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INFLUENCE OF VARIATION OF LENGTH AND DOSAGE OF NYLON FIBER ON COMPRESSIVE AND SPLIT TENSILE STRENGTH OF CONCRETE

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Abstract – *Nylon cable tie-fibre reinforced concrete is investigated for its compressive and split tensile strength after 7days and 28 days of curing in water, as nylon fibre which is able to withstand a certain amount of stress before it breaks, which is then compared to that of conventional concrete. Standard concrete cube and cylinder of Grade 20 was casted as trial samples to test the mix designed. Nylon cable ties were cut to length of 30mm and 50 mm with aspects ratios of 120 and 200 respectively. The concentration of nylon cable tie content is varied in percentages of 0.0%, 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, and 0.6% of weight of concrete used i.e. small dosage (below 5 kg/m³), medium dosage (5-10 kg/m³) and small dosage (above 10 kg/m³). The optimum nylon cable tie content for both compressive and split tensile strength was obtained, which is at 0.3%(medium dosage) fibre content and 30mm length. NFRC shows a higher compressive strength and higher tensile strength compared to the controlled concrete because when FRC cracks due to load being applied to it; the fibres were activated, arresting the formation of further cracks. When using higher dosage the strength decreases as the concrete workability decreases which will trap more air than highly workable concrete, creating larger voids and honeycombed surface and the existence of this large air voids reduces the strength of concrete due to less friction and poor interlocking between aggregates. The crack bridging effect of fibres that are existent at the crack face allows additional stress to be taken by the Post-Failure Compressive Strength.*

***Key Words*: Nylon Fiber Reinforced Concrete, Aspect Ratio, Dosage, Length variation, Percentage Variation**

1. INTRODUCTION

The most basic building component is concrete and steel. Plain Concrete is weak tension building material poor toughness, which is often susceptible to cracking connected to plastic and hardened states, drying shrinkage, and the like. The infrastructure needs of our construction industries is increasing each day and with concrete as one of the main constituent of construction system, it is necessary to enhance its characteristics by means of strength and durability. To counteract the tensile cracks, a fighting strategy has come into use, which mixes the concrete with the addition of discrete fibers. Experimental studies have shown that nylon fiber improves many of the structural properties of concrete, notably impact strength and toughness. Tensile strength, flexural strength, fatigue strength and ability to withstand spalling are also enhanced. In addition to this, it has also stepped up the performance after the appearance of cracks and has been able to sustained high stresses.

1.1 Benefits of Nylon-Fiber-Reinforced Concrete:

Fig. 1 *Nylon Fibre*

- Improve ductility,
- Improve structural strength,
- Improve freeze-thaw resistance,
- Reduce steel reinforcement requirements,
- Improve impact– and abrasion–resistance,
- Increase resistance to plastic shrinkage during curing,
- Improve resistance to explosive spalling in case of a severe fire,
- Improve mix cohesion, improving pumpability over long distances,
- Reduce crack widths and control the crack widths tightly, thus improving durability.

1.2 Limitations of Application of Nylon-Fiber-Reinforced Concrete:

- It should not be used with structural elements of concrete but just with secondary reinforcement.
- The engineer should confirm that if the steel screen is being used for structural capacity; if so, then the NYLON FIBERS can be added, but not as a substitute for the steel screens.
- When used in elevated slabs the nylon fibers, if used by themselves, cannot guarantee the absence of fissures. The steel screen should be incorporated together with the fibers.

2. MATERIALS

In this experimental study cement, sand, coarse aggregate, water and nylon fibres were used. Bulk of each items from their individual source was obtained in one batch is used to eliminate discrepancies and variation in material properties. Whose properties are given below.

Table -1: Physical Requirements and Results of OPC

Sr. No.	Characteristic	Test Values	Requirements
1)	Fineness, m^2/kg	301	>225
2)	Normal consistency, %	27	-
3)	Soundness By Le Chatelier method, mm	1.5	<10
4)	Setting Time		
	Initial Set(Minutes)	155	>30
	Final Set(Minutes)	210	<600
5)	Compressive strength(N/mm^2)		
	72 ± 1 h(3 Days)	34	≥27
	168 ± 2 h(7 Days)	45	≥37
	672 ± 4 h(28 Days)	55	≥53
6)	Specific Gravity	3.15	

Table -2: Chemical Requirements and Results of OPC

Sr. No.	Characteristic	Test Values (%)	Requirements (%)
1)	Lime saturation factor	0.87	>0.6&<1.02
2)	Alumina iron ratio	1.07	>0.66
3)	Magnesia	1.12	<6
4)	Sulfuric anhydride	2.27	3.35
5)	Insoluble Residue	2.08	<5
6)	Loss on ignition	1.32	<5
7)	Alkalis	0.42	0.6
8)	Chlorides	0.01	<0.10

Table -3: Physical Characteristics of Coarse Aggregate

Sr. No.	Characteristic	Test Results
1)	Specific gravity	2.77
2)	Shape	Angular
3)	Size of aggregate	20mm
4)	Crushing Value	24
5)	Impact Value	9

Table -4: Physical Characteristics of Fine Aggregate

Sr. No.	Characteristic	Test Results
1)	Specific gravity	2.65

2.1 NYLON FIBER

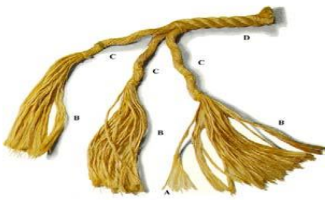

Fig -2: Nylon Fibre from Nylon Rope

Nylon fibers are used as a reinforcement material for concrete. Nylon ropes are supplied from local market. Which were cut into 30 mm and 50 mm length and then nylon fibers were then obtained by unwinding these smaller cut sections. The aspect ratios (l/d) of these fibers used were 120 and 200 respectively. Fibers helical in shape with flat ends were used in concrete with different percentages by weight of concrete.

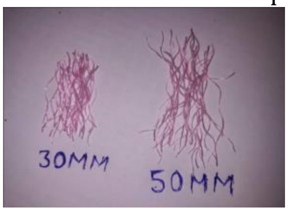

***Fig. 3:** Nylon Fibre Classification*

Table -4: Physical Characteristics of Nylon Fiber

Sr. No.	Characteristic	Values
1)	Specific gravity	1.14
2)	Tenacity, g/den	
	Dry	4-9
	Wet	90% of dry
3)	Stiffness, gm/den	20-40
4)	Moisture Regain	3.5-5% (not absorbent

		due to crystallinity)
5)	Abrasion Resistance	Excellent
6)	Dimensional Stability	Good
7)	Resiliency	Excellent
8)	Softening Point	190˚C
9)	Melting Point	235˚ C
10)	Hand Feel	Soft and Smooth
11)	Elasticity (Breaking Extension)	20-40%
12)	Mean Filament Diameter(µm)	350
13)	Ultimate Tensile Strength (MPa)	900

3. METHODOLOGY AND PROCEDURES OF WORK

3.1 Specimen Preparation and Dosage:

The concrete specimens such as cubes (of size 150mm×150mm×150mm) and cylinders (of size 150 mm diameter and 300 mm height) were casted and tested at 7days and 28 days of their strengths for two lengths which are 30 mm and 50 mm, for different percentage proportions of nylon fiber by the weight of and with conventional concrete which are 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, and 0.6% were first casted for 7-days compressive strength and split tensile strength. Out of these six percentages, three percentages with both 30 mm and 50 mm lengths which are 0.1%, 0.3%, and 0.6% were casted finally for 28 days of compressive strength and split tensile strength. A Controlled concrete was also casted to get compressive strengths and split tensile strengths of these specimens to compare the results obtained from those of NFRC. The selection of these three different proportions (0.1%, 0.3%, and 0.6%) were taken as these three percentages only showed a remarkable and a very distinct variations in strengths of specimens when tested under testing equipments used. Nylon fiber Proportions by the weight of concrete is also expressed in the form of dosage which is actually the weight of nylon fiber per cubic meter of concrete. Numbers of specimen casted for different proportions are shown in table. Dosage of below **5 kg/m³**; **5 kg/m³ to 10 kg/m³** and **above 10 kg/m³** are considered as **small, medium** and **high dosage** respectively.

Fig. 4 *Casted Specimen*

Mix	Nylon	Dosage kg/m³	Cube (NoS)		Cylinder (NoS)	
			7 Days 30 & 50 mm	28 Days 30 & 50 mm	7 Days 30 & 50 mm	28 Days 30 & 50 mm
M1	0.0%	0	3+3	3+3	3+3	3+3
M2	0.1%	2.448	3+3	3+3	3+3	3+3
M3	0.2%	4.896	3+3	0+0	3+3	0+0
M4	0.3%	7.344	3+3	3+3	3+3	3+3
M5	0.4%	9.792	3+3	0+0	3+3	0+0
M6	0.5%	12.24	3+3	0+0	3+3	0+0
M7	0.6%	14.688	3+3	3+3	3+3	3+3
		Total	**21+21**	**12+12**	**21+21**	**12+12**
			42	**24**	**42**	**24**
			Total Cubes **66**		Total Cylinders **66**	
			Grand Total 132			

3.2 Mixing

The first task carried out was to determine the best method in distributing the fibers into concrete. The mixing method was crucial in determining a uniform fiber distribution and in preventing the formation of fiber clumps and balls. A preliminary investigation was made using trial batches to select the best mixing technique for making FRC. The main difference in the mixing techniques was in the mechanism in which the fiber was added. Two different techniques of adding the fiber were tested to compare the distribution of fibers and their susceptibility to fiber balling. The first technique was mixed by adding the fibers in dry state along with the coarse and fine aggregates prior to the addition of water. In the second technique the fibers were added in the wet state after

Fig. 5 *Dry Mixing*

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Fig. 6 Fiber Ball Formation

the addition of water. The fibers were dumped into the mixing tray. Visual inspection of the concrete in plastic state was carried out to check for instances of fiber balling. The hardened specimens from both techniques were cut and visually inspected for uniformity of the fiber distribution along the concrete matrix. Check for the presence of defects due to improper mixing and fiber balling was done. Based on the visual inspection results, both techniques provided good distribution of fiber in concrete. However, the second technique provided better matrix consistency for nylon fiber where balling was encountered. The nylon fibers get wet easily when water is added to the dried mixture when using the mixing procedure developed for the first technique. As the nylon fiber becomes wet, it tends to clamp together forming fiber balls. These fiber balls produced corner pockets and prevented proper consolidation. Nylon cable tie fibres were added bit by bit to prevent clumping of fibres. This also allows the fibres to be spread evenly in the concrete. Weight Batching was used.

Fig. 7 *Hand Mixing*

4. TESTS AND RESULTS

The specimen casted were tested for their compressive (150mm cube) and split tensile strength(150 mm dia 300mm height cylinder) in Compression testing machine of 2000N capacity at 7 days and 28 days of cuing. The post-failure compressive strengths of cubes are also obtained. Whose results are shown in graphs below, where y-axis represents strength in N/mm².

Fig. 8 *Compression Testing Machine*

4.1 Compressive Strength Results

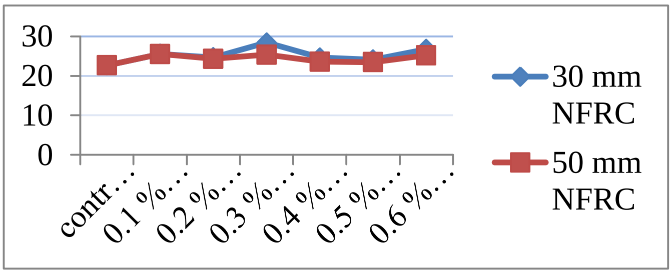

Chart 1: *7-day Nominal Compressive Strength*

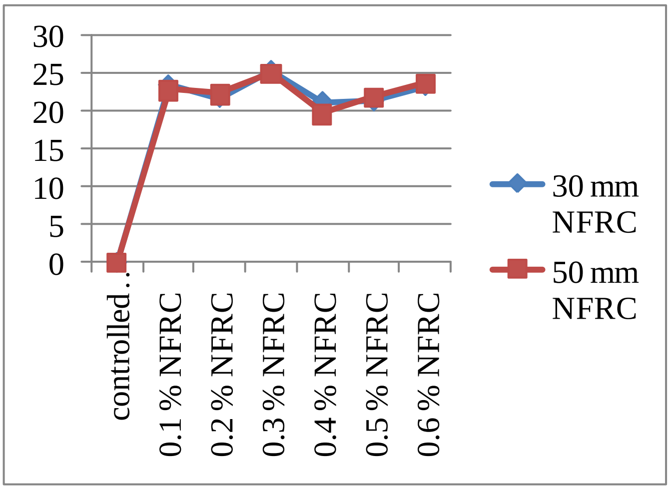

Chart 2: 7-Day post-failure Compressive Strength

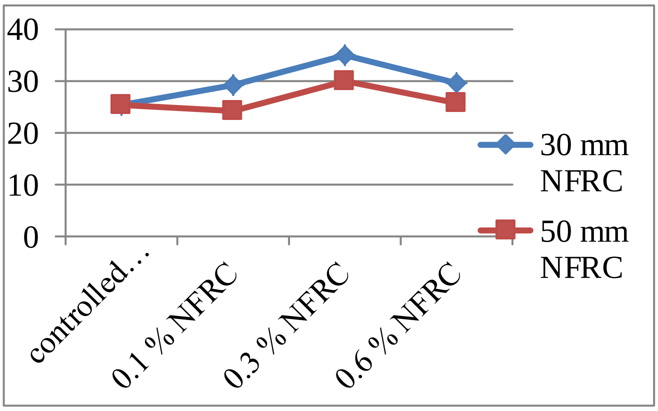

Chart 3: 28-day Nominal Compressive Strength

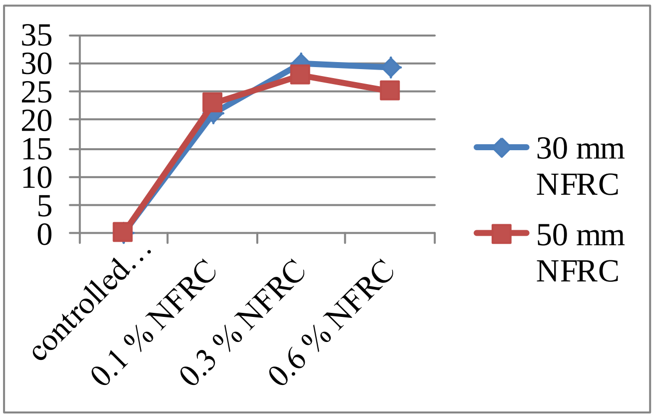

Chart 4: *28-Day post-failure Compressive Strength*

4.2 Split Tensile Strength Results

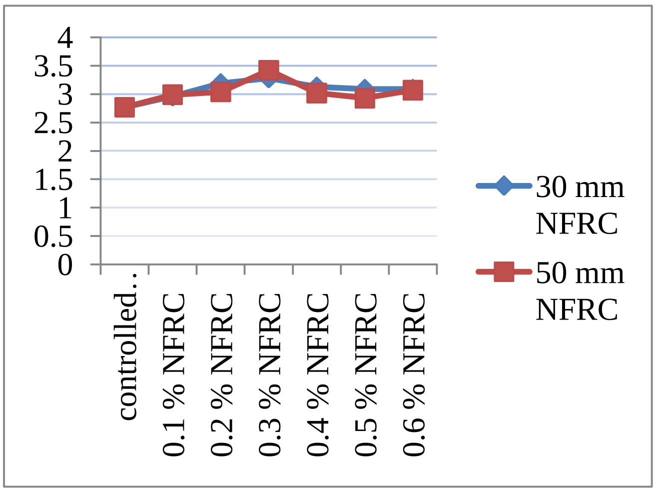

Chart 5: *7-Day Split Tensile Strength Test*

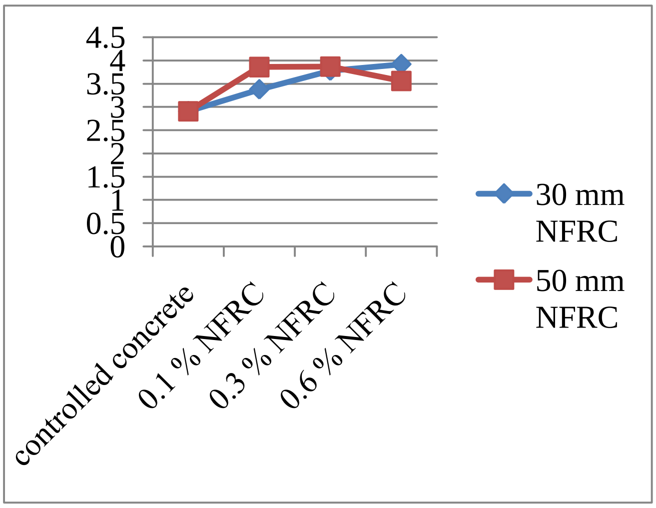

Chart 6: *28-Day Split Tensile Strength Test*

5. DISCUSSION

5.1 Compressive Strength

From the results, it can be observed that the compressive strength value is increased due to the incorporation of the fiber to the mix for the used fiber fraction compared to the controlled concrete mix. The explanation for this is that, under axial loads, cracks occur in microstructure of concrete and fibers arrest the crack formation and progression. Thus, compressive strength of concrete increases. When withstanding an increasing compression load, the fibrous concrete specimens may develop lateral tension, and then it initiates those cracks and advances them. As the advancing crack approaches a fiber, the debonding at the fiber–matrix interface begins due to the tensile stresses perpendicular to the expected path of the advancing crack. As the advancing crack finally reaches the interface, the tip of the crack encounters a process of blunting because of the already present debonding crack. The blunting process reduces the crack-tip stress concentration, thus blocking the forward propagation of the crack and even diverting the path of the crack. The blunting, blocking, and even diverting of the crack allow the fibrous concrete specimen to withstand additional compressive load, thus upgrading its compressive strength over the non-fibrous control concrete.

Fig. 9 *Non-NFRC cubes spalled after testing*

5.2 Split Tensile Strength

The substantial increase in splitting-tensile strength can contribute to the bridging action of the fibres. Once the splitting occurred and continues, the fibres bridging across the split portions of the matrix acted through the stress transfer from the matrix to the fibres and, thus, gradually supported the entire load. The stress transfer improved the tensile strain capacity of the two fibre-reinforced concretes and, therefore, increased the splitting tensile strength of the reinforced concretes over the unreinforced control counterpart. As stated earlier, the increasing in tensile strength due to incorporation of using nylon fiber. Fibers, (here nylon fibers) make the concrete less brittle and more ductile. Tensile strength of ductile materials is higher than brittle materials.

Fig. 10 *Bridging Action shown by cylinder*

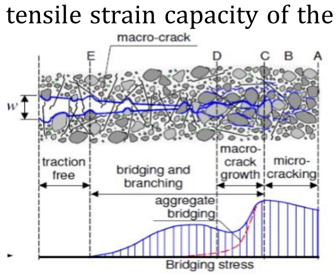

Fig. 11 *Bridging Mechanism*

5.3 Post Failure Compressive Strength

Post-failure compressive strength (PFCS) is a simplified method to assess the post-failure strength of concrete. The crack bridging effect of fibres that are existent at the crack face allows additional stress to be taken by the PFCS. In the concrete with fibres, additional force has to be applied on to the concrete for the crack to propagate further, compared to concrete without fibres. Thus, the addition of fibres is expected to enhance the post-failure

Fig. 12 *Post Failure Cracks on Reloading*

toughness of concrete. As expected, PFCS with nylon fibres produced about 85%-95% of strengths of normal NFRC. The magnitude of PFCS depends on the fibre bridging to sustain further compressive loading.

5.4 Relationship between Nylon Fiber Content and the Compression and Split Tensile Strength of Concrete

The existence of fibres in concrete develop a post tensile stress capacity which can hold the concrete together when excessive loading is applied to it before the concrete ultimately fails. The nylon cable tie in this research acts as fibres in concrete and the effect it brought to the compression and split tensile strength of concrete was analyzed. The concrete with 0.3% added fibre has higher mean compression and split tensile strength than that of the controlled sample and other percentage of added fibre because when fibre reinforced concrete cracks due to load being applied to it; the fibres were activated, arresting the formation of further cracks. The development of cracks will be slowed down by the fibre, until the fibre fails. The low dosage of fibre added also causes the water-cement ratio to be slightly lower than controlled sample, resulting in a higher strength concrete. However, the inversely proportional relationship between the amount of fibres added into concrete and the water content in concrete causes detrimental effects on concrete with nylon cable tie content of higher dosage. As the amount of nylon cable tie increases in concrete, it absorbs more water from the concrete mix, resulting in a lower water-cement ratio. When the water-cement ratio is too low, it produces a less workable concrete. Concrete that has low workability will trap more air than highly workable concrete, creating larger voids and honeycombed surface. The existence of large air voids reduces the strength of concrete due to less friction and poor interlocking between aggregates. This is why concrete samples with nylon cable tie content of 0.6% show a decreasing trend in terms of the compression and split tensile strength as the fibre content increases. When nylon cable tie is added into concrete with a dosage of more than 0.6%, it is expected that the compression and split tensile strength will continue to decrease.

5.5 Failure Mode of Nylon Cable Tie Fibre-Reinforced Concrete

The failure mode of nylon cable tie fibre reinforced concrete were observed after compressive and split tensile test were carried out to the concrete specimens. For nylon cable tie FRCs samples tested with compressive test, it was seen that the concrete specimens crushes parallel to the direction of the loading during failure. The crushing of concrete reduces as the nylon cable tie content in concrete increases. It was also observed that at locations where fibres are present, the crushing of concrete was not as bad as locations where fibres are absent. For nylon cable tie FRCs samples tested with split tensile test, a crack was developed parallel to the direction of loading upon failure for all specimens. However, the crack that was developed is clearly visible in concrete with nylon cable tie content of low dosage, but is less visible in concrete with fibre content of higher dosage. The fibres that are added in concrete holds the concrete together, creating a concrete that does not break abruptly upon failure

6. CONCLUSIONS

The following conclusions are driven from the present study:

1) Inclusion of nylon fibers to the concrete mix strongly increased the compressive strength. The increment is 37.21% for fiber volume fraction equal to 0.3% in case of 30 mm size fiber.
2) The use of nylon fibers will increase the split tensile strength of concrete. The maximum increment is for fiber ratio 0.6% in case of 30mm long fibers, which increases by 34.98% strength of control specimen.
3) Small dosage of NF (below 5 kg/m^3) shows some increase in strengths but the effect is not remarkable.
4) Medium dosage of NF (5-10 kg/m^3) is seems to have the highest potential of increase in strength and can be effectively used without much of workmanship.
5) High dosage of NF (Above 10 kg/m^3) shows some great increase in strengths but from the practical point of view, this requires the lot of labor, casting becomes tedious and the effect of ball formation becomes the most prominent issue.
6) Here we dealt with two fiber length 30 mm and 50 mm. Both showed increase in strengths in a very competitive manner to each other. 30mm was better in compressive strength and the other was better in split tensile strength. Again it is seen that 50 mm fiber at higher doses are more prone to ball formation as compared to 30 mm fiber.
7) It is clear from the above statement that both lengths are susceptible to ball formation and hence utter care should be taken during mixing operation. This could be the cause for 0.1% NFRC of 50 mm showing negative results.
8) Lengths lesser than 30 mm have not been taken into account as from previous researches it is seen that they have very least reinforcing ability also fibers more than 50 mm fiber have not been included in the study as they shows high degree of ball formation.
9) NFRC remains intact even after the development of crack once formed, which is not always true for Non-Fibre Reinforced Concrete as the spalling and shuttering of these concrete may immediately be seen. While NFRC has some residual compressive strengths about 85% - 95 % of their un-cracked strength, hence they will prove to be live saving at conditions of earthquakes and other accidents.

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REFERENCES

[1] Song PS, Hwang S, Sheu BC. Strength properties of nylon- and polypropylene fibre reinforced concretes. Cement and Concrete Research 2005; 35(8):1546–1550.
[2] Shetty M. S., Concrete Technology-Theory and Practice", S. Chand and Company, New Delhi, (1982).
[3] Fraternali F, Ciancia V, Chechile R, Rizzano G, Feo L, Incarnato L, Experimental study of the thermo-mechanical properties of recycled PET fiber-reinforced concrete. Composite Structures 2011; 93:2368–2374.
[4] Ozger OB, Girardi F, Giannuzzi GM, Salomoni VA, Majorana CE, Fambri L, Baldassino N, Di Maggio R. Effect of nylon fibres on mechanical and thermal properties of hardened concrete for energy storage systems. Materials and Design 2013; 51:989–997.
[5] Nili M, Afroughsabet V. The effects of silica fume and polypropylene fibres on the impact resistance and mechanical properties of concrete. Construction and Building Materials 2010; 24(6):927–933.
[6] AP Sathe and AV patil (2013); Experimental Investigation on Polypropylene Fiber Reinforced Concrete with Artificial. IJSR ISSN: 2319-7064 Volume 4 Issue 6.
[7] Er. Darole J. S., Prof. Kulkarni V.P., Prof. Shaikh A.P., Prof. Gite B.E. (2013); "Effect of Hybrid Fiber on Mechanical Properties of Concrete". IJERA ISSN: 2248-9622 Vol. 3, Issue 4, pp.1408-1411.
[8] Berke, N.S. and Dallaire, M.P. (1994), "The Effect of Low Addition Rates of Polypropylene Fibers on Plastic Shrinkage Cracking and Mechanical Properties of Concrete," SP-142, American Concrete Institute, Eds Daniel, J.I. and Shah, S.P., pp. 19- 42.
[9] Hughes, B.P. and Fattuhi, N.I. (1976), "Improving the Toughness of High Strength Cement Paste with Fibre Reinforcement," Composites, Vol. 7, pp. 185-188.
[10] Z. Bayasi, J. Zeng, Properties of polypropylene fiber reinforced concrete, ACI Mater. J. 90 (6) (1993) 605 – 610.
[11] P. Soroushian, H. Elyamany, A. Tlili, K. Ostowari, Mixed-mode fracture properties of concrete reinforced with low volume fractions of steel and polypropylene fibers, Cem. Concr. Compos. 20 (1998) 67 – 78.
[12] H. Toutanji, S. McNeil, Z. Bayasi, Chloride permeability and impact resistance of polypropylene-fiber-reinforced silica fume concrete, Cem. Concr. Res. 28 (7) (1998) 961 – 968.
[13] IS: 456-2000, Plain and reinforced concrete - code of practice", BIS New Delhi.
[14] IS: 10262-2009, "Recommended guidelines for concrete mix design", BIS New Delhi.
[15] IS: 12269-2013, "Ordinary Portland Cement, 53 Grade — specification", BIS New Delhi.
[16] IS: 1199-1959, "Methods of Sampling and Analysis of Concrete", BIS New Delhi.
[17] IS: 516-1959, "Methods of tests for strength of concrete", BIS New Delhi.
[18] IS: 5816-1999, "Splitting tensile strength of concrete - method of test", BIS New Delhi.
[19]