EFFECT ON PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN AND SUPERPLASTICIZER

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Abstract - Metakaolin, a pozzolanic material, has been recognized for its potential to enhance concrete properties, while superplasticizers are commonly used to improve workability and reduce water content in concrete mixtures. The experimental program involves the preparation of concrete mixtures with metakaolin replacements at different levels (by 0%, 5%, 10%, 15%, and 20% by weight of cement). A commercially available superplasticizer is added to the mixtures (by 0%, 0.5%, 1%, 1.5%, and 2% by weight of cement) to optimize workability. The properties of the resulting concrete, including slump cone test, compressive strength, flexural strength, split tensile strength are assessed. The results show that the incorporation of metakaolin in concrete leads to improved mechanical properties, with significant enhancements observed in compressive and flexural strengths. Moreover, the inclusion of a superplasticizer improves the workability of the concrete mixtures containing metakaolin, ensuring easier placement and compaction.

***Key Words*:** Concrete, Metakaolin, Superplasticizers.

1.INTRODUCTION

METAKAOLIN: Metakaolin, derived from the calcination of kaolin clay, exhibits remarkable properties that make it a valuable supplementary cementitious material in concrete. One significant benefit of incorporating metakaolin in concrete is the enhancement of strength and durability properties. Metakaolin contributes to increased compressive strength, flexural strength, and overall mechanical performance of the concrete. Its pozzolanic behavior allows it to react with calcium hydroxide, a byproduct of cement hydration, forming additional cementitious compounds. This reaction leads to improved chemical resistance, reduced permeability, and mitigated alkali-silica reactions, ultimately enhancing the durability and service life of concrete structures.

PROJECT OBJECTIVES:

- Evaluating the workability of concrete mixtures containing metakaolin by measuring slump flow. Determine the effect of metakaolin content.

- Determining the effect of metakaolin content on the compressive strength, flexural strength of concrete.

- Determining the most effective and efficient dosage of metakaolin as a partial replacement for cement in concrete mixtures. Identify the metakaolin content that offers the best balance of strength, durability, and workability properties.

2.LITERATURE REVIEW

Arka Saha et al. (2014): conducted a comprehensive study to evaluate the feasibility of integrating fly ash as a replacement material in concrete production. The investigation involved utilizing varying percentages of fly ash, ranging from 0% to 40%, to replace traditional cement in the concrete mixture. The primary objective was to assess the impact of different fly ash contents on various concrete properties, including compressive strength, durability, and other critical factors.

Bhutta, M. A. R (2015): Bhutta et al.'s review focuses on the utilization of waste materials such as glass and ceramic powder as partial replacements for cement in concrete. It discusses the effects on workability, strength, and durability, along with the environmental benefits of recycling glass and ceramic waste.

Ganesan K (2007): This study delves into the use of industrial byproducts, such as ground granulated blast furnace slag (GGBFS) and silica fume, as partial replacements for cement in concrete. It covers the impact on strength, durability, and environmental sustainability.

Mehta, P. K (2006): In their study a comprehensive overview of the use of supplementary cementitious materials, including fly ash, slag, and silica fume. They discuss the impact on concrete properties and the sustainability aspects of these materials.

Zhang, L (2006): Zhang and Gjorv's review delves into the use of high-volume fly ash concrete, where a significant portion of the cement is replaced with fly ash. The paper discusses the effects on workability, strength, and durability, emphasizing the economic and environmental advantages of high-volume fly ash mixes.

3.METHODOLOGY

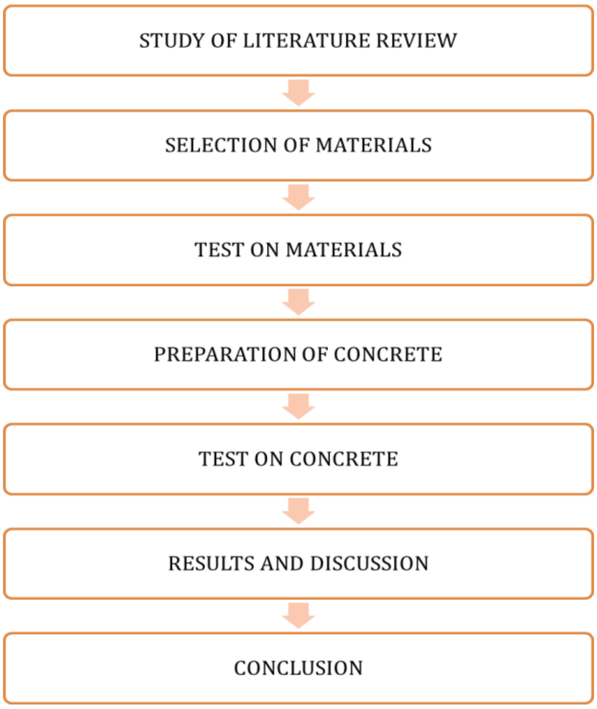

Fig 3.1: Flow Chart of Methodology

4. EXPERIMENTAL PROGRAMME

Table 4.1 Test results of Cement

S. No	Property	Values
1	Specific gravity	3.17
2	Fineness	2%
3	Consistency	31%
4	Initial setting time	41 minutes
	Final setting time	356 minutes
5	Compressive strength	55.6 N/mm^2

Table 4.2 Test results of Fine Aggregate

S. No	Test name	Test Results
1.	Specific Gravity	2.68
2.	Fineness Modulus	2.9
3.	Silt Content	0.8%
4.	Clay Content	0.5%

Table 4.3 Test Results of Coarse Aggregate

S. No	Test name	Test Results
1.	Specific Gravity	2.71
2.	Flakiness Index	12%
3.	Elongation Index	7%
4.	Impact Value	15%
5.	Water Absorption	0.9%
6.	Crushing Strength	23%

Table 4.4 Physical Properties of Metakaolin

S. No	Property	Values
1	Specific gravity	2.64
2	Percentage of voids %	11.22
3	Bulk density g/cc	1452 kg/m2
4	Fineness modulus	7.35
5	Water absorption %	28.5
6	Moisture content	4.2

Table 4.6 Chemical Properties of Metakaolin (AS PER SUPPLIER)

S. No	Property	% of component
1	Silicon dioxide	84
2	Aluminium oxide	1.12
3	Iron oxide	1.46
4	Calcium oxide	0.4
5	Magnesium oxide	0.7
6	Sodium oxide	0.6
7	Potassium oxide	1.0
8	Loss on ignition	5

Table 4.7 Chemical properties of superplasticizer (AS PER SUPPLIER)

S. No	Property	% of Component
1	Silicon dioxide	84
2	Aluminium oxide	1.12
3	Iron oxide	1.46
4	Calcium oxide	0.4
5	Magnesium oxide	0.7
6	Sodium oxide	0.6
7	Potassium oxide	1.0
8	Loss on ignition	5

5.RESULTS AND DISCUSSION

Table 5.1 Variation of Slump Values Due to Metakaolin

Sample No	Metakaolin (%)	Slump Value (mm)
1	0	100
2	5	105
3	10	110
4	15	115
5	20	110

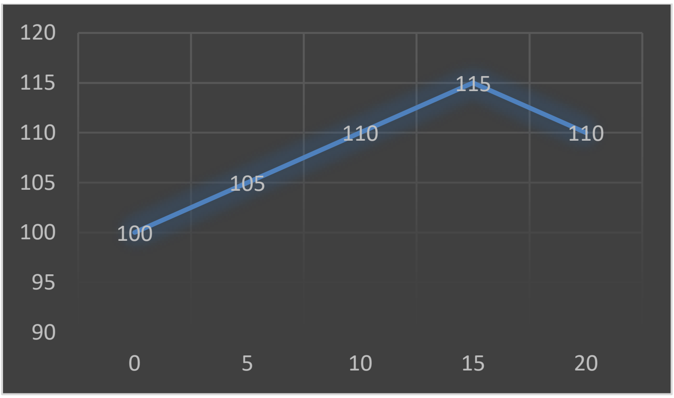

Fig 5.1 Variation of Slump Values Due to Metakaolin

Table 5.2 Variation of Slump Values Due to Superplasticizer

Sample No	Superplasticizer (%)	Slump Value (mm)
1	0	60
2	0.5	100
3	1.0	150
4	1.5	180
5	2.0	170

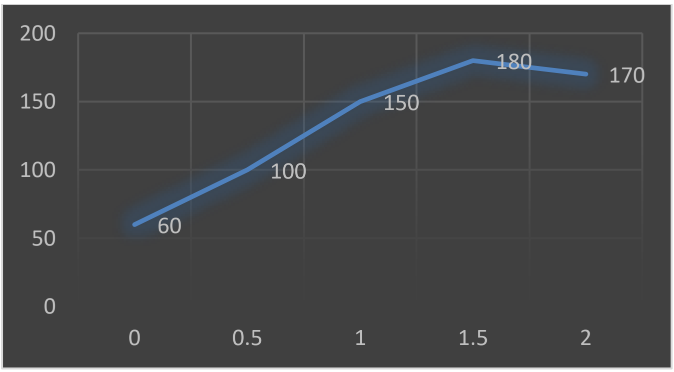

Fig 5.2 Variation of Slump Values Due to Superplasticizer

Table 5.3 Variation of Slump Values Due to Both Metakaolin & Superplasticizer

Sample No	Metakaolin (%)	Superplasticizer (%)	Slump Value (mm)
1	15	0.5	85
2	15	1.0	92
3	15	1.5	98
4	15	2.0	93

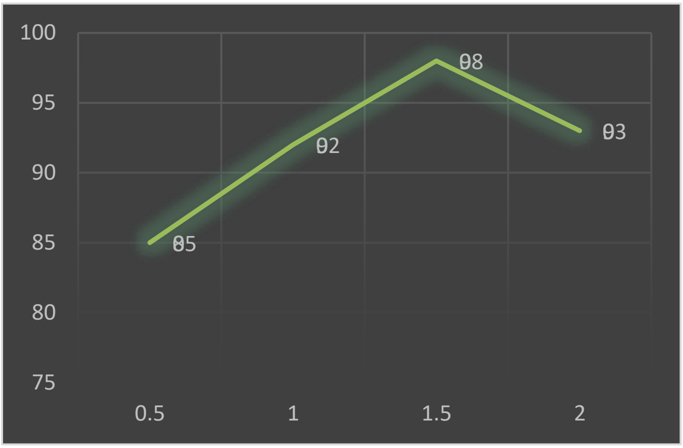

Fig 5.3 Variation of Slump Values Due To Both Metakaolin & Superplasticizer

Table 5.4 Variation of Compressive Strength Due to Metakaolin

Sample No	Metakaolin (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0	18.5	24.8	30.5
2	5	20.2	26.4	32.2
3	10	22.0	28.5	34.8
4	15	23.8	29.7	35.7
5	20	21.5	27.3	33.1

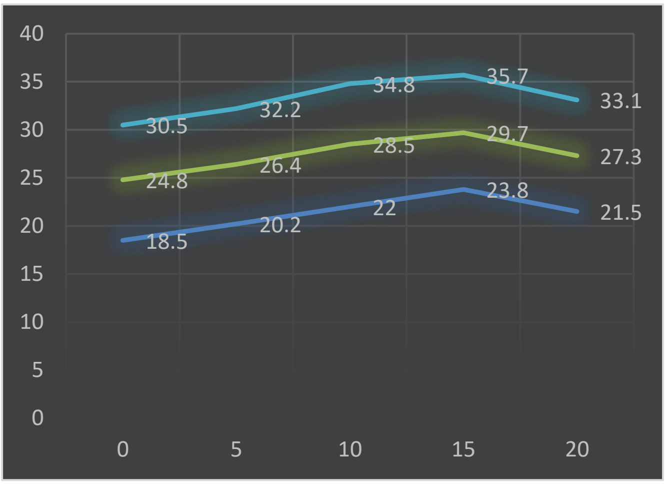

Fig 5.4 Variation of Compressive Strength Due to Metakaolin

Table 5.5 Variation of Compressive Strength Due to Superplasticizer

Sample No	Superplasticizer (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0	25.5	35.2	41.8
2	0.5	28.9	37.6	44.5
3	1.0	31.2	39.8	46.7
4	1.5	32.8	41.2	48.3
5	2.0	31.6	40.5	47.6

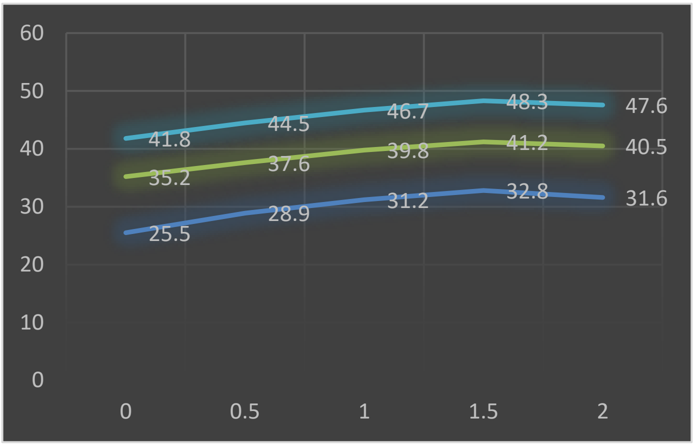

Fig 5.5 Variation of Compressive Strength Due to Superplasticizer

Table 5.6 Variation of Compressive Strength Due to Both Metakaolin & Superplasticizer

Sample No	Superplasticizer (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0.5	28.5	34.2	42.6
2	1.0	30.1	36.7	44.8
3	1.5	31.8	38.2	46.5
4	2.0	30.2	37.6	45.7

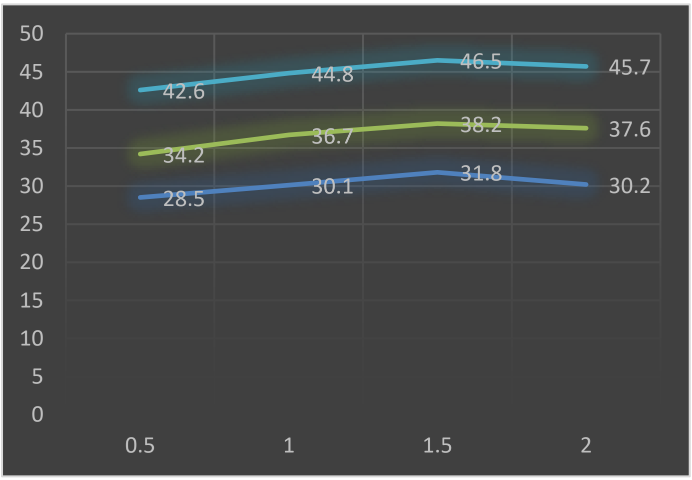

Fig 5.6 Variation of Compressive Strength Due to Both Metakaolin & Superplasticizer

Table 5.7 Variation of Split Tensile Strength Due To Metakaolin

Sample No	Metakaolin (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0	1.85	2.10	2.40
2	5	2.00	2.30	2.60
3	10	2.15	2.40	2.75
4	15	2.30	2.55	2.90
5	20	2.10	2.35	2.65

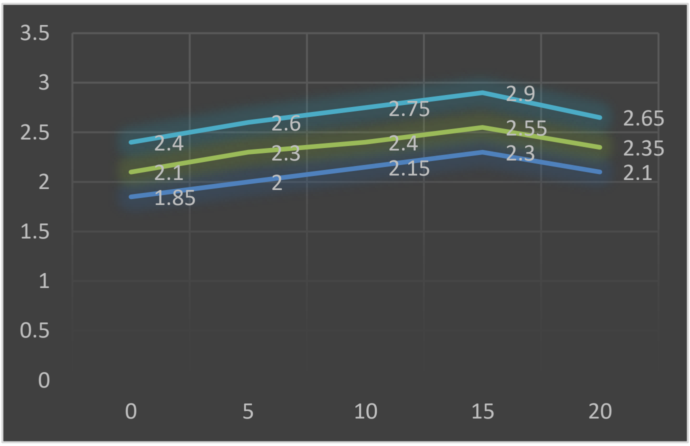

Fig 5.7 Variation of Split Tensile Strength Due to Metakaolin

Table 5.8 Variation of Split Tensile Strength Due to Superplasticizer

Sample No	Superplasticizer (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0	2.1	2.6	3.0
2	0.5	2.3	2.8	3.2
3	1.0	2.5	3.0	3.4
4	1.5	2.7	3.2	3.6
5	2.0	2.5	3.1	3.5

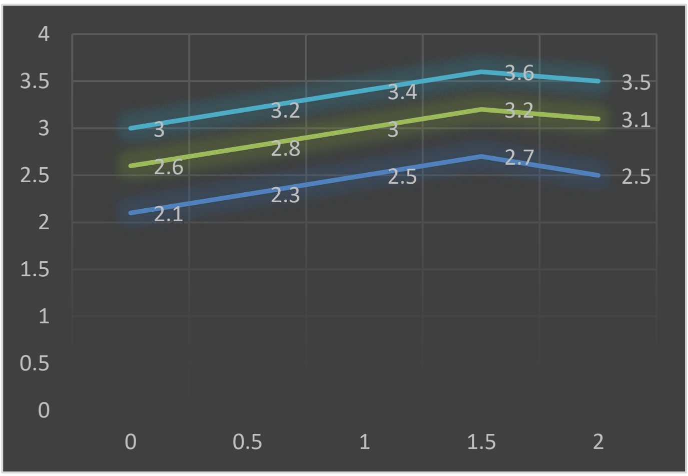

Fig 5.8 Variation of Split Tensile Strength Due To Superplasticizer

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Table 5.9 Variation of Split Tensile Strength Due To Both Metakaolin & Superplasticizer

Sample No	Superplasticizer (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0.5	2.1	2.5	2.9
2	1.0	2.3	2.8	3.2
3	1.5	2.5	3.0	3.4
4	2.0	2.4	2.9	3.2

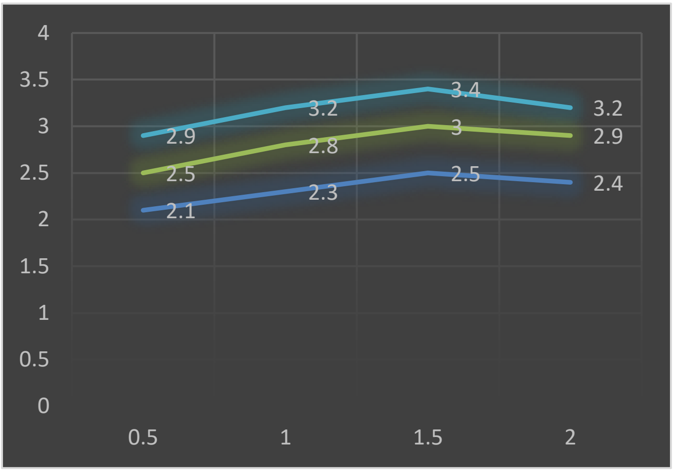

Fig 5. 9 Variation of Split Tensile Strength Due to Both Metakaolin & Superplasticizer

Table 5.10 Variation of Flexural Strength Due to Metakaolin

Sample No	Metakaolin (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0	4.20	4.70	5.20
2	5	4.50	5.00	5.40
3	10	4.60	5.10	5.50
4	15	4.70	5.20	5.60
5	20	4.40	4.90	5.30

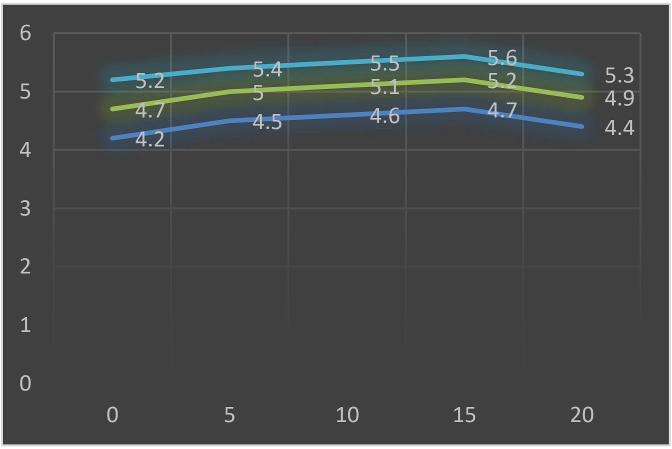

Fig 5.10 Variation of Flexural Strength Due to Metakaolin

Table 5.11 Variation Of Flexural Strength Due To Superplasticizer

Sample No	Superplasticizer (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0	4.5	5.2	6.0
2	0.5	4.8	5.5	6.3
3	1.0	5.0	5.8	6.6
4	1.5	5.2	6.0	6.8
5	2.0	5.1	5.9	6.6

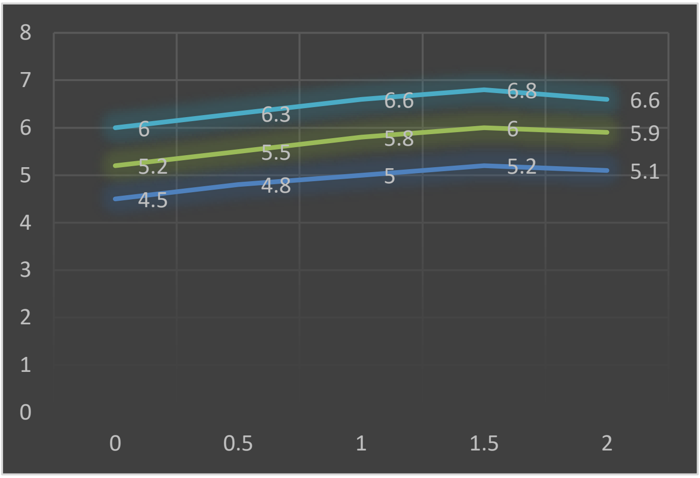

Fig 5.11 Variation of Flexural Strength Due To Superplasticizer

Table 5.12 Variation of Flexural Strength Due To Both Metakaolin & Superplasticizer

Sample No	Superplasticizer (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1	0.5	4.8	5.3	6.0
2	1.0	5.1	5.6	6.3
3	1.5	5.4	5.9	6.6
4	2.0	5.2	5.8	6.4

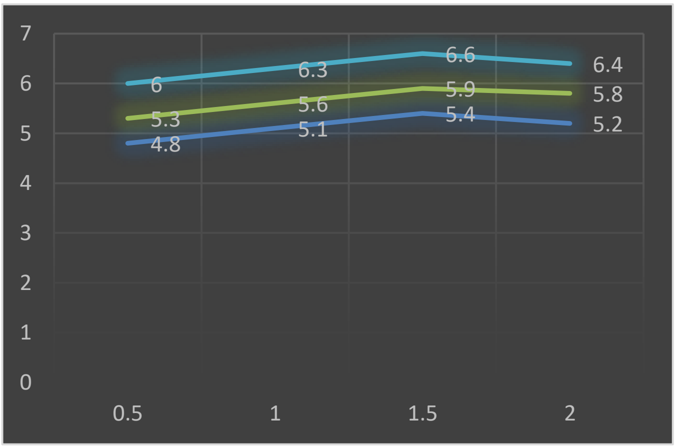

Fig 5.12 Variation of Flexural Strength Due to Both Metakaolin & Superplasticizer

6. CONCLUSION

Slump Values:

- Metakaolin: The addition of metakaolin led to an increase in slump values, indicating improved workability with higher metakaolin percentages.
- Superplasticizer: Superplasticizer significantly increased slump values, demonstrating its effectiveness in enhancing the workability of concrete. The increase was directly proportional to the superplasticizer dosage.
- Both Metakaolin & Superplasticizer: Combining metakaolin and superplasticizer showed a synergistic effect, resulting in improved workability compared to individual additions.

Compressive Strength:

- Metakaolin: The addition of metakaolin generally increased compressive strength, with the highest strength observed at 15% metakaolin content. Beyond 15%, there was a slight decrease in strength.
- Superplasticizer: Superplasticizer addition also increased compressive strength, with a consistent improvement as the dosage increased up to 1.5%.
- Both Metakaolin & Superplasticizer: Combining metakaolin and superplasticizer led to further enhancement in compressive strength, indicating a positive interaction between these materials.

Split Tensile Strength:

- Metakaolin: Metakaolin addition resulted in improved split tensile strength, with the maximum strength achieved at 15% metakaolin content.
- Superplasticizer: Superplasticizer increased split tensile strength, and higher dosages led to higher strength values.
- Both Metakaolin & Superplasticizer: The combined use of metakaolin and superplasticizer further improved split tensile strength, showcasing their compatibility and positive influence on concrete strength.

Flexural Strength:

- Metakaolin: Flexural strength increased with metakaolin addition, peaking at 15% metakaolin content before slightly decreasing at 20%.
- Superplasticizer: Superplasticizer addition also enhanced flexural strength, with higher dosages leading to higher strength values.
- Both Metakaolin & Superplasticizer: The combination of metakaolin and superplasticizer led to an increase in flexural strength, demonstrating their complementary effects.

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