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An Experimental Study on Mechanical Properties of Metakaolin Based Concrete with Addition of Fibers

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Abstract: **The main aim of this paper is to study the mechanical properties of metakaolin based concrete with addition of fibers. The project is divided into two phases, in first phase cement is replaced with metakaolin in the variations of 5%, 10%, 15% and 20% by weight of cement, then it is tested for its workability and mechanical properties on fresh and hardened concrete. In the second phase of the project fibers like Sisal (natural) and Concrix (artificial) are added to the optimum strength mix of metakaolin based concrete in the percentages of 0.25%, 0.50%, 0.75% and 1% separately (by weight of cement). Then the fibre concrete is studied for its fresh and mechanical properties. Finally, the fibre concrete test results are compared with conventional concrete.**

Keywords: **Metakaolin, sisal fiber, concrix fiber, fresh properties, mechanical properties, conventional concrete.**

1. Introduction

Since many decades, usage of concrete has increased on large scale all over the world. Metakaolin, sisal fibers and concrix fibers are used in this work, in order to increase the strength of the concrete. Metakaolin is used mainly to reduce the usage of cement (whose production leads to the pollution for environment) it is available in abundant and low cost and fibers are used to increase the strength of concrete because the pozzolanic material alone cannot gain the strength as much as the cement. Both the hardened and fresh tests are conducted on the conventional concrete and metakaolin based sisal fiber, metakaolin based concrix fiber concrete and the results were compared.

2. Literature Review

Nova John (2013): Investigated the cement replacement levels were 5%, 10%, 15%, 20% by weight for metakaolin. The strength of all metakaolin admixed concrete mixes overshoot the strength development of concrete. Mix with 15% metakaolin is superior to all other mixes. The increase in metakaolin content improves the compressive strength, split tensile strength and flexural strength upto 15% replacement. The result encourages the use of metakaolin, as pozzolanic material for partial cement replacement producing high strength concrete. The inclusion of metakaolin results in faster early age strength development of concrete.

The utilization of supplementary cementitious material like metakaolin concrete can compensate for environmental, technical and economic issues caused by cement production

Abdul Rahuman, Saikumar Yeshika (2015): Studied the behaviour of concrete with addition of sisal fiber. He concluded that Compression strength increased by 50.53% after addition of 1.5% fiber for M20 mix design, whereas the increase was up to 52.51% for the same percentage addition of fiber in M25.Tensile strength increment was almost same for 1% and1.5% addition of fiber. The increased tensile strength for M20 mix design with1% and1.5% addition of fiber was 41.37% and 44.378%. There was a decrease in percentage increase in tensile strength for M25 when compared with M20. The increase in tensile strength for M25 mix design with1% and1.5% addition of fiber is 30.83% and 36.027%. He concluded that 1.5% addition of fiber will give better strength

Mohan Lal (2015): Compressive strength, both at7-days and 28days, is found to increase with addition of metakaolin. The maximum increase in compressive strength occurs. Flexural strength both at 7-days and 28-days is also found to increase with addition of metakaolin. The maximum increase in flexural strength occurs at 20% replacement level of cement by metakaolin. The increase in flexural strength follows the same pattern as that of compressive strength.

3. Objectives of the Study

Main objectives of this study are,

- To optimize the optimum value of the Metakaolin based concrete via compressive, tensile and flexural tests.
- To carry out the investigation on the mechanical properties via compressive, tensile and flexural tests of metakaolin based concrix fibre concrete and metakaolin based sisal fibre concrete.
- To carry out the investigation on the mechanical properties via compressive, tensile and flexural tests of metakaolin based concrix fibre concrete and metakaolin based sisal fibre concrete.

A. *Methodology*

The main aim of this paper is to carry out an experimental

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study on the mechanical behavior of the metakaolin based sisal fiber concrete, mechanical behaviour of the metakaolin based Concrix fiber concrete and which attains strength more when compared to conventional concrete.

B. Fiber Concrete

Fibers were introduced in early's of 1950's. Fibers are of two types natural fibers and artificial fibers. Fibers like steel, brass, polyprelene etc., are known as artificial fibers. Fibers like sisal, banana, coiret, are known as natural fibers. The sisal fibers increase the flexural strength of the concrete and also arrest the crack development in the concrete. They also reduce the permeability of concrete and decrease the bleeding of concrete. Concrix fibers were developed in Switzerland and combines all the advantages of steel fibers. Concrix resistance of the concrete, and can also be used in structural, applications. Concrix, prevents, sedimentation i.e., subsequent settlement of the matrix.

C. Metakaolin based Concrete

Pozzolanic materials are those which are not cementitious in nature, they react with calcium hydroxide in the presence of water and form the cementitious compounds. They are available in both natural and artificial. The most commonly used pozzolanic materials are metakaolin, silica fume, fly ash etc.

The beneficial effects of metakaolin addition in terms of higher compressive strength, performance & greater durability are mostly attributed to the pozzolanic reaction in which calcium hydroxide is consumed to produce additional C-S-H & C-A-H, reaction products. These pozzolanic reaction products fil in pores and result in are fining of the pore size distribution or pore structure and increases the strength.

4. Materials

A. Cement

Cement is a binding material having cohesive and adhesive properties, which makes it capable to unite the different construction materials and form the compacted assembly. The cement used in this work is OPC53 Grade. It was tested for physical requirements in accordance with IS:12269-1987and the values are shown in table 1.

Table 1
Physical properties of cement

S. No.	Property	Value	IS12269-1987
1	Specific gravity	3.03	3.15
2	Fineness	3%	<10%
3	Initial Setting	36 min	>30min
4	Final setting	580 min	<600min

B. Metakaolin

Metakaolin is a pozzolanic material, which is a dehydroxylated form of the kaolinite clay mineral. It is obtained by the calcinations of pure or refined kaolinite clay mineral at a temperature between 650 °C and 850 °C, followed by grinding to achieve a fineness of 700-900 m^2/Kg. The physical and chemical properties are shown in the table 2 and table 3.

Table 2
Physical properties of Metakaolin

S. No.	Property	Value
1	Specific Gravity	2.65
2	Fineness	4%
3	Appearance	Orange-Red

Table 3
Chemical properties of Metakaolin

Chemical	Composition (%)
Sio_2	53
Al_2o_3	44
Fe_2o_3	1.0
Tio_2	0.65
Cao	0.09
Mgo	0.03
Na_2o	0.10

C. Aggregates

Aggregates were obtained from crushing of Quarries. Tests were conducted according to IS 383:1970 and their properties are shown in table 4 and 5.

Table 4
Physical properties of Fine aggregate

S. No.	Property	Test value
1	Specific gravity	2.54
2	Fineness Modulus	2.08
3	Zone	III

Table 5
Physical properties of coarse aggregate

S. No.	Property	Test value
1	Specific gravity	2.72
2	Fineness Modulus	6.28
3	Water Absorption	0.1

D. Sisal Fiber

Sisal fibers are natural one. It is a species of Agava plant, which is botanically known as Agave Sisalana. These fibers improve the impact strength of the concrete. The physical property of these fiber has no deterioration in a concrete medium. Sisal is a hard fiber extracted from the leaves of sisal plants which are perennial succulents that grow best in hot and dry areas. Sisal is an environmentally friendly fiber as it is biodegradable natural fiber material containing major chemical composition of cellulose. The physical properties of the fiber were shown in table 6. The Agava plant and the fibers after attraction are shown in figures 1 and 2.


Fig. 1. Agave sisal plant

Fig. 2. Sisal fiber

Table 6
Physical properties of sisal fiber

S. No.	Property	Value
1	Length	40mm
2	Diameter	0.5mm
3	Aspect ratio	80

E. Concrix Fiber

This fiber was developed in Switzerland. Concrix is a bi-component Macrofiber serving as a structural concrete reinforcement. The rough fiber surface ensures superior bonding within the concrete, and the fiber bundles guarantee fast three-dimensional distribution throughout the matrix during the mixing process. The enhanced technical parameters of the concrete can be used for structural design purposes. Concrix serves as a structural reinforcement, increases the impact resistance of the concrete, and can also be used in structural applications. The fibers after removal from the foil are shown in the figure 3 and their physical properties are shown in table 7.

Fig. 3. Concrix fiber

Table 7
Physical properties of concrix fiber

S. No.	Property	Value
1	Length	45mm
2	Diameter	0.5mm
3	Aspect ratio	90

F. Water

Potable water, free from, organic, matter silt, oil, chloride and acidic material as per Indian Standard was used for the entire concreting and pH value is 7.5.

5. First Phase of Investigation

A. Specimens Specification

In this project the specimens that were used are cubes, cylinder and Prisms.
Cubes – 10cm x10cm x 10cm
Cylinder – 10cm Dia and 30 cm Height
Prism – 10cm x 10cm x 50cm

B. Mix Designations

The following table no 8 shows the mix designations for various mixes

Table 8
Mix designations

Mix	Metakaolin (%)
N	0
M1	5
M2	10
M3	15
M4	20

1) Mix design

The mix design for M25 grade of concrete having a compressive strength 31.5mPa was prepared by using the above materials. The mix proportions weight was 1:2.23:3.38 Cement: Fine aggregate: Coarse aggregate). The water cement ratio is taken as 0.46. The workability and compressive, split and flexural strength of different mixes were tested at 7 and 28 days.

C. Fresh Properties

1) Slump cone

It is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at the site of the work. The fresh concrete is tested for the slump and the values are shown in table 9.

Table 9
Slump values

Mix	Value (mm)
N	63
M1	65
M2	**59**
M3	55
M4	53

2) Compaction factor

In the compaction factor test the degree of compaction is determined by a standard amount of compaction allowing the concrete to fall through a standard height and the values are shown in table 10.

Table 10
Compaction factor

Mix	Factor
N	0.92
M1	0.92
M2	**0.91**
M3	0.91
M4	0.90

D. Hardened Properties

1) Compressive strength

After 7 and 28 days of curing, cubical specimens are placed on compressive testing machine having a capacity of 1000 KN and a constant rate is applied on test specimen and the compressive values are shown in table 11.

Table 11
Compressive strength values

Mix Designation	Compressive Strength	
	7Days (mPa)	28 Days (mPa)
N	16.8	26.7
M1	17.2	27.8
M2	19.5	30.28
M3	17.27	27.9
M4	13.85	22.71

2) Split tensile strength

After 28 days of curing, cylinder specimens are placed on tensile testing machine having a capacity of 1000 KN and a constant rate is applied on test specimen by placing two steel plates above and below the cylinder in the horizontal direction the two-point loading should be placed at a distance of 13.3cm from both the ends. The split tensile values are shown in table 12.

Table 12
Split tensile values

Mix Designation	Split tensile strength	
	7 Days (mPa)	28 Days (mPa)
N	1.5	2.81
M1	1.98	2.90
M2	**2.21**	**3.27**
M3	1.8	2.6
M4	1.7	2.02

Fig. 4. Cube testing

Fig. 5. Cylinder testing

3) Flexure strength

After 7 and 28 days of curing, prismatic specimens are placed on flexural testing machine having a capacity of 1000KN and a constant rate is applied on test specimen by placing the specimen. The flexural values are shown in table 13 and the testing of prism is shown in figure 6.

Fig. 6. Flexural testing

Table 13
Flexural strength values

Mix	Flexural strength	
	7 Days (mPa)	28 Days (mPa)
N	2.80	3.62
M1	2.9	3.68
M2	**3.1**	**4.08**
M3	2.61	3.70
M4	2.60	3.28

6. Second Phase of Investigation

In the second phase of the project fibers like Sisal (natural) and Concrix (artificial) are added to the optimum strength mix of metakaolin based concrete. The fibre concrete is studied for its fresh and mechanical properties. Finally, the fibre concrete test results are compared with conventional concrete.

A. Specimens Specification

In this project the specimens that were used are cubes, cylinder and prisms.

Cubes – 10cm x 10cm x 10cm
Cylinder – 10cm Dia and 30 cm Height
Prism – 10cm x 10cm x 50cm

B. Mix designations

The following table 14 shows the mix designations for various mixes.

Table 14
Mix designations

Mix	Metakaolin (10%) + % Sisal fiber
M2+S1	10+0.25
M2+S2	10+0.5
M2+S3	10+0.75
M2+S4	10+1

C. Fresh Properties

Table 15
Slump cone

Mix	Value (mm)	Mix	Value (mm)
M2+S1	58	M2+C1	55
M2+S2	**56**	M2+C2	54
M2+S3	53	**M2+C3**	**53**
M2+S4	51	M2+C4	50

Table 16
Compaction factor

Mix	Factor	Mix	Factor
M2+S1	0.90	M2+C1	0.88
M2+S2	**0.89**	M2+C2	0.85
M2+S3	0.85	**M2+C3**	**0.80**
M2+S4	0.80	M2+C4	0.76

D. Hardened Properties

Table 17
Compressive strength

Mix Designation	Compressive Strength	
	7 Days (mPa)	28 Days (mPa)
M2+S1	18.32	29.25
M2+S2	**21.20**	**32.52**
M2+S3	20.81	28.30
M2+S4	20.16	27.39
M2+C1	19.86	30.12
M2+C2	21.20	31.00
M2+C3	**23.85**	**34.81**
M2+C4	19.25	29.28

Table 18
Split tensile strength

Mix Designation	Split tensile strength	
	7 Days (mPa)	28 Days (mPa)
M2+S2	**3.02**	**4.84**
M2+S3	2.85	3.80
M2+S4	2.88	3.69
M2+C1	3.06	4.26
M2+C2	3.26	4.76
M2+C3	**4.02**	**5.36**
M2+C4	3.00	4.50

Table 19
Flexure strength

Mix Designation	Flexural strength	
	7 Days (mPa)	28 Days (mPa)
M2+S1	3.85	5.07
M2+S2	**4.24**	**5.70**
M2+S3	4.10	4.90
M2+S4	3.90	4.82
M2+C1	3.90	4.45
M2+C2	4.49	5.24
M2+C3	**5.12**	**6.07**
M2+C4	3.81	4.62

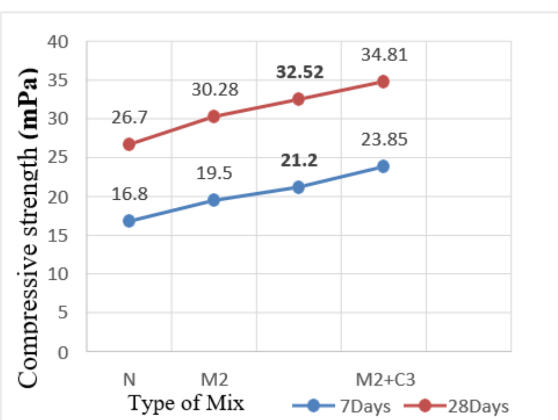

Fig. 7. Comparison of compressive strengths of various mixes

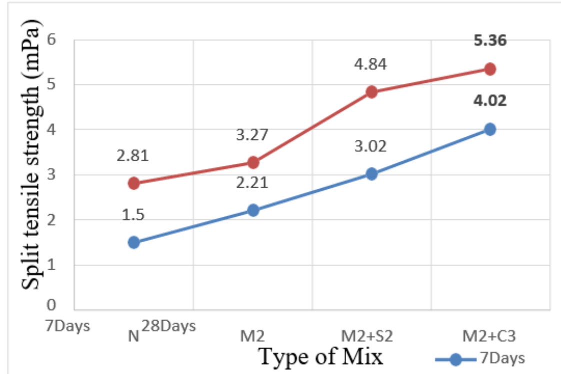

Fig. 8. Comparison of split tensile strengths of various mixes

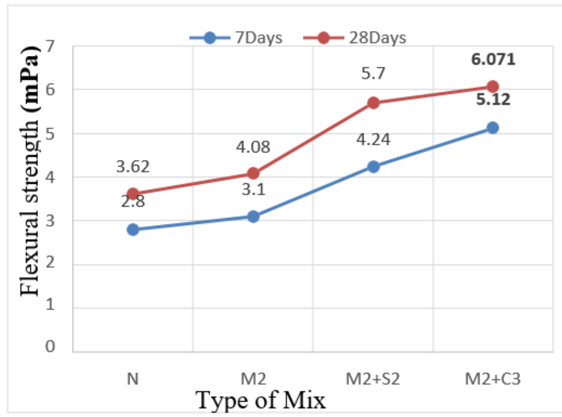

Fig. 9. Comparison of flexural strengths of various mixes

The tests were conducted on cube, cylinder and prism. The following figure 10 shows the failure of cube which is tested for its compressive strength. The prism is tested for its flexural strength and the failure prism is shown in the figure 11.

Fig. 10. Tested cube

Fig. 11. Tested cylinder

Fig. 12. Tested prism specimen

7. Observations

The strength of MK concrete is increased upto 10%, i.e., the pozzolanic reaction was done until the availability of free lime content in the cement, therefore the reaction was slow downed which led to the decreasing in strength of MK concrete.

8. Results and Discussion

1. With the increase in METAKAOLIN content upto 10%, mechanical properties end to increase, there after those mechanical properties showed decreasing pattern
2. The strength of concrete is increased upto 10% due to the presence of free lime in the cement and its reaction with metakaolin, there after due to the absence of free lime, decreased the strength of the concrete.
3. The compressive strength of metakaolin based concrete is increased by 13.40% similarly the split tensile strength and flexure are increased by 16.3% and 12.7% when compared to nominal concrete.
4. At the optimum percentage of Metakaolin based 0.25% sisal fiber concrete, the compressive strength is increased by 21.79%similarly the split tensile strength and flexure are increased by 72.24% and 57.45% when compared to nominal concrete.
5. At the optimum percentage of Metakaolin based 0.75% concrix fiber concrete, the compressive strength is increased by 30.37% similarly the split tensile strength and flexure are increased by 90.74% and 67.67% when compared to nominal concrete.

9. Conclusion

From the experimental study, fiber concrete possesses improved properties than nominal concrete hence it is recommended that fiber concrete can be used as structural concrete.

References

[1] Nova John, “Strength Properties of Metakaolin Admixed Concrete,” in International Journal of Scientific and Research Publications, vol. 3, no. 6, June 2013.

[2] Abdul Rahuman, Sai Kumar Yeshika, “Study on properties of sisal fiber reinforced concrete with different mix proportions and different percentage of fiber addition, 2015.

[3] Mohan Lal, “Investigation of various properties of metakaolin based concrete,” in International Journal of Technical Research, vol. 4, no. 2, July-Aug. 2015.

[4] Patil B. B, Kumbhar P. D, “Strength and durability properties of high-performance concrete incorporating high reactivity metakaolin”, in International Journal of Modern Engineering Research, vol. 2, no. 3, pp. 1099-1104, May-June 2012.

[5] J. M. Khatib, E. M. Negim and E. Gjonbalaj, “High volume metakaolin as cement replacement in mortar,” World journal of chemistry, vol. 7, no. 1, pp. 7-10, 2012.

[6] G. Murali, P. Sruthee, “Experimental study of concrete with metakaolin as partial replacement of cement,” IJETED, vol. 4, no. 2, pp. 344-348, 2012.

[7] Hemant Chauhan, Bhavana K. Shah, “Effect of activated fly ash in metakaolin based cement”, National conference on recent trends in Engineering & Technology, 2011.

[8] Supriya K. Nalawade, Hemalata K. Munot, Balkrishnadawari, “Properties of concrete with metakaolin and fly ash as partial replacement to cement”, IJESE, vol. 4, no. 6, 2011.

[9] P. Muthupriya, K. Subramanian, B. G. Vishnuram, “Investigationon behavior of high performance reinforced concrete columns with Metakaolin and fly ash as admixture”, IJAET, vol. 2, no. 1, pp. 190-202, 2011.

[10] S. Priyadharshini, G. Ramakrishna, “Strength and durability evaluation of latex modified sisal fiber reinforced concrete,” vol. 8, 2016.