comparing Compressive Strength and 7 days and 28 days

At 20% fly ash replacement is optimal for maximizing 28-day compressive strength in M40 concrete, offering performance and sustainability benefits. M-Sand is a viable substitute for river sand, with compressive strength exceeding or meeting the target strength of 40 MPa. The 30% fly ash replacement has slightly lower 28-day strength than the 10% and 20% replacements, but the long-term strength and durability benefits of higher fly ash content should be explored further. The combined use of fly ash and M-Sand creates an eco-friendly concrete mix, contributing to sustainable construction practices by reducing reliance on natural resources and mitigating environmental impacts.

### 4.3 Split Tensile Strength

In a universal testing machine (UTM), the cured cylindrical specimens are positioned horizontally between two loading plates. The application is made uniform and centered by applying the load progressively until failure occurs.

The test determines the load at which the specimen breaks, which usually happens when tensile strains from the applied load cause vertical cracks along the diameter. The following formula is used to get the split tensile strength (fct):

$$f_{ct} = \frac{2P}{\pi dl}$$

Where:

P = Load at failure (in Newtons)

d = Diameter of the cylinder (in mm)

l = Length of the cylinder (in mm)

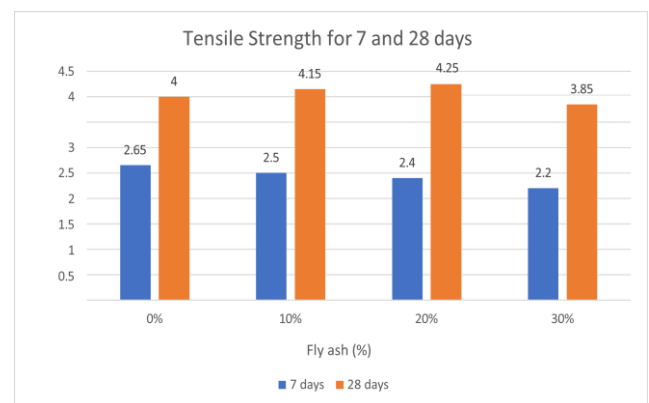


Fig 9: Tensile Strength of concrete at 7 days and 28 days

The 7-day tensile strength is largely dependent on the amount of cement in the mix. Since fly ash reacts more slowly than cement, mixes with higher fly ash content (20% and 30%) tend to have lower early tensile strength compared to the control mix. However, the addition of chemical admixtures (such as superplasticizers) helps maintain workability, ensuring proper bonding between the M-Sand and cementitious materials, even in mixes with fly ash. By 28 days, the pozzolanic reaction of fly ash has had sufficient time to contribute to strength development. Mixes with 10-20% fly ash replacement show an improvement in split tensile strength compared to the control mix, indicating that fly ash helps improve the long-term tensile properties of concrete. However, at 30% fly ash, the tensile strength gain stabilizes or slightly decreases, as the reduced cement content limits the early strength gain, and fly ash cannot fully compensate within 28 days.

## 5. CONCLUSION

This study examines the performance of M40 concrete in terms of compressive and split tensile strength compared to a conventional mix. The study found that the 20% fly ash mix significantly improved compressive strength, reaching 42.89 MPa. The optimal combination of early strength and long-term performance was found with 10-20% fly ash, with the 20% mix yielding the highest split tensile strength at 4.3 MPa. The study also found that M-Sand can effectively replace natural sand in concrete production, indicating its potential as a workable and environmentally friendly substitute.

Overall, this study demonstrates that fly ash can be replaced up to 10% to 20% of cement and M-Sand can successfully replace conventional materials in M40 concrete, enhancing long-term compressive strength and tensile strength while offering environmental and economic benefits.

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