Workability and Strength Properties of Nylon Fiber Reinforced Concrete

Zahid Ali Bhat[1] Ajay Bhukal[2]
[1]M-Tech Scholar [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]Universal Group of Institutions Lalru, Punjab India

Abstract— Presence of fibers in a fibre-reinforced concrete has been associated with its better shrinkage, durability, and toughness characteristics. Such a concrete by virtue of its relatively improved properties has found its application in structures where permeability and/or toughness have an important role to play; e.g. water retaining structures, and airfield pavements etc. Steel fibers are the commonly used fibers for the production of such a concrete, however, recently synthetic fibers like polypropylene, polyethylene, polyolefin, and nylon have attracted the attention of many concrete technologists around the world for their relatively lightweight, better dispersion characteristics, and good tensile strength. In the present study, nylon fibers have been incorporated in the concrete mix to assess their effect on its workability and strength characteristic. Nylon is stable at relatively high temperatures, in addition to being relatively inert, and resistant to a wide variety of chemicals, thus making it a potential candidate for its incorporation in concrete. Concrete mixes containing different percentages of nylon fibers; viz. 0.2, 0.3, and 0.4 by volume of concrete mix, in addition to the control mix, have been prepared and it has been observed that the addition of nylon fibers has a marginal effect on the compressive strength of concrete, however, the flexural strength improves to an appreciable extent, thereby making it a potential candidate for its application in concrete pavements. Moreover, addition of nylon fibers decreases the workability of the concrete, therefore, proper measures should be taken while designing such a concrete mix, giving due consideration to the required workability.

Keywords: Workability, Nylon Fiber, Mix Proportioning, Compaction Factor, Slump, Flexural Strength, Compressive Strength

I. INTRODUCTION

Concrete is relatively strong in compression but its tensile strength is very low, which leads to its cracking in the tensile zone with consequent failure if no measures are taken to arrest the growth of tensile cracks. It fails, whether in compression or tension, in a brittle manner. Therefore, steel reinforcement is introduced in the tensile zone, being more vulnerable to failure, of Reinforced Concrete construction to take the tensile loads. But, there are still cracks induced in concrete because of drying and plastic shrinkage, which could prove to be the entry points to aggressive chemicals into the concrete, thus impairing the durability of concrete. The chloride-based chemicals could result in the corrosion of embedded steel reinforcements thus, further deteriorating the situation. However, the introduction of fibers in the concrete mix has enabled the concrete technologists to arrest these plastic and drying shrinkage cracks to a large extent. So, the permeability of the concrete is decreased, and the concrete becomes relatively durable. Fibers have also been observed to increase the toughness of concrete and convert the brittle behavior into the ductile one by acting as bridges across the cracks. Steel fiber is the commonly used fiber in concrete to impart toughness and arresting cracks. However, these fibers have their disadvantages. Steel fibers are relatively heavy and thus settle towards the bottom portion of the mix. These fibers tend to clump together when in contact with cement and water, the phenomenon known as balling. Therefore, skilled labor is necessary to ensure the uniform dispersion of these fibers in a concrete mix. In recent times, synthetic fibers like polypropylene, polyethylene, polyolefin, nylon have attracted the attention of many concrete technologists around the world for their relatively lightweight, better dispersion characteristics, and good tensile strength. In the present study, the introduction of different volume fractions of nylon fiber in the concrete have been evaluated with respect to the workability and strength properties of the resulting concrete mixes and their performance have been compared with the control mix. The study will further pave the way for better recycling and utilization of waste nylon fishnets which have been found to comprise a good fraction of the total waste fishnets in the marine waters.

A. Project Objectives:

The following are the objectives that have been achieved during the execution of the project:

1) Evaluation of strength variation of Nylon Fiber Reinforced Concrete with variation in volume fraction of Nylon fibers in the concrete mix.
2) Evaluation of the effect of fiber content on the workability characteristics of Nylon Fiber Reinforced concrete.
3) Prospective recommendations regarding the application of Nylon fibers in concrete, depending on the performance of the resulting concrete mixes.

II. METHODOLOGY:

The research work shall include the preparation of a control mix. In addition, three nylon fiber reinforced mixes containing different percentages of nylon fiber by volume shall be prepared. Each of the mixes; i.e. control as well as fiber-reinforced, shall then be evaluated for the workability and strength characteristics and the results would be analyzed and, depending on the performance, prospective recommendations for the application of nylon fibers for making fiber reinforced concrete shall be provided.

A. Proposed Laboratory Investigations:

The laboratory investigations to be carried out during the execution of the project are as follows:

1) Material testing.
2) Design of concrete mix.
3) Slump test.
4) Compaction factor test.
5) Cube compression test.
6) Flexural beam test.

All the tests would be performed as per relevant IS Code specifications [5-17].

III. EXPERIMENTAL PROGRAM

A. Testing of Constituent Materials:

1) Cement Testing:

In all concrete mixes, Khyber Cement Limited's Ordinary Portland Cement of Grade 43 (OPC 43) was used. Fineness, soundness, standard quality, initial and final setting time, compressive power, and basic gravity of cement are all tested using procedures outlined in Bureau of Indian Standards specifications. Cement fineness was determined using the protocol outlined in BIS 4031 (Part 1):1996, which included sieving through a 90-micron sieve. Le-Charlier apparatus was used to measure soundness according to BIS 4031 (Part 3):1988 method. IS 4031 (Part 4):1988 and BIS 4031 (Part 5):1988 Vicat apparatus was used to test standard accuracy and beginning and final setup times. The BIS 4031 (Part 6):1988 method is used to evaluate the compressive strength of cement. Standard sands conforming to BIS 650:1991 were used to make 1:3 cement mortar cubes with dimensions of 70.6mm70.6mm70.6mm. These cubical specimens were measured at a loading rate of 70kN/minute on a compression testing machine (CTM) following the BIS 516:1959 to determinethe compressive strength of cement-mortar cubes aged 3, 7, and 28 days. According to BIS 4031 (Part 11):1988 procedure, the density bottle method was utilized to estimate the specific gravity of cement. All the cement's physical properties must meet the specifications of BIS 8112:1989.

2) Coarse Aggregate:

The coarse aggregate in this experiment is a mixture of 20mm nominal size aggregate and 10mm nominal size aggregate. Both coarse aggregate forms were obtained from a local source. Physical characteristics of both forms of coarse aggregate are tested using techniques described in the Bureau of Indian Standards, such as sieve analysis, specific gravity, water absorption, and bulk density. Aggregates were sieved through a collection of sieves to get sieve analysis, as described in BIS 2386 (Part 1):1988, and compared to BIS 383:1970 requirements. The procedure for testing specific gravity, water absorption, and bulk density of coarse aggregate was outlined in BIS 2386 (Part 3):1963. The water basket method was used to calculate the basic gravity of both forms of coarse aggregate.

3) Natural Sand:

Locally procured, natural sand was used as a fine aggregate in concrete. The procedures specified in the Bureau of Indian Standards are used to analyze the physical properties of natural sand, including sieve analysis, specific gravity, water absorption, and bulk density. Natural sand was sieved through a collection of sieves to obtain sieve analysis, as described in BIS 2386 (Part 1):1988, and compared to BIS 383:1970 requirements. The fineness modulus was measured and the zone of the sand was defined according to BIS 383:1970. Natural sand was measured for specific gravity, water absorption, and bulk density using the method outlined in BIS 2386 (Part 3):1963. The picometer method was used to determine the specific gravity of natural sand.

4) Mix Proportioning of Concrete Ingredients:

The proportion of aggregate in concrete was estimated using BIS 383:1970's All-In aggregate grading for 20mm nominal size aggregate. Using the trial-and-error technique, the proportions of 20mm nominal size aggregate, 10mm nominal size aggregate, and natural sand in concrete were determined based on their gradations.Based on this all-in aggregate grading, a percentage of 20mm nominal size aggregate, 10mm nominal size aggregate, and natural sand was fixed, which was to be used in the calculation of coarse aggregate and fine aggregate amounts at the time of mix design.

IS 10262:2009 was used to design a concrete mix. The control concrete was graded M60, and the goal slump was set at 125mm. The exposure conditions were deemed severe. First, the target strength was determined using the IS 10262:2009 method, assuming a reasonable standard deviation value. Estimated water content was measured for the desired workability, and the free w/c ratio was chosen based on previous experience and the desired concrete strength. The cement content was determined using the estimated water content and free w/c ratio. The amount of coarse and fine aggregate required was determined based on the amount of aggregate in the concrete, and the proportions were set as per all-in aggregate grading. The SSD (Saturated Surface Dry) condition was used to measure coarse and fine aggregate amounts. As a result, based on the moisture content of coarse and fine aggregate at the time of casting, appropriate water corrections must be made.

The proportions of various materials in control concrete were used to establish the mix proportions of concrete mixed with nylon fiber. NF2, NF3, and NF8 are the designations for concrete mixes containing 0.2 percent, 0.3 percent, and 0.8 percent nylon fiber, respectively.

B. Test Procedures:

1) Workability:

Workability refers to the ease with which concrete can be properly mixed, transported, compacted, and finished with minimal loss of homogeneity.The Slump test is the most frequently used test in the world for determining the workability of concrete in the construction industry. A slump test was used to determine the concrete's workability, according to Indian Standard Specifications BIS 1199:1959. Four roughly equal layers were filled into a mold in the shape of a frustum of a cone with a bottom diameter of 200mm, top diameter of 100mm, and height of 300mm, and each layer was tempered with a regular tempering rod with 25 strokes.

The mold was removed once the area had been filled and leveled by raising it vertically and permitting the concrete to settle. The slump in mm was used to record the results of the workability tests, which is the difference between the height of the mold and the highest point of the subsided concrete mass.

2) Flexural strength:

To calculate the force required to bend a plastic beam and determine the material's resistance to flexing or stiffness. It determines whether unreinforced concrete beams can survive bending failure. The flexural strength test is a way of determining the tensile strength of concrete indirectly. The flexural strength test was carried out following Indian Standard Specifications and the technique outlined in BIS 5816:1999. Standard specimens of 15x I5 x 70 cm were used to evaluate the flexural strength of concrete after 7 days, 28 days, and 90 days. To ensure adequate curing, specimens were demoulded 24 hours after casting and put in the curing tank. The UTC-5533 manual flexure testing machine with a capacity of 100 KN was used to test the flexural strength of concrete. For flexural strength testing, each specimen was placed on the roller and centered on the specimen's longitudinal axis, as indicated in the figure. The load is applied without shock and gradually rises at a rate of 400 kg/min till the extreme fiber stress is reached. The load was raised until the specimen cracked, and the maximum load taken by each specimen was recorded, as well as the presence of broken concrete faces and any unusual failure characteristics. The flexural strength of the specimen is measured by the modulus of rupture, where 'a' is the distance between the line of fracture and the closer support, measured on the tensile side of the specimen's centerline 0-5 kg/sq. cm in cm, to the nearest 0-5 kg/sq. cm. When 'a ' is greater than 20 cm for 15 cm specimen then flexural strength was calculated according to the following formula:

$$f_b = \frac{p * l}{b * d^2}$$

Where b = measured width (in cm) of the specimen,

d = measured depth (in cm) of the specimen at the point of failure,

l = length in cm of the span on which the specimen was supported, and

p = maximum load in kg applied to the specimen

C. *Mix Proportioning of Concrete:*

1) All-In Aggregate Grading:

All-in aggregate grading was performed according to the requirements of BIS 383:1970, based on individual sieve analysis of coarse and fine aggregate, to correct their proportions during the mix construction of concrete. All-In aggregate grading, as per the proportions taken in mix design, is given in Fig. 4.5.Summary of the mix proportions of aggregate used in the mix design of control concrete, as per the all-in aggregate grading is given in Fig. 1

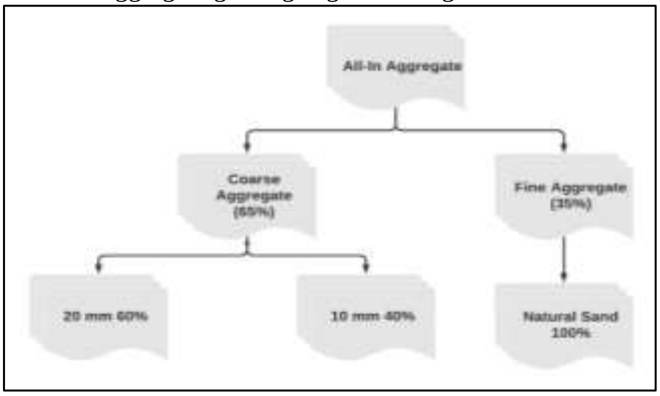

Fig. 1: Mix Proportioning of Aggregate as per All-In Aggregate Grading

2) Mix Design of Concrete:

The mix design of concrete used in the experimental program was as per Indian Standard Specifications given in BIS 10262:2009. The grade of the concrete selected was M60. Exposure conditions were selected as per the specifications of BIS 456:2000.

– Step-1: General Stipulations for Mix Proportioning:
  Grade of Concrete: M50
  Type of Cement: OPC 43 grade conforming to BIS 8112
  Maximum Nominal Size of Aggregate: 20mm
  Exposure Conditions: Severe (for RCC)
– Step-2: Target Strength for Mix Proportioning:
  Assume, Standard Deviation, s = 6.5 N/mm^2
  Target Mean Strength at 28 days, $f_t = f_{ck} + 1.65 \times 6.5$
  $= 50 + 1.65 \times 6.5 = 60.725$N/$mm^2$
– Step 3: Selection of Water-Cement Ratio:
  As per Table 5 of IS 456:2000, maximum water-cement ratio for severe exposure conditions in RCC = 0.45
  For M50 grade of concrete, adopted water-cement ratio = 0.33
– Step 4: Selection of Water Content:
  As per Table 7 of IS 10262:2019, maximum water content for concrete with 20mm nominal size aggregate with slump of 50mm = 186 kg
  Assuming efficiency of superplasticizer = 20%
  Therefore, final water content = 0.8×186 = 148.5 kg
– Step 5: Calculation of Cement Content:
  Water-cement ratio = 0.33
  Cement Content = 0.33 × 148.5 =450 kg
  As per Table 5 of IS 456:2000, for moderate exposure conditions in RCC, minimum cement content = 320 kg (Hence ok)
– Step 6: Proportions of Volume of Coarse Aggregate and Fine Aggregate:
  Now, for 20 mm nominal max aggregate size, Zone IV sand, and w/c ration of 0.50 we have,
  Vol of coarse aggregates per unit volume of total aggregate = 0.66

For w/c ratio of 0.33, vol. of coarse aggregate per unit vol. of total aggregates = 0.694
The volume of Fine Aggregate per unit vol. of total aggregates = 0.306
Also, 20mm: 10mm = 50:50

– Step 7: Mix Calculations:
The mix calculations for unit volume of concrete are given below:
Volume of entrapped air = 0.01 m^3
Volume of Cement = $\frac{450}{3150}$ = 0.143 m^3
Volume of water = 0.1485 m^3
Volume of superplasticizer = $\frac{1.35 \times 450}{100 \times 1060}$ = 5.731×10^{-3} m^3
Vol of all-in aggregate = 0.6928 m^3
Mass of sand = 0.6927× 0.306× 2670 = 568.40 m^3
Mass of 20mm aggregate = 0.6927× 0.694× 2710 × 0.50 = 651.39 kg
Mass of 10mm aggregate = 0.6927× 0.694× 2710 × 0.50 = 651.39 kg

– Step 8: Mix Proportioning for Control Concrete:
Summary of mix proportioning of control concrete with all aggregate in SSD conditions is given below:
Cement = 450 kg/m^3
Water =148.5 kg/m^3
Fine Aggregate =568 kg/m^3
20 mm nominal size Coarse Aggregate =651 kg/m^3
10mm nominal size Coarse Aggregate =651 kg/m^3
Water-cement ratio = 0.33

IV. RESULTS AND DISCUSSION

A. *Fresh properties of concrete:*

1) *Workability:*

Table 1.gives the slump values for different concrete mixes. It has been observed that the slump decreases with an increase in the quantity of nylon fiber. This can be attributed to the increase in surface area due to the presence of nylon fibers for the same quantity of water added.

Mix designation	Slump (mm)
CM	210
F_1	105
F_2	90
F_3	73

Table 1: Slump Values

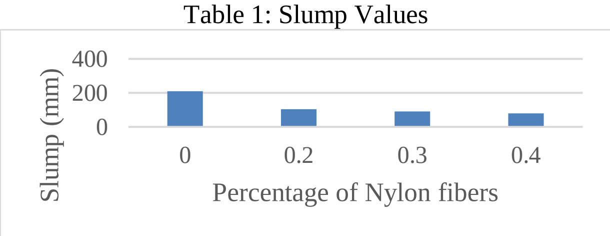

Fig. 2: Effect of Nylon Fibers on Slump of concrete.

B. *Compaction factor:*

The compaction factor is the ratio of weights of partially compacted to fully compacted concrete. The observations for the compaction factor are given in Table 2. below. The compaction factor decreases with an increase in fiber content. Thus the addition of nylon fibers results in a decrease in the workability of the concrete.

Mix designation	Compaction factor
CM	0.98
F_1	0.86
F_2	0.80
F_3	0.73

Table 2: Compaction factor test results of fresh concrete mix

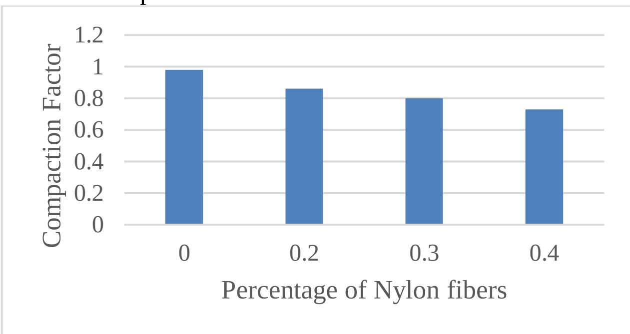

Fig. 3: Effect of Nylon Fibers on Compaction factor of concrete

C. *Mechanical Properties:*

1) *Compressive Strength:*

The compressive strength of different concrete mixes was evaluated at the age of 7 days, and 28 days and the observations are given in Table 3. It has been observed that the compressive strength of the concrete increases with an increase in fiber content. However, the increase is marginal. This may be due to the bridging effect provided by nylon fibers after the first crack.

Mix designation	Compressive Strength			
	7 days		28 days	
	Individual (N/mm^2)	Average (N/mm^2)	Individual (N/mm^2)	Average (N/mm^2)
CM	42.222	44.444	67.111	63.851
	45.33		63.111	
	45.777		61.331	
F_1	50.666	48.518	63.752	66.158
	50.222		66.222	
	46.666		68.050	
F_2	53.775	53.221	65.863	68.9
	54.666		71.692	
	51.222		69.245	
F_3	55.368	53.198	72.69	70.63
	50.893		69.489	
	53.333		69.711	

Table 3: Compressive Strength Test Results of Concrete Mixes

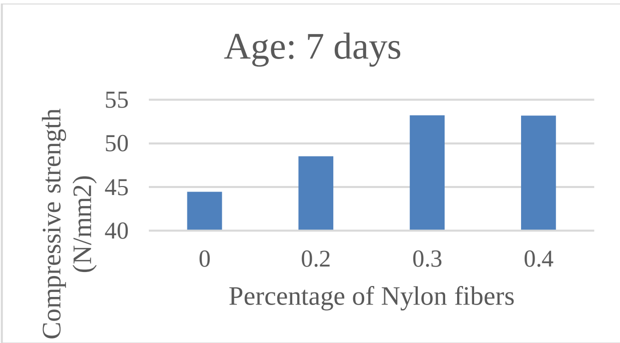

Fig. 4: Effect of Nylon Fibers on 7 days compressive strength of concrete

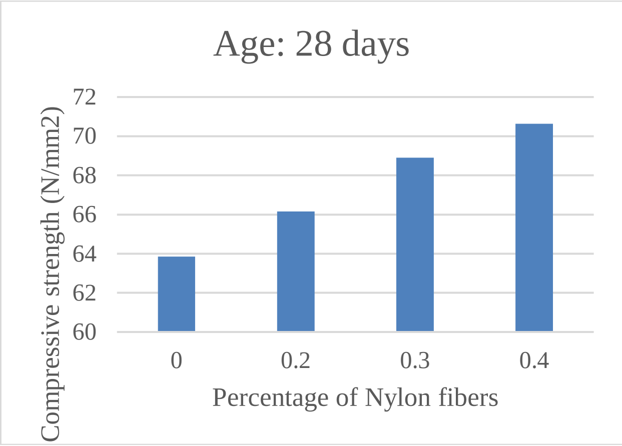

Fig. 5: Effect of Nylon Fibers on 28 days compressive strength of concrete

2) Flexural Strength:

Flexural strength of different concrete mixes was evaluated at age of 7 days and 28 days to study the effect of the addition of nylon fibers and observations are given in Table 4. It has been observed that the addition of nylon fibers improves the flexural strength of concrete to an appreciable extent. The prime factor for this behavior is the bridging effect of fibers in the tensile zone of flexure. This makes the nylon fiber reinforced concrete a potential candidate for application in concrete pavements where flexural strength plays an important role in the estimation of required pavement slab depth.

Mix designation	Flexural strength Test			
	7 days		28 days	
	Individual (N/mm^2)	Average (N/mm^2)	Individual (N/mm^2)	Average (N/mm^2)
CM	4.32	4.54	5.49	5.66
	4.59		5.63	
	4.71		5.86	
F_1	5.21	5.26	6.98	6.91
	5.16		6.83	
	5.41		6.92	
F_2	6.51	6.56	7.65	7.72
	6.63		7.97	
	6.54		7.54	
F_3	6.79	6.93	8.18	8.03
	6.84		7.99	
	7.16		7.92	

Table 4. Flexural Strength Test Results of Concrete Mixes

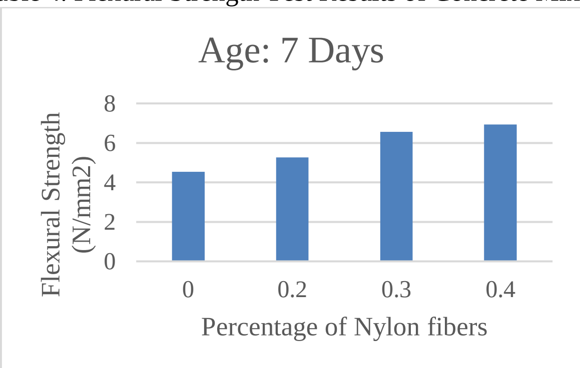

Fig. 6: Effect of Nylon Fibers on 7 days flexural strength of concrete

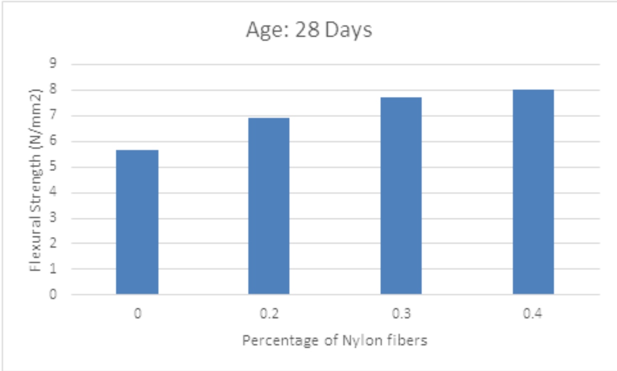

Fig. 7: Effect of Nylon Fibers on 28 days flexural strength of concrete

V. CONCLUSION

In the present study, attempts have been made to access the effect of the addition of nylon fibers on the workability and strength properties of concrete. Concrete mixes containing three different percentages of nylon fibers; viz. 0.2, 0.3, and 0.4 by volume of concrete mix, besides the control mix, have been prepared to access the properties. It has been concluded that:

1) The addition of nylon fibers results in a decrease in the workability of the concrete mix. Therefore, proper measures need to be taken while designing a nylon fiber reinforced concrete mix with required workability performance.
2) Nylon fibers, by their bridging effect, improve the strength properties of the concrete mix. The improvement in compressive strength is marginal. However, the flexural strength undergoes an appreciable increase due to the addition of nylon fibers.
3) Nylon fiber reinforced concrete, due to its improved flexural performance, seems to be a potential candidate for its application in concrete pavements.

REFERENCE

[1] Rafat Siddique, "Properties of concrete incorporating high volumes of class F fly ash and san fibers", Cement and Concrete Research, 2003.
[2] Alavi Nia, "An experimental and numerical study on how steel and polypropylene fibers affect the impact resistance in fiber-reinforced concrete", International Journal of Impact Engineering, 46 (2012), pp 62-73.
[3] M. Hanif, "Effect of nylon fiber on mechanical properties of cement-based mortar", IOP Conf Series: Material Science and Engineering, 271 (2017) 012080.
[4] Seungtae Lee, ”Effect of Nylon fiber addition on the performance of Recycled Aggregate Concrete”, Applied Sciences, (2019) 9, 767; doi:10.3390/app9040767
[5] Anirudh Swami, Shishir Gupta, “ Use of Nylon Fiber in Concrete” International Journal for Scientific Research & Development| Vol. 4, Issue 05, 2016 | ISSN (online): 2321-0613.
[6] Jaya Saxena1, Prof. Anil Saxena, “Enhancement the Strength of Conventional Concrete by using Nylon Fibre.” International Journal of Engineering and Science

Vol.5, Issue 2 (February 2015), PP 56-59 Issn (e): 2278-4721, Issn (p):2319-6483.
[7] Manikandan, A. Arun Kumar, M. Deepak Kumar, V. Manikandan, V. Satish Kumar, “Experimental Investigation on Nylon Fiber Reinforced Concrete.,” International Research Journal of Engineering and Technology.Volume: 04 Issue: 03 | Mar -2017.
[8] SaravanakumarJagannathan “An Experimental Investigation on Nylon Fibre (Textile Waste) Reinforced Concrete”.
[9] E. Siva Subramanian, V.R. Vaishnavi, V.T.S Vignesh, “Experimental Investigation of Concrete Composite using Nylon Fibre” International Journal of Engineering Sciences &Research Technology,December 2016.
[10] SaverioSpadea, Ilenia Farina, Anna Carrafiello, Fernando Fraternali, “Recycled nylon fibers as cement mortar reinforcement”, Construction and Building Materials, 80(2015), 200-209.
[11] Alex Tharun P J, Aneesha S Pushpan, Anjitha U G, Jasmine Johnson, Megha Thomas, Priya P, ShifaK,“Experimental investigation on strength properties of Nylon Fiber Reinforced concrete pavements”.
[12] P. Govintharaj, E. Prabu, S. Sundharrajan, M. Shivasankara, R. Parasuraman, “Study on Mechanical Properties of Nylon Fiber Reinforcement of Concrete,” International Journal of Scientific Development and Research. April 2020, Volume 5, Issue 4.
[13] Md. Akhtar Hossain, Md. Mahbubur Rahman, Abu ZakirMorshed, and SK. MarufulHaque, “Investigation of the Effect of Nylon Fiber in Concrete Rehabilitation”. 1st International Conference on Civil Engineering for Sustainable Development (ICCESD-2012).
[14] IS 4031-1 (1996), "Methods of Physical Tests for Hydraulic cement, Part 1: Determination of Fineness by Dry sieving," *Bureau of Indian Standards,* New Delhi.
[15] IS 4031-3 (1988), "Methods of Physical Tests for Hydraulic cement, Part 3: Determination of Soundness," *Bureau of Indian Standards,* New Delhi.
[16] IS 4031-4 (1988), “Methods of physical tests for hydraulic cement, Part 4: Determination of Consistency of Standard Cement paste,” *Bureau of Indian Standards,* New Delhi.
[17] IS 4031-5 (1988), “Methods of physical tests for hydraulic cement, Part 5: Determination of initial and final setting times,” *Bureau of Indian Standards,* New Delhi.
[18] IS 4031-6 (1988), “Methods of physical tests for hydraulic cement, Part 6: Determination of Compressive strength of Hydraulic cement (other than masonry cement),” *Bureau of Indian Standards,* New Delhi.
[19] IS 2386-1 (1963), "Methods of Test for Aggregates for concrete, Part I: Particle size and shape," *Bureau of Indian Standards,* New Delhi.
[20] IS 2386-3 (1963), “Methods of test for aggregates for concrete, Part 3: Specific gravity, Density, Voids, Absorption and Bulking,” *Bureau of Indian Standards,* New Delhi.
[21] IS 383: 2016, “Coarse and Fine Aggregate for Concrete-Specification,” *Bureau of Indian Standards,* New Delhi.
[22] IS 2386-4 (1963), "Methods of Test for Aggregates for Concrete, Part 4: Mechanical properties," *Bureau of Indian Standards,* New Delhi.
[23] IS 456 (2000), “Plain and Reinforced Concrete - Code of Practice,” *Bureau of Indian Standards,* New Delhi.
[24] IS 10262 (2009), “Guidelines for Concrete Mix design proportioning,” *Bureau of Indian Standards,* New Delhi.
[25] IS 1199 (1959), “Methods of Sampling and Analysis of Concrete,” *Bureau of Indian Standards,* New Delhi.
[26] IS 516 (1959), “Method of Tests for Strength of Concrete,” *Bureau of Indian Standards,* New Delhi.
[27] M. Neville, “Properties of Concrete,” 5th Edition, John Wiley & Sons, Inc., New York, 1996.
[28] Nitin, Dr. S. K. Verma, "Effect on Mechanical Properties of Concrete using Nylon Fibers” International Research Journal of Engineering and Technology. Volume: 03 Issue: 07 | July -2016.
[29] Enjoy Reufi, JozefitaMarku, “Effect of Steel Fiber and Polypropylene Fiber on Reinforced Concrete” International Conference on Civil Engineering, Infrastructure and Environment, Nov 2015.
[30] Akaram Ali, AleemAijaz, Mohammad Arsalan3, “A Study on Nylon Fibre Reinforced concrete by Partial Replacement of Cement with Metakaolin: A Literature Review” International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 03 | Mar-2018.

