CONTRASTIVE APPROACH TO THE USE OF NANO-MATERIAL AND POLY-PROPYLENE FIBERS IN REINFORCED CONCRETE

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Abstract - *This present work explains the effect of use of nano-silica material and polypropylene fibers with traditional concrete mix. In past, initially PCC was used for construction and then it was replaced by RCC. This present study explores the replacement of RCC by fiber reinforced concrete. For this study, total thirty five specimens are investigated for various properties of concrete such as flexural tensile strength, compressive strength, split tensile strength, etc. The tests are carried out at the casting age of 28 days.*

During casting of specimens, the main emphasis is given on various parameters including fiber orientation, its quantity, and aspect ratio. Cubes are casted for determination of compressive strength of mix while flexural tensile strength is tested by the use of cylindrical shaped specimen of concrete. Moreover, the specimen in the form of beam is used to measure split tensile strength. It is concluded that use of nano-material and polypropylene fibers has minute change on its compressive strength. However, the impact resistant strength i.e., tensile strength, modulus of rupture or flexural tensile strength gets enhanced by some considerable amount.

Key Words: Poly-propylene Fiber, Nano-Silica, Modulus of Rupture, Impact Resistance

1. INTRODUCTION

The concrete structures, after 1970 or after that made by use of high strength oriented steel bars with their maximum surface deformations, changed constituents and cement properties and different supplementary materials in cement and admixtures with their capacity of acceleration or deceleration. Now, in place of steel bars, fibers of steel, polypropylene, natural polymers etc. are in use.

The reasons of demands are more, but as structural engineer, we should think about durability along with the properties of structures by using materials. With long term durability expectations, we need to be able the fulfilling the needs.
Now days, the construction industries are turning towards precast building elements and fulfilling the pre tensioning and post tensioning requirements with high strength concrete. Also, the engineers have to overcome these drawbacks, because in massive concreting, sometimes the concrete combines with different chemicals present in soil and does changes in their properties.

OPC is the main ingredient, used for concrete formation and has no alternative in construction industry. The production of cement emits a considerable amount of CO_2 gas in to atmosphere, which affects environment as accounted green house effect and global warming. Hence it will be a great initiative if we search for other material with either partial replacement or full replacement of cement. It produces impacts directly on environment and global sustainable development, if any such material can be used in place of cement as alternative or supplementary.

With the passing of time and to meet the demand, there is a continuous advancement and development in the field of construction and civil engineering. High strength concrete production started before 35 years, in late 1960s, the invention of water reducing admixtures took place and it was to lead the high strength precast products. Since then technology has come fast, concrete grades changes in order to M60 to M120. These are based on laboratory tests.

1.1 FIBER REINFORCED CONCRETE

The various materials that may be used for FRC may be glass fiber, natural or man-made fiber, steel fiber, nano-silica, etc. Poly-propylene fiber and nano-fibers are used for this present study since, they are one of the most common fibers.

The properties of concrete gets improve by mixing of fibers. The properties of concrete are durability, flexural strength, toughness, impact resistance and compressive strength. The physical improvement depends on the fiber type, size, configuration and fibers amount [V. Mohod, 2012].

1.2 NANO-MATERIALS- USE IN CONCRETE

Nano-materials are tiny-sized particles or materials having grain size in terms of nm. These are found to be very efficient and effective in terms of altering the characteristics of concrete at their fines level due to their smaller grain sized. This particles consists of very higher specific surface. These are capable of improving the permeability as well as the strength of concrete by filling the pores of concrete in microstructures.

Their use in the concrete has increased the compressive strength, flexural tensile strength, direct tensile strength and split tensile strength. These particles tends to produce the nano sized crystals of C – S – H gel during hydration process. These small sized crystals gain space of micro level pores in concrete which indirectly improves the permeability and strength characteristics of concrete mix.

1.3 POLYPROPYLENE FIBER REINFORCED CONCRETE

Polypropylene fiber is capable to impart the primary level of reinforcement towards the concrete mix due to its lower value of strength and lower value of elasticity as compared with the concrete mixes having concrete formed using Nano-Silica mixes. These are very widely used to impart the support in order to form the required behavior of material like reduction in the plastic behavior of concrete, its shrinkage properties and improves its toughness.

These are used in formation of structural domes, repairing works, etc. These are also used in pavement formation. These fibers are available in the market in the form of monofilament or film fibers. It may also resist the heating up to $100\pm5^{o}C$ for small instant of time just before its softening. But for road design and all ground construction work gets improvement in their strength by using fiber reinforced concrete. There is no special man power required when we use the FRC because the cost of any construction increases maximum due to man power.

The fiber reinforcement can be used in different forms just like randomly distribution over the length of the structural member. The benefit of this addition is the increase in the value of shear resistance, which further controls crack. Moreover, these fibers are used to impart the tension resistant properties which balances the steel requirement in the structures if their orientation is as per the geometry of the member.

2. OBJECTIVES

The prime research objectives of this present work are as follows:

- To study the effect of nano-silica on the compressive strength of concrete.
- To explain the microstructure/macrostructure of hardened concrete along with the variations in their characteristics.
- Conventional concrete strengths at normal temperature and pressure.
- Comparison between the strength of the conventional plain cement concrete with the polypropylene fiber reinforced concrete.
- Comparison of strengths of both nano-silica mixed concrete and polypropylene fiber reinforced concrete.

3. MATERIAL CONSIDERED AND METHODOLOGY

3.1 FIBER:

In the recent years, there have been several studies carried out to examine the flexural tensile strength of the reinforced concrete members having fiber reinforcement as the composite fabrics. Now a day, the green signal have been shown to the utilization of high strength fiber-reinforced polymer (FRP) materials.

In this science of composite material, the discrete fibers are distributed randomly all over the concrete mass. The behaviorist efficiency of the composite materials is always found to be superior to the use of plain cement concrete and the other materials of constructions which are of same cost. As a result, the FRC has been used steadily very widely on large scale from the past two decades and its application are in the various fields including airport runway, taxiways and highway pavements, seismic resistant structures and the structures having tendency to resist explosions, tunnel linings, hydraulic structures, overlays of bridge deck, and stabilization of rock slope. The large scale research work on FRC has been converted into a theoretical aspect that the use of different types of fibers like glass, synthetic, steel, carbon, in the concrete enhances the strength, ductility, post cracking resistance and toughness, etc. The major benefits of FC are resistance towards the formation of micro-cracks, resistance to fatigue, reduced permeability, and resistance to impact, increase in strength in terms of shear, flexure, tension and compression.

The variation in the performance and character of FRC takes place with the variation of formulation of concrete binder and the type of fiber material, geometry of the fibers, their distribution, orientation and concentration.

FIBER ASPECT RATIO:

The parameter is a measure of straightness or slenderness ratio of the individual fibers. This parameter is determined by the ratio of fiber length to its equivalent diameter of the individual fiber. The variation in the value of aspect ratio for the concrete lies in the range of 40 to 1000 but lower than 300 in general practice. It also acts as the measurement parameter of the stiffness of fiber and also affects the mixing and placing of concrete.

Table 1: Properties of Fibers

Fiber	**Diameter (μm)**	**Specific Gravity**	**Modulus of elasticity (GPa)**	**Tensile strength (GPa)**	**Elongation at break (%)**
Steel	5-500	7.84	200	0.5-2.0	0.5-3.5
Glass	9-15	2.60	70-80	2-4	2-3.5
Polypropylene:					
Aramid (Kevlar)	10	1.45	65-133	3.6	2.1-4.0
Carbon (high strength)	9	1.90	230	2.6	1.0
Cellulose	-	1.2	10	0.3-0.5	-
Acrylic	18	1.18	14-19.5	0.4-1.0	3
Polyethylene	-	0.95	0.3	0.7×10-3	10

3.2 PROPERTIES OF NANO-SILICA

From the grain size distribution analysis, the mean size of nano-silica particle is observed as 236nm. Table 2 presents the basic properties of nano-silica material used in concrete design. Fig. 1. Shows the nano silica used in the experiment.

Fig. 1: Image of the Nano SiO2 used

Table 2: Properties of Nano SiO2

TEST ITEM	**STANDARD REQUIREMENTS**	**TEST RESULTS**
SPECIFIC SURFACE AREA (m^2/g)	200 ± 20	202
PH VALUE	3.7 – 4.5	4. 12
LOSS ON DRYING @ 105 DEG.C (5)	≤ 1. 5	0. 47
LOSS ON IGNITION @ 1000 DEG.C (%)	≤ 2.0	0.66
SIEVE RESIDUE (5)	≤ 0. 04	0. 02
TAMPED DENSITY (g/L)	40 – 60	44
SiO2 CONTENT (%)	> 99. 8	99. 88
CARBON CONTENT (%)	≤ 0. 15	0. 06
CHLORIDE CONTENT (%)	≤ 0. 0202	0. 009
Al2O3	≤ 0. 03	0. 005
TiO2	≤ 0. 02	0. 004
Fe2O3	≤ 0. 003	0. 001

3.3 CASTING AND CURING

According to goal of this study and related tests, the following specimens were cast from each mix:

- For evaluation of compression test: 5 Cubes for each with size of 150 x 150 x 150 mm with mixing of 0%, 1%, 2% and 3% by volume of concrete for conventional concrete, nano-silica and polypropylene fibers respectively.
- For evaluation of flexural test: 5 beams for each mix with size of 100 × 100 × 500 mm with mixing of 0%, 1%, 2% and 3% by volume of concrete for conventional concrete, nano-silica and polypropylene fibers respectively.
- For evaluation of impact resistance test: 5 cylinders of each mix with size of 150 × 600 mm with mixing of 0%, 1%, 2% and 3% by volume of concrete for conventional concrete, nano-silica and polypropylene fibers respectively.
- After preparing the moulds concrete was placed in two layers vibrated with 50 Hz frequency leading to proper consolidation and concrete compaction. The curing of specimen in the fog room takes place having temperature range between 22° C – 24° C. The samples were extruded and cured in temperature in controlled water tank for 28 days.

4. RESULTS AND ANALYSIS

Table 3: Compressive Strength for Nana-Silica Mix

Compressive strength(N/sqmm) of 1%, 2% and 3% Nana-Silica Mix Grade M40							
Aspect Ratio		**1%**	**Avg.**	**2%**	**Avg.**	**3%**	**Avg.**
50	Sample CS1.1	52.2	52.74	53.1	54.34	55.6	55.66
	Sample CS1.2	54.8		54.8		55	
	Sample CS1.3	53.2		54		54	
	Sample CS1.4	52.5		55		57.5	
	Sample CS1.5	50.9		54.8		56.2	
60	Sample CS2.1	53.3	53.4	54.8	56.94	56	58.12
	Sample CS2.2	52.1		54.5		55.8	
	Sample CS2.3	54.4		58		58	
	Sample CS2.4	55.1		58		60.2	
	Sample CS2.5	52.1		59.4		60.6	

For different aspect ratios i.e. 50 and 60, with mixing of 1%, 2% and 3% Nana-Silica Mixs added. The results found were more compressive strength as compared with conventional concrete. For more Nana-Silica Mix mixing (3%), more strength observed on aspect ratio 60 whereas in case of minimum percentage of Nana-Silica Mix i.e. 1%, compressive strength minimum compressive strength 52.74MPa came out. Table 4 is telling about the compressive strength of polypropylene fiber mix reinforced concrete.

Table 4: Compressive Strength for Polypropylene fiber Mix

Compressive strength(N/sqmm) of 1%, 2% and 3% Polypropylene Fiber Grade M40							
Aspect Ratio		**1%**	**Avg.**	**2%**	**Avg.**	**3%**	**Avg.**
50	Sample CP1.1	38.8	41.32	48.8	47.02	49.4	49.2
	Sample CP1.2	40.4		44.4		50.8	
	Sample CP1.3	41.5		49.5		43.5	
	Sample CP1.4	42.4		44		57.8	
	Sample CP1.5	43.5		48.4		44.5	
60	Sample CP2.1	40.5	45.28	44.8	50.98	49.4	54.48
	Sample CP2.2	45.5		50.4		45.4	
	Sample CP2.3	48.9		53.6		60.1	
	Sample CP2.4	43.5		52.2		55.4	
	Sample CP2.5	48		53.9		62.1	

30 samples have been taken for polypropylene fiber mixes. Five samples of each percentage taken out. When 1% of polypropylene fiber added, 41.32MPa compressive strength got on Compressive Testing Machine for aspect ratio 50. Similarly for aspect ratio 60, compressive strength 45.28MPa measured. Table 5 having Flexural strength for steel reinforced concrete mix.

Table 5: Flexural Strength for Nana-Silica Mix

Flexural strength(N/sqmm) of 1%, 2% and 3% Nana-Silica Mix Grade M40							
Aspect Ratio		**1%**	**Avg.**	**2%**	**Avg.**	**3%**	**Avg.**
50	Sample FS1.1	8.9	8.54	8.5	9.18	10.5	10.62
	Sample FS1.2	8.1		8.4		10.2	
	Sample FS1.3	9.1		9.4		11.2	
	Sample FS1.4	8.4		9.8		11.4	
	Sample FS1.5	8.2		9.8		9.8	
60	Sample FS2.1	8	8.58	8.9	9.622	11.5	11.54
	Sample FS2.2	8.2		9.5		9.4	
	Sample FS2.3	8.1		9.4		12	
	Sample FS2.4	9.2		10.2		12.4	
	Sample FS2.5	9.4		10.11		12.4	

As similar to compressive strength, here again 30 samples collected and measured their respective strengths with 1%, 2% and 3% Nana-Silica Mixs by volume. The flexural strength for Nana-Silica Mixs is more than conventional concrete flexural strength. Table 6 is showing results after 28 days of flexural strength for polypropylene fiber mix.

Table 6: Flexural Strength for Polypropylene fiber Mix

Flexural strength(N/sqmm) of 1%, 2% and 3% Polypropylene Fiber Grade M40							
Aspect Ratio		**1%**	**Avg.**	**2%**	**Avg.**	**3%**	**Avg.**
50	Sample FP1.1	36.5	37.76	39.5	39.18	40.1	41.4
	Sample FP1.2	36.5		37.8		40.5	
	Sample FP1.3	40		38.4		42.7	
	Sample FP1.4	38.2		40		41.8	
	Sample FP1.5	37.6		40.2		41.9	
60	Sample FP2.1	40.5	40.14	39	42.18	32.8	44.26
	Sample FP2.2	42.5		45.5		34.9	
	Sample FP2.3	36.4		40		50.8	
	Sample FP2.4	40.2		43.2		51	
	Sample FP2.5	41.1		43.2		51.8	

Here, after mixing of polypropylene fibers with conventional concrete, the flexural strengths are higher than Nana-Silica Mixs. If we talk about 1% addition of polypropylene fibers, we achieved 37.76MPa flexural strength for aspect ratio 50. Similarly, for aspect ratio 60, this value is 40.14MPa. Whereas for same aspect ratio, 44.26MPa at 3% addition of polypropylene fibers.

For split tensile strength, cylinders were casted and tested in Compression Testing Machine after 28 days. The minimum and maximum values of split tensile strength were noted 2.9MPa and 4.2MPa respectively. Split tensile strength for Nana-Silica Mix with different percentages are presented in Table 7.

Table 7: Split Tensile Strength for Nana-Silica Mix

Split Tensile strength(N/sqmm) of 1%, 2% and 3% Nana-Silica Mix Grade M40							
Aspect Ratio		1%	Avg.	2%	Avg.	3%	Avg.
50	Sample TS1.1	3.2	3.26	4.1	4.36	5.2	5.16
	Sample TS1.2	3		4.1		4.2	
	Sample TS1.3	2.9		4.3		5.4	
	Sample TS1.4	3.4		4.2		5.4	
	Sample TS1.5	3.8		5.1		5.6	
60	Sample TS2.1	2.9	3.36	6	4.76	4.5	5.28
	Sample TS2.2	3.2		3.5		5.6	
	Sample TS2.3	3.1		3.5		5.8	
	Sample TS2.4	3.4		5.2		5.9	
	Sample TS2.5	4.2		5.6		4.6	

In case of Nana-Silica Mix addition, 5 samples of aspect ratio 50 with 1%, given 3.26MPa average split tensile strength, for 2% the average strength is 4.36MPa and for 3% the average strength is 5.16MPa whereas for aspect ratio 60 with 1% Nana-Silica Mixs, the average strength is 3.36MPa and with 2% fibers, average strength is 4.76MPa and the maximum strength is 5.28MPa with 3% addition of Nana-Silica Mixs. These values show that the split tensile strength of Nana-Silica Mixs is more durable than conventional concrete. Table 8 is presenting the split tensile strength of polypropylene reinforced concrete after 28 days.

Table 8: Split Tensile Strength for Polypropylene fiber Mix

Split Tensile strength(N/sqmm) of 1%, 2% and 3% Polypropylene Fiber Grade M40							
Aspect Ratio		1%	Avg.	2%	Avg.	3%	Avg.
50	Sample TP1.1	4.2	4.16	4.5	5.3	5.1	5.76
	Sample TP1.2	2.4		4.5		5.1	
	Sample TP1.3	4.5		5.6		5.2	
	Sample TP1.4	4.5		5.8		6.2	
	Sample TP1.5	5.2		6.1		7.2	
60	Sample TP2.1	4.8	5.5	4.8	5.98	4.6	6.58
	Sample TP2.2	5.1		5.2		8	
	Sample TP2.3	5.6		6.2		6.1	
	Sample TP2.4	5.8		6.4		6.8	
	Sample TP2.5	6.2		7.3		7.4	

If we compare the strengths of both steel and polypropylene fibers with conventional concrete, we get polypropylene fibers shows maximum split tensile strength. At 1% polypropylene fiber mixing with conventional concrete, the average value is 4.16MPa, and for 2% and 3%, 5.3MPa and 5.76MPa respectively for aspect ratio 50. For aspect ratio 60 and 1% mixing of polypropylene fibers, the strength is 5.5MPa, 2% mixing of polypropylene fibers, the strength is 5.98MPa and lastly, for 3% mixing of polypropylene fibers, the strength is 6.58MPa.

5. Conclusions

In this present study with the stipulated time and laboratory set up afford has been taken to enlighten the use of so called fiber reinforced concrete in accordance to their proficiency. It was concluded that:

- With the use of superplasticizer, it is possible to get a mix with low water to cement ratio to get the desired strength.
- In case of ordinary portland cement with the use of Nana-Silica Mix, the 28 days compressive strength at 3% fiber content the result obtained is maximum.
- When polypropylene fiber mixed with nominal concrete, it shows compressive strength is less than steel i.e. 11%.
- After mixing of fibers (i.e. steel & polypropylene) with by 1%,2% and 3%, the compressive strengths increases gradually. Which means slightly changes comes by increasing the percentage fibers for both aspect ratios.
- As shown in graphs for aspect ratios i.e. 50 and 60, compressive strength changes maximum limit in aspect ratio 60. This shows if the length of fibers is more, then compressive strengths will be more.

- When there is no mixing of fibers, no changes will come in any strength.
- Maximum flexural strength is coming in polypropylene, it means for casting of beams is helpful by using the polypropylene fibers.
- The orientations of fibers also giving a good result for polypropylene fibers. Because as compared to steel, it is more flexible and able to resist the uniformly distributed loads.
- The flexural strength for aspect ratio 60 and polypropylene fibers is showing a long gap between steel and polypropylene fibers.
- If we compare the split tensile strength, for the aspect ratio 50, it is 10% variation between steel and polypropylene. Whereas for aspect ratio 50, it is approximately 20% variation in same.
- Polypropylene fibers will be more effective in tensile zone because they have property of plasticity.