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A Research Investigations on Mix Design for High Strength Concrete

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Abstract- Concrete is one of the most widely used construction materials due to its strength, durability, versatility, and ease of availability. It is a composite material made of cement, fine aggregates, coarse aggregates, and water, along with the addition of admixtures to enhance its properties. In modern construction, there is an increasing demand for materials with higher strength and durability to meet the requirements of high-rise buildings, bridges, and heavy load structures. This has led to the development of High Strength Concrete (HSC). The present study focuses on the development of High Strength Concrete using proper mix design techniques and the incorporation of mineral and chemical admixtures. The main objective of this research is to achieve a compressive strength greater than 50 MPa by optimizing the proportions of materials. The trial and error method is adopted for mix design, and two trial mixes are prepared to study the effect of water-binder ratio and superplasticizer on the performance of concrete. Trial Mix 1 is prepared without the use of superplasticizer and with a higher water-binder ratio, while Trial Mix 2 is prepared with the inclusion of superplasticizer (Auramix-400) and a lower water-binder ratio. Fly ash and marble dust are used as mineral admixtures to improve strength, durability, and density of concrete. Cube specimens of standard size are cast and tested for compressive strength at 3, 7, and 28 days. The experimental results indicate that compressive strength increases with curing age for both mixes. Trial Mix 2 shows superior performance and achieves a compressive strength of 50.47 MPa at 28 days, satisfying the requirements of M50 grade concrete. The use of superplasticizer significantly improves workability and allows reduction in water content, resulting in higher strength. Fly ash contributes to long-term strength gain, while marble dust acts as a filler material, reducing voids and increasing density. The study concludes that High Strength Concrete can be successfully developed using locally available materials by optimizing mix design and using suitable admixtures. The developed concrete mix is economical, durable, and suitable for modern construction applications.

Keywords: High Strength Concrete, Mix Design, Admixtures, Sustainable Concrete, Recycled Materials, UHPC, HPC, Optimization Techniques.

I. INTRODUCTION

Concrete is one of the most widely used construction materials in the world due to its versatility, strength, durability, and ease of availability. It is a composite material formed by mixing cement, fine aggregates (sand), coarse aggregates (gravel or crushed stone), and water in suitable proportions. When water is added to cement, a chemical reaction known as hydration takes place, which binds the aggregates together and gradually hardens to form a strong and durable mass. In modern construction practices, various additional materials known as admixtures are incorporated into the concrete mix to improve its performance characteristics such as workability, strength, durability, and resistance to environmental effects.

The importance of concrete in the field of civil engineering cannot be overstated. It is used in almost every type of construction, including residential buildings, commercial complexes, industrial structures, bridges, highways, dams, tunnels, and water retaining structures. The widespread use of concrete is mainly due to its ability to be moulded into any shape, its high compressive strength, and its relatively low cost compared to other construction materials such as steel. Moreover, the raw materials required for making concrete are easily available in most parts of the world, making it an economical and sustainable choice for construction. Historically, concrete has been used for thousands of years. Ancient civilizations such as the Romans used early forms of concrete for constructing massive structures like aqueducts, amphitheaters, and temples. Over time, with advancements in technology and material science, the quality and performance of concrete have improved significantly. Today, modern concrete is engineered to meet specific requirements of strength, durability, and environmental resistance.

In recent years, the construction industry has witnessed rapid growth due to increasing population, urbanization, and industrialization. This has led to a rising demand for high-rise buildings, long-span bridges, offshore structures, and heavy industrial facilities. Such structures require construction materials that can withstand high loads, harsh environmental conditions, and long service life. Conventional concrete, which generally has compressive strength up to 40 MPa, may not always be sufficient to meet these demanding requirements. Therefore, there is a need for advanced types of concrete with improved performance characteristics. This need has led to the development of High Strength Concrete (HSC), which is specially designed to achieve higher compressive strength compared to normal concrete. High Strength Concrete typically has compressive strength greater than 40 MPa and can go up to 100 MPa or even higher depending on the mix design and materials used. The development of HSC has revolutionized the construction industry by enabling the construction of taller buildings, longer bridges, and more durable infrastructure. One of the key factors that influence the strength of concrete is the water-cement ratio. It is well established that lower water-cement ratio leads to higher strength and better durability. However, reducing water content in concrete makes it less workable and difficult to handle. To overcome this problem, chemical admixtures such as superplasticizers are used. These admixtures improve the workability of concrete without increasing the water content, thus allowing the production of high strength concrete with low water-cement ratio. In addition to chemical admixtures, mineral admixtures such as fly ash, silica fume, and marble dust are also used in concrete. These materials not only enhance the strength and durability of concrete but also help in reducing the cost and environmental impact by utilizing industrial waste products. Fly ash, for example, is a by-product of thermal power plants and is widely used as a partial replacement for cement. It improves the long-term strength and durability of concrete while reducing heat of hydration. Similarly, marble dust acts as a filler material, improving the density and reducing voids in the concrete mix.

II. METHODOLOGY

METHOD USED: The development of High Strength Concrete (HSC) in the present study is carried out using a systematic and practical approach based on experimental investigation. Concrete mix design is not a completely theoretical process, as the properties of concrete depend on various factors such as material quality, environmental conditions, and mixing techniques. Therefore, a suitable method is required to achieve the desired strength and performance of concrete. In this study, the Trial and Error Method is adopted for the development of High Strength Concrete.

The following method is used:

1. Trial and Error Method
2. Target Mean Strength: 50 MPa

EXPERIMENTAL APPROACH:

To achieve the objectives of the present study, a systematic and well-planned experimental approach is adopted for the development and evaluation of High Strength Concrete (HSC). The experimental program is designed in such a way that it helps in understanding the influence of different parameters such as material properties, water-binder ratio, and use of admixtures on the compressive strength and overall performance of concrete. Concrete is a material whose properties are highly dependent on the quality of ingredients and the method of preparation. Therefore, a controlled laboratory investigation is essential to obtain reliable and accurate results.



OPC 53 Grade



Fly Ash



Sand-1 (2.36 mm)



Sand-2 (finer)



C. A. (10 mm)



C. A. (20 mm)



Marble Dust



Superplasticizer



Water

Figure 3.3: Collection of Materials

The following step-by-step approach is adopted in this study:

- Selection of suitable materials
- Design of concrete mix using trial method
- Preparation of two trial mixes
- Casting of cube specimens
- Curing for different time periods
- Testing for compressive strength

INGREDIENTS OF HIGH STRENGTH CONCRETE:

Apart from conventional ingredients, High Strength Concrete includes mineral and chemical admixtures.

Table 3.1: Materials Used in HSC

Ingredient	Size/Grade
Cement	OPC 53 Grade
Fly Ash	Class-F
Fine Aggregate	2.36 mm
Coarse Aggregate	10 mm
Coarse Aggregate	20 mm
Water	Potable
Superplasticizer	Auramix-400
Marble Dust	2.36 mm

TRIAL MIX – 1:

Proportion of Ingredients:

Component	Ratio
Powder (Cement + Fly Ash)	1
Fine Aggregate	1.25

Coarse Aggregate	1.65
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Water-Powder Ratio: 0.42

Admixture Content:

Admixture	Quantity
Fly Ash	10%
Marble Dust	10%

Table 3.4: Material Quantities (Trial Mix 1)

No.	Material	Quantity (kg)
1	Cement	21.6
2	Fly Ash	2.4
3	Sand (2.36 mm)	15
4	Sand (1.18 mm)	15
5	Coarse Aggregate (10 mm)	20
6	Coarse Aggregate (20 mm)	20
7	Marble Dust	2.4
8	Water	10

TRIAL MIX – 2:

Proportion of Ingredients:

Component	Ratio
Powder	1
Fine Aggregate	1.30
Coarse Aggregate	1.70

Water-Powder Ratio: 0.32

Admixture Content:

Admixture	Quantity
Fly Ash	10%
Marble Dust	10%
Superplasticizer	1%

Table 3.5: Material Quantities (Trial Mix 2)

No.	Material	Quantity (kg)
1	Cement	35.3
2	Fly Ash	3.9
3	Sand (2.36 mm)	25.5
4	Sand (1.18 mm)	25.5
5	Coarse Aggregate (10 mm)	33
6	Coarse Aggregate (20 mm)	33
7	Marble Dust	3.9
8	Superplasticizer	0.39
9	Water	12.68



Compaction by Vibration



Casted Elements



Broken Element



Casted Elements

Figure 3.4: Casted Specimen

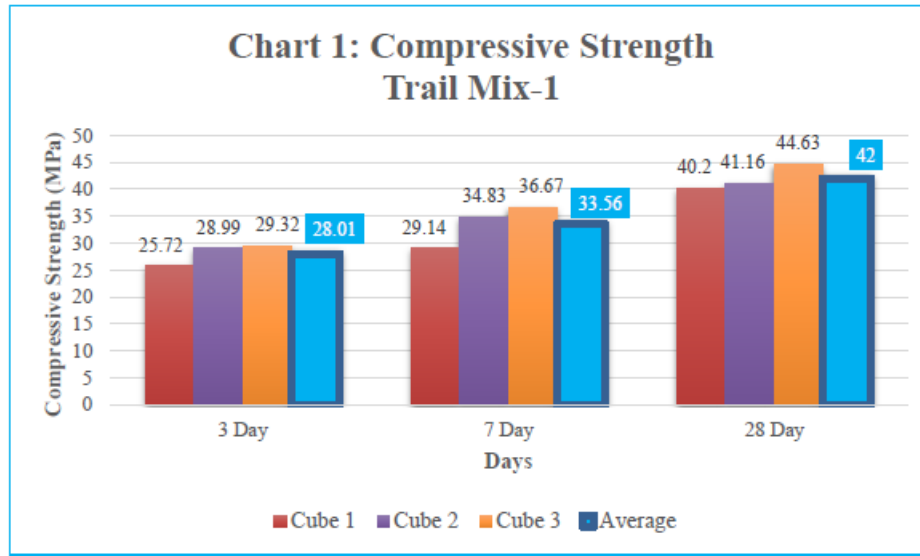
III. RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH RESULTS – TRIAL MIX 1:

The compressive strength results of Trial Mix 1 are presented in this section based on experimental testing carried out at different curing periods. Trial Mix 1 was prepared without the use of superplasticizer and with a relatively higher water-binder ratio of 0.42. The objective of this mix was to evaluate the performance of conventional high strength concrete using mineral admixtures such as fly ash and marble dust. Standard cube specimens were cast and tested at 3 days, 7 days, and 28 days to determine the strength development over time. The compressive strength test was conducted using a compression testing machine, and three specimens were tested for each curing period to ensure accuracy of results. The average compressive strength was calculated from these readings. The results indicate that the compressive strength of Trial Mix 1 increases gradually with curing age. At 3 days, the concrete exhibits moderate strength, indicating the early hydration of cement. At 7 days, there is a noticeable increase in strength due to continued hydration and pozzolanic reaction of fly ash. At 28 days, the concrete achieves its maximum strength, reaching up to 42 MPa. The presence of fly ash contributes to long-term strength gain, while marble dust improves the density of the mix by filling voids. However, due to the absence of superplasticizer and higher water content, the strength achieved is comparatively lower than optimized mixes. The higher water-binder ratio results in increased porosity, which reduces the overall strength of concrete.

Table 4.1: Compressive Strength Results for Trial Mix – 1

Days	Cube 1 (MPa)	Cube 2 (MPa)	Cube 3 (MPa)	Average (MPa)
3 Days	25.72	28.99	29.32	28.01
7 Days	29.14	34.83	36.67	33.56
28 Days	40.20	41.16	44.63	42.00



Graph 4.1: Compressive Strength – Trial Mix 1

COMPRESSIVE STRENGTH RESULTS – TRIAL MIX 2:

The compressive strength results of Trial Mix 2 are presented in this section based on experimental investigation carried out at different curing periods. Trial Mix 2 was prepared with the inclusion of superplasticizer (Auramix-400) and a lower water-binder ratio of 0.32. The main objective of this mix was to evaluate the effect of chemical admixture and reduced water content on the strength and performance of High Strength Concrete. Concrete cube specimens were cast and tested at 3 days, 7 days, and 28 days using a compression testing machine. For each curing period, three specimens were tested, and the average compressive strength was calculated to ensure reliability and accuracy of results.

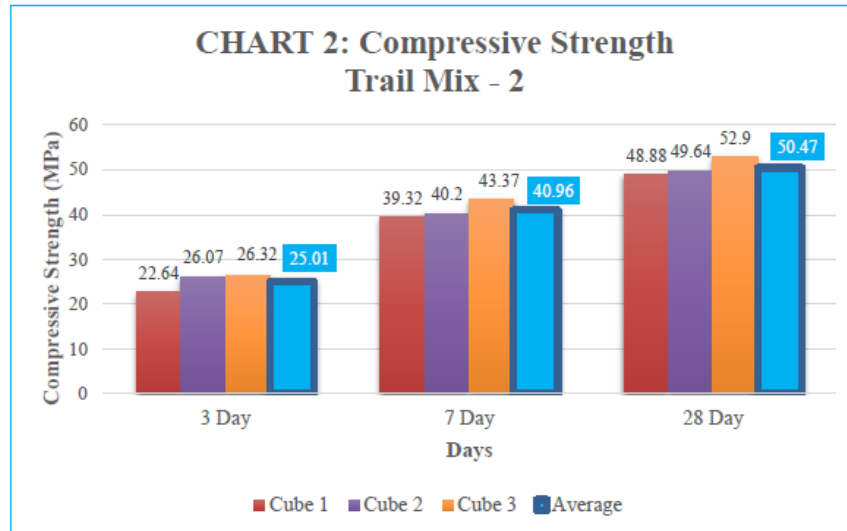
The results show that the compressive strength of Trial Mix 2 increases significantly with curing age. At 3 days, the strength is slightly lower compared to Trial Mix 1 due to the slower initial hydration process associated with low water content. However, a substantial increase in strength is observed at 7 days, indicating improved hydration and pozzolanic activity. At 28 days, Trial Mix 2 achieves a compressive strength of 50.47 MPa, which satisfies the requirements of M50 grade High Strength Concrete.

The remarkable increase in strength is primarily due to the lower water-binder ratio and the use of superplasticizer, which enhances particle dispersion and reduces voids within the concrete matrix.

The superplasticizer improves workability without increasing water content, allowing better compaction and uniform distribution of materials. This results in a dense and homogeneous concrete structure with improved bonding between particles. Additionally, the presence of fly ash contributes to long-term strength gain, while marble dust enhances density by acting as a filler material.

Table 4.2: Compressive Strength Results for Trial Mix – 2

Days	Cube 1 (MPa)	Cube 2 (MPa)	Cube 3 (MPa)	Average (MPa)
3 Days	22.64	26.07	26.32	25.01
7 Days	39.32	40.20	43.37	40.96
28 Days	48.88	49.64	52.90	50.47



Graph 4.2: Compressive Strength – Trial Mix 2

COMPARATIVE ANALYSIS:

Table 4.3: Comparison of Trial Mix 1 and Trial Mix 2

Parameter	Trial Mix 1	Trial Mix 2
W/B Ratio	0.42	0.32
Superplasticizer	No	Yes
3 Day Strength	28.01 MPa	25.01 MPa
7 Day Strength	33.56 MPa	40.96 MPa
28 Day Strength	42 MPa	50.47 MPa

M50 GRADE CONCRETE MIX – PROPORTION:

Table 4.4: Mix Proportion of M50 Grade Concrete

Component	Proportion
Binder (Cement + Fly Ash)	1
Fine Aggregates	1.30
Coarse Aggregates	1.70

Table 4.5: Mix Parameters

Parameter	Value
Water/Binder Ratio	0.32
Fly Ash	10% replacement of cement content
Marble Dust	10% of binder content
Superplasticizer	1% of binder content

M50 Grade Concrete Mix Design for 1 m³:**Table 4.6: Material Quantities for 1 Cubic Metre**

Sr. No.	Ingredient	Quantity
1	Cement	540 kg
2	Fly Ash (Class-F)	60 kg
3	Sand-1 (2.36 mm)	390 kg
4	Sand-2 (1.18 mm)	390 kg
5	Coarse Aggregate (10 mm)	510 kg
6	Coarse Aggregate (20 mm)	510 kg
7	Water (Potable)	192 litres
8	Superplasticizer (Auramix-400)	6 kg
9	Marble Dust	60 kg

CONCLUSION

The study concludes that High Strength Concrete (HSC) can be effectively produced using proper mix design, suitable admixtures, and controlled water-binder ratio. The results show that compressive strength increases with curing age, and Trial Mix 2 achieved 50.47 MPa, confirming M50 grade concrete with about 20% higher strength than Trial Mix 1. A lower water-binder ratio (0.32) significantly improved strength, density, and reduced porosity. The use of superplasticizer (Auramix-400) enhanced workability without increasing water content, ensuring proper compaction and strength gain. Additionally, fly ash improved long-term strength and durability, while marble dust acted as a filler to reduce voids and permeability. Overall, HSC demonstrated better durability, lower permeability, and suitability for high-rise and heavy structures, proving that high-performance concrete can be developed using locally available materials with proper design and curing practices.

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