Experimental Investigation on Nylon Fibre Reinforced Concrete by Partial Replacement of Cement with Metakaolin

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Abstract: Concrete is probably the most extensively used construction material in the world. The addition of mineral admixture in cement has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources. However, environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption by the use of supplementary materials.

The nylon fibres are very useful as it has variety of applications like high strength, durability, tensile strength but its disposal pose a serious threat in environment. In present study, various proportions of nylon fibre are added in concrete and its effect on workability, compressive strength and tensile strength will be evaluated. The nylon fibre material of diameter 0.35mm and length of 1800mm will be used in 1% from 0.5 to 1.5% by weight in cement after getting optimum result from the experiment. Nylon fibre added in concrete improves the tensile strength but decreases the workability. For this Metakaolin will be added which improves the workability of concrete. So, In present study cement is partially replaced with 1% Nylon fibres and Metakaolin in variation of 3%, 6%, upto 21% are added in M50 and M60 grade of concrete. Comparison will be carried in terms of workability, compressive strength and durability.

Index Terms **- Concrete, Nylon Fibre, Metakaolin, Workability, Compression, Durability**

I. INTRODUCTION

Concrete is one of the most durable building materials. Structures made of concrete can have a long service life. Concrete is used more than any other artificial material in the world. Approximately, yearly concrete production is about 10 billion cubic meters. One tone production of cement contributed 7% of all CO_2 emissions produced globally. However, environmental concerns caused due to carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption by the use of supplementary materials. Mineral admixtures such as fly ash, metakaolin, silica fume etc. are used as a cement admixture. Addition of such admixtures in cement can help in reducing overall consumption of cement, thereby environmental damage is also reduced. It also increases the workability, compressive strength and durability of the concrete.

Concrete is a tension-weak building material. It is often crack ridden connected to plastic and hardened states, drying shrinkage, etc. To counteract the cracks, different fibres are added to the concrete. Plain cement concrete has some limitations like low tensile, limited ductility, low resistance to cracking, high brittleness poor toughness, etc. which restrict its use. The cracking of concrete may be due to economic structural, environmental factors, but most of the cracks are formed due to inherent internal micro cracks and the inherent weakness of the material to resist tensile forces. To overcome these deficiencies, extra materials are added to improve the performance of concrete. Nylon fibre reinforced concrete provides solutions for these shortcomings. Inclusion of fibres as reinforcement to concrete results as crack arrestor and improves its static and dynamic properties by preventing the propagation of cracks as well as increases tensile strength of concrete.

II. OBJECTIVES

- To prepare Concrete using Nylon fibre and Metakaolin.
- To study Workability, Compressive strength, Durability of concrete using Nylon fibre and Metakaolin.
- To find out Optimum Percentage of Nylon fibre and Metakaolin in M50 and M60 Grade of Concrete.

III. LITERATURE REVIEW

[1] Akaram Ali, Aleem Aijaz and Mohammad Arsalan investigated that addition of Nylon fibre on concrete mixture result in increased the tensile strength of the concrete. The compressive strength, split tensile strength, flexural strength of concrete gets increased on addition of 1% nylon fibre. The metakaolin is used with 13% as a replacement of cement and after testing he found that there is 41% increase in strength at the age of 7 days.

[6] Nitin and Dr. S.K. Verma investigated that with addition of 1.0% volume fraction of nylon fibers in M30 concrete there was an increment of the compressive strength up to 10% at 28 days strength.

[3]Ganesh. N and JegidhaK. J investigated that the Quantity of fibre 0.5%, 1.0% by weight was added in concrete and their strength was compared and hence found that the concrete containing 1.0% of fibre has the good strength as compared to others.

[5]M.Narmatha and Dr.T.Felixkala investigated that the Strength of All Metakaolin Concrete Mixes over Shoot the Strength of OPC. 15% cement replacement by Metakaolin is superior to all other mixes. The increase in Metakaolin content improves the compressive strength and split tensile strength up to 15% cement replacement.

[7]Umer UL Nazir, Abhishek Jandiyal, Sandeep Salhotra and Raju Sharma investigated that for good strength parameters, Metakaolin can be replaced up to 25% & optimum is at 10%. The increase of Compressive strength varies between 5-38% for M20 grade, 2-37% for M30 grade, 3-13% for M40 grade and 3-18% for M50 grade of concrete.

IV. MATERIAL AND METHODOLOGY

***Fine Aggregate*:** The naturally available river sand used as fine aggregate. The properties of sand were determined by conducting tests as per IS 2386 (Part- I).

Table 1 Physical Properties of Fine Aggregate

Properties	Sand
Sieve analysis	Zone II
Fineness modulus	2.870
Specific Gravity	2.63
Water Absorption	1.76
Bulk Density	1.61 (Loose) 1.75 (Compacted)

Coarse aggregate: Crushed coarse aggregate conforming to IS 383-1987 was used. Coarse aggregate of size 20mm and10 mm were used.

Table 2 Physical Properties of coarse Aggregate

Properties	20mm	10mm
Specific Gravity	2.87	2.98
Water Absorption	1.45%	0.28%
Aggregate Impact Value	9.20%	9.32%
Aggregate Crushing Value	11.74%	9.97%
Flakiness Index	10.88%	25.25%
Elongation Index	6.83%	7.65%
Bulk Density	1.656 (Loose) 1.74 (Compacted)	1.52 (Loose) 1.67 (Compacted)

Nylon Fibre: Nylon is generic name that identifies a family of polymers. Nylon is particularly effective imparting impact resistance and flexural toughness, sustaining and increasing the load carrying capacity of concrete following first crack.

Table 3 Physical Properties of Nylon fibre

Property	Value
Material	100% Virgin Nylon Fibre
Fibre Cross Section	Trilobal
Fibre Length	18 mm (ISO: 6989: 1981)
Sp. Gravity	1.14
Color	Brilliantly White
Melting point	220 °C
Chemical Resistance	Very good Against Alkalis, Hydrocarbons

Fig. 1 Nylon Fibre

Metakaolin: Manufactured by thermally activating purified Kaolinite clay within a specific temperature range 600 to 900 °C. Metakaolin is produced by heat-treating kaolin, one of the most abundant natural minerals and it is highly pozzolanic in nature.

Table 4 Physical Properties of Metakaolin

Property	Values
Specific gravity	2.54
Bulk density (gms/litre)	300-355
Water Absorption (%)	13.64%
Moisture Content (%)	6%
Shrinkage	17.77%

Fig. 2 Metakaolin

Table 5 Mix Proportion for M50 Grade of Concrete

Water	Cement	Sand	Aggregate. Proportions as per table 2 of IS 383	
			(20mm)	(10mm)
157.50	450	675.5	635.5	659.8
0.40	1	1.47	1.40	1.45

Table 6 Mix Proportion for M60 Grade of Concrete

Water	Cement	Sand	Aggregate. Proportions as per table 2 of IS 383	
			(20mm)	(10mm)
153.60	480	690.5	691.2	563.8
0.37	1	1.41	1.43	1.16

V. RESULTS

Workability:

- The concrete slump test measures the Workability of fresh concrete before it sets.
- It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.
- It can also be used as an indicator of an improperly mixed batch.
- The slump test is used for the measurement of a property of fresh concrete as per IS: 1199 - 1959.

Table 7 Slump Test Results

	M_0 N_0	M_3 N_0	M_6 N_0	M_9 N_0	M_{12} N_0	M_{15} N_0	M_{18} N_0	M_{21} N_0	M_0 N_1	M_3 N_1	M_6 N_1	M_9 N_1	M_{12} N_1	M_{15} N_1	M_{18} N_1	M_{21} N_1
M50	120	118	115	110	100	95	90	85	55	50	45	35	30	30	25	25
M60	125	125	120	115	110	105	100	95	59	52	50	40	30	30	25	25

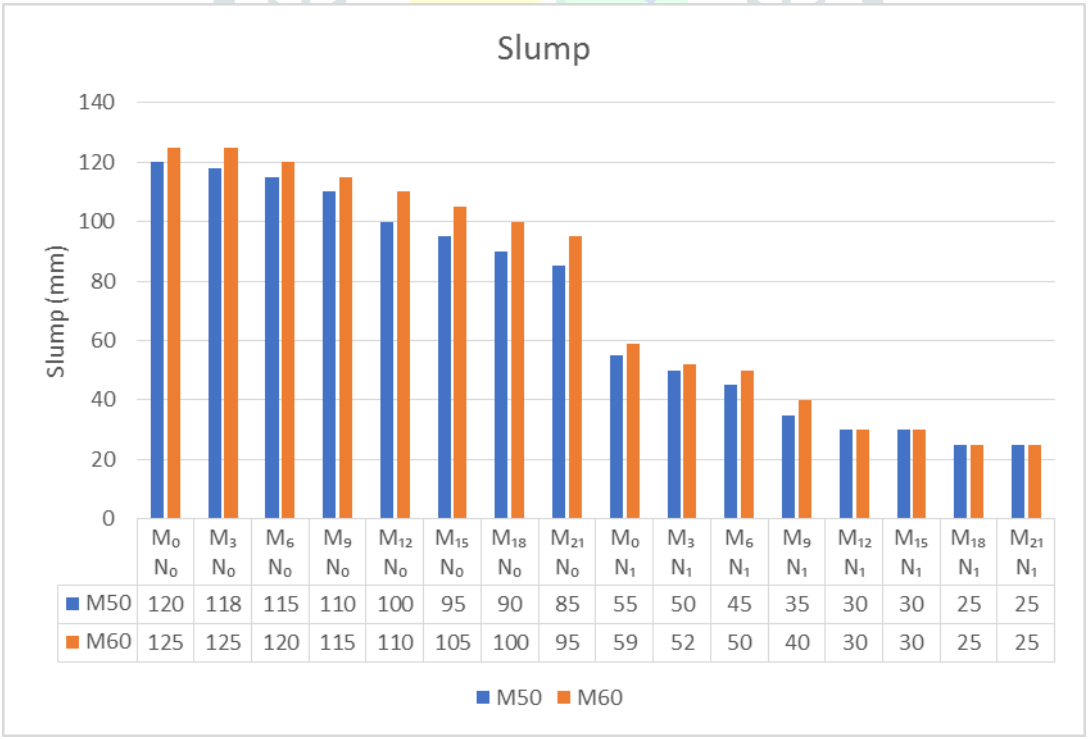


Fig. 3 Slump Comparison

Compressive Strength Test:

- Determination of compressive strength using by cube where size of cube specimen is 150×150×150 mm and this test was performed on a 2000 KN capacity compression testing machine.
- Bureau of Indian Standards suggests that the compressive strength of concrete be considered as the basis for determining all properties and studying response of concrete. As such more emphasis was given on this test. The compressive strength of concrete was evaluated at the age of 3 days, 7 days and 28 days.
- The compressive strength of cube specimen is calculated using the following formula:

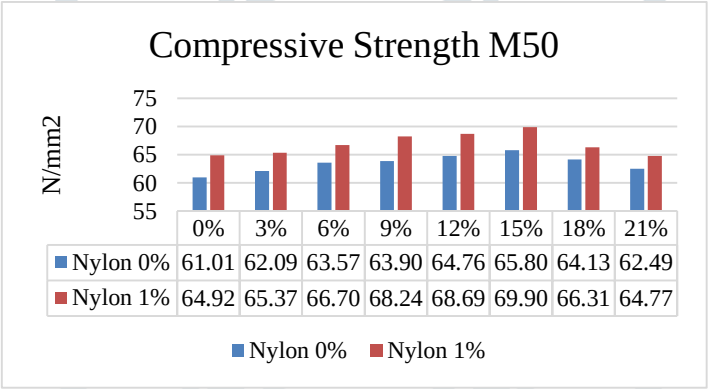
$$\sigma = P/A$$

Where, P = failure load

A = cross sectional area of cube in mm

Table 8 Compressive Strength Test Result

	M_0 N_0	M_3 N_0	M_6 N_0	M_9 N_0	M_{12} N_0	M_{15} N_0	M_{18} N_0	M_{21} N_0	M_0 N_1	M_3 N_1	M_6 N_1	M_9 N_1	M_{12} N_1	M_{15} N_1	M_{18} N_1	M_{21} N_1
28 Days M50	61.01	62.09	63.57	63.90	64.76	65.80	64.13	62.49	64.92	65.37	66.70	68.24	68.69	69.90	66.31	64.77
28 Days M60	71.6	72.8	74.5	75.39	76.24	77.3	75.51	73.47	73.81	74.69	76.43	77.48	78.59	79.9	77.07	75.03



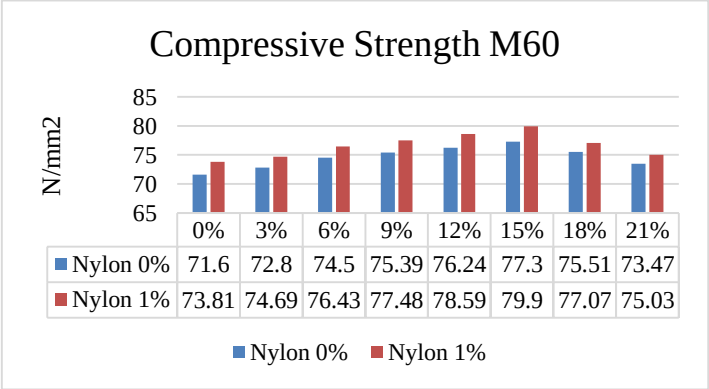
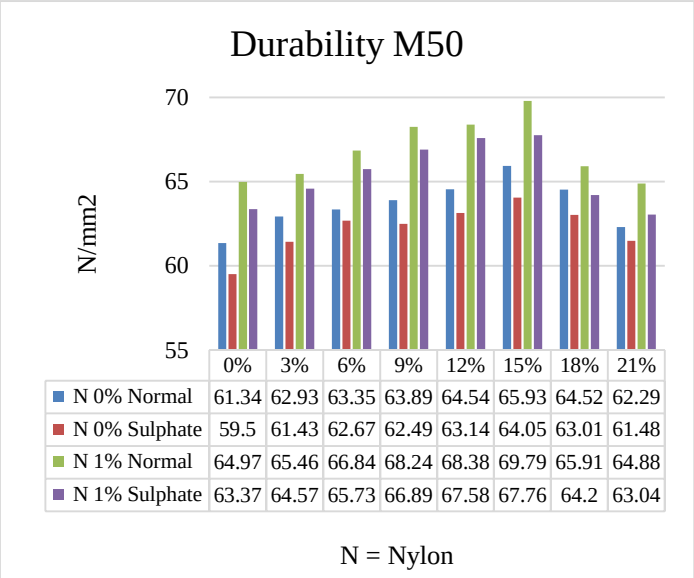


Fig. 4 Compressive Strength

Durability Test (Sodium Sulphate Attack):

- The sulphate resistivity of concrete was studied by immersing the specimens in sulphate solution.
- The specimens of size 150x150x150mm were casted and cured in water for 28 days.
- After 28 days of curing the specimens were removed from the curing tank and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen.
- The initial weights were measured and the specimens were immersed in 3% sodium sulphate solution for the next 28 days of sulphate exposure, specimens were tested for compressive strength and compared with the strength of concrete specimens which were not exposed to acid environment.



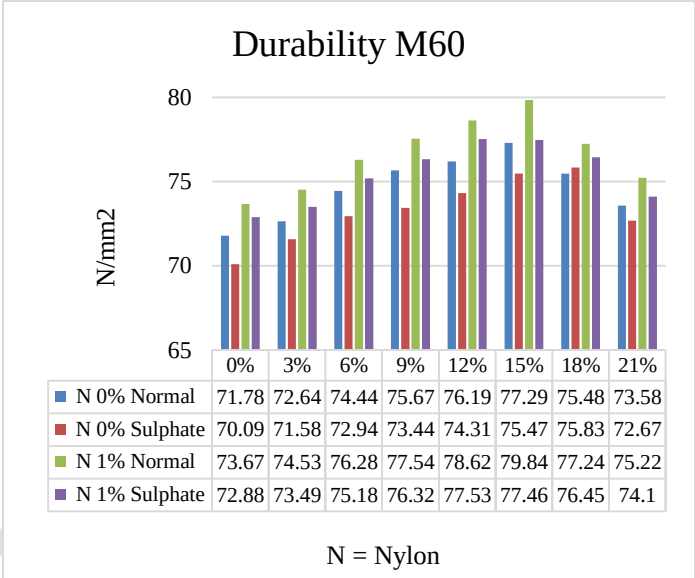


Fig. 5 Durability Test Result

VI. Conclusion

- It is found that there is decrease in workability (Slump test) up to **79.16 %** and **80%** for the M50 and M60 grade respectively with combination of **Metakaolin 21% and Nylon fibre 1%.**
- It is found that there is increase in strength by **7.85 % and 7.96%** for the M50 and M60 grade respectively with combination of **Metakaolin 15% and Nylon fibre 0%.**
- It is found that there is increase in strength by **14.57 % and 11.59%** for the M50 and M60 grade with combination of **Metakaolin 15% and Nylon fibre 1%.**
- It is found that there is decrease in strength by **2.97%** for 28 days result when it immersed in Sodium Sulphate.
- It is found that Optimum combination is 15% Metakaolin adding with 1 % nylon fibre.

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