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Performance of Polypropylene Fibre Reinforced Concrete

Milind V. Mohod[1]
[1] *Assistant Professor, Department of Civil Engineering ,Prof. Ram Meghe Institute of Technology And Research,Badnera, Amravati, India*

Abstract: *The paper deals with the effects of addition of various proportions of polypropylene fibers on the properties of High strength concrete (M30and M40 mixes). An experimental program was carried out to explore its effects on compressive, tensile, flexural strength under different curing condition. The main aim of the investigation program is to study the effect of Polypropylene fiber mix by varying content such as 0% ,0.5%,1%,1.5% & 2% and finding the optimum Polypropylene fibre content. The concrete specimens were tested at different age level for mechanical properties of concrete, namely, cube compressive strength, split tensile strength, flexural strength. A detailed study was carried out for curing conditions. Half of the concrete specimens were left exposed to the surrounding to cure by themselves and the remaining half were cured in a curing tank. Initially the concrete specimen's shows appreciable strength for irregular curing but as the days advances the curing specimens gave satisfactory strength. A notable increase in the compressive, tensile and flexural strength was observed. However, further investigations were highly recommended and should be carried out to understand more mechanical properties of fibre reinforced concrete.*

Keywords: *Different curing condition, High strength concrete, mechanical properties of concrete, polypropylene fibers*

I. Introduction

Polypropylene fibers are hydrophobic, that is they do not absorb water. Therefore, when placed in a concrete matrix they need only be mixed long enough to insure dispersion in the concrete mixture. The mixing time of fibrillated or tape fibers should be kept to a minimum to avoid possible shredding of the fibers .The type of polypropylene fiber recommended by manufacturers for paving applications is the collated fibrillated fiber. The length of fiber recommended is normally tied to the nominal maximum size of aggregate in the mixture. Manufacturers recommend that the length of the fiber be greater than twice the diameter of the aggregate. This would be consistent with past experiences with steel fibers and also with current theories on fiber dispersion and bonding". The manufacturers of fibrillated fibers recommend their products for the following purposes in paving: to reduce plastic shrinkage and permeability, to increase impact resistance, abrasion resistance, fatigue, and cohesiveness (for use in slip forming and on steep inclines), and to provide a cost effective replacement for welded wire fabric (WWF). However, they do not recommend specifying fibers for the control of cracking from external stresses, increased structural strength, slab thickness reduction, joint spacing reduction, or replacement of structural steel reinforcement. Monofilament fibers, according to fiber manufacturers, only provide control of cracking caused by shrinkage and thermal stresses occurring at early ages. These fibers provide no post-crack benefit and are used only for shrinkage cracking and not to provide improvements to other engineering properties.

The amount of polypropylene fibers recommended by most manufacturers for use in paving mixtures and most other mixtures is **0.1** percent by volume of concrete (0.889 to 0.949 kg per cubic meter). Researchers have experimented with fiber volumes up to 7.0 percent. Fiber volumes greater than 2.0 percent normally involve the use of continuous fibers, which are not usually considered for paving applications due to constructability problems. Fiber volumes up to 0.5 percent can be used without major adjustments to the mixture proportions. As volume levels approach 0.5 percent, air-entraining and water-reducing admixtures are required.

1.1 Literature Review

Review of work done by various researchers discusses the mechanism of fibre-matrix interaction, where various models are used to compute the bonding between the fibres and cement matrix. As the bonding of fibre and the matrix plays a major role in the composite behavior. Furthermore, this chapter also presents a review of literature relevant to the investigation and tests done for fibre reinforced concrete in general with a prominence of civil engineering application.

Fiber reinforced concrete was successfully used in variety of engineering applications, because of its satisfactory and outstanding performance in the industry and construction field. However, most of the engineers and researchers have thought that how and why the fibers perform so successfully. So, to recognize the usage of fibers in concrete, in these last four decades, most of the research was done on mechanical behavior of fiber reinforced concrete and the fibers itself.

According to Balaguru (1988) the uniaxial compression test is normally used to evaluate the behavior of concrete in compression. This produces a combination of shear failure near the ends of the specimen with lateral swelling of the unconfined central section accompanied by cracking parallel to the loading axis when the lateral strain exceeds the matrix cracking strain in tension. Fibers can affect these facets of uniaxial compressive behavior that involve shear stress and tensile strain. This can be seen from the increased strain capacity and also from the increased toughness (area under the curve) in the post-crack portion of the stress-strain curve.

Khajuria and Balaguru, (1989) .in some instances, if more water is added to fiber concrete to improve its workability, a reduction in compressive strength can occur. This reduction should be attributed to additional water or due to an increase in entrapped air, not fiber addition.

Johnston and Skarendahl, (1992). The addition of fibers up to a volume fraction of 0.1% does not affect the compressive strength. When tested under compression, failure occurs at or soon after the peak load providing very little toughness. It is found that the fibers have very little effect on compressive strength calculated from the peak load, and both slight increase and decrease in strength have been reported with increase in fiber content. The decrease in strength is mostly reasoned due to incomplete consolidation.

Alhozaimy, A.M., et al (1995) carried out experimental investigations on the effects of adding low volume fractions (<0.3%) of calculated fibrillated polypropylene fibres in concrete on compressive flexural and impact strength with different binder compositions. They observed that polypropylene fibres have no significant effect on compressive (or) flexural strength, while flexural toughness and impact resistance showed increased values. They also observed that positive interactions were also detected between fibres and pozzolans.

Bentur, (2007). (Hasan Et Al., 2011 Roesler Et Al. (2006), the addition of polypropylene fibres does not have a significant effect on the direct tensile cracking strength (Bentur, 2007). However, in moderate volume replacements (0.33-0.5%) the addition of macro-synthetic polypropylene fibres showed a 10 to 15% increase in splitting tensile strength.

II. Methodology

As in the literature review I have chosen the polypropylene fibre for making the concrete mix and I have select the different proportions of polypropylene fibre for obtaining the strength variation at 0.5%,1%,1.5%,2% and for making the PPFRC we required different materials which are described below.

2.1 Materials

2.1.1 Cement

The cement used was Pozzolana Portland cement (PPC) with a specific gravity of 3.11. Initial and final setting times of the cement were 69 min and 195 min, respectively.

2.1.2 Aggregates

Good quality river sand was used as a fine aggregate of WARDHA SAND. The material whose particles are of size as are retained on I.S Sieve No.480 (4.75mm) is termed as coarse aggregate. The size of coarse aggregate depends upon the nature of work. The coarse aggregate used in this experimental investigation are of 20mm size crushed angular in shape. The aggregates are free from dust before used in the concrete.

2.1.3 Fibres

Fibres vary in types, geometry, properties and availability in construction industry. Most common types of fibres are steel fibres, glass fibres, and polypropylene fibres. These usages may alter in concrete for different applications. The fibres are selected from their properties like, effectiveness, cost and availability. Special types of fibres such as carbon, and Kevlar, natural fibres, mineral fibres, and asbestos fibres may use in harsh environment. These differences and usage of fibres depends on the requirement of behavior and properties for a concrete, allowing the increase the explicit effects and mechanical properties. Fibre geometry varies from hooked end fibres, deformed fibres, deformed wires, fibre mesh, wave-cut fibres, large end fibres till different types and geometries.

Different types of fibres used in the construction of different structures are:
1. Steel fibre.
2. Glass fibre.
3. Polypropylene fibre.

2.2 Polypropylene Fibres

Polypropylene is available in two forms, monofilament fibers and film fibers. Monofilament fibers are produced by an extrusion process through the orifices in a spinneret and then cut to the desired length. The newer film process is similar except that the polypropylene is extruded through a die-that produces a tubular or flat film. This film is then slit into tapes and uniaxially stretched. These tapes are then stretched over carefully designed roller pin systems which generate longitudinal splits and these can be cut or twisted to form various types of fibrillated fibers. The fibrillated fibers have a net-like physical structure. The tensile strength of the fibers is developed by the molecular orientation obtained during the extrusion process. The draw ratio (final length/initial length), a measure of the extension applied to the fiber during fabrication, of polypropylene fibers is generally about eight.

Polypropylene has a melting point of 165 degrees C and can withstand temperatures of over **100** degrees C for short periods of time before softening'. It is chemically inert and any chemical that can harm these fibers will probably be much more detrimental to the concrete matrix'. The fiber is susceptible to degradation by **UV** radiation (sunlight) and oxygen; however, in the concrete matrix this problem is eliminated'. Monofilament fibers were the first type of polypropylene fiber introduced as an additive in PFRC. Monofilament fibers are available in lengths of 1/2, 3/4, and 1-1/2 inches **.**The monofilament fibers have also been produced with end buttons or in twisted form to provide for greater mechanical anchorage and better performance. The majority of fiber manufacturers recommend the fibrillated type of fiber for use in paving applications. The exact chemical composition and method of manufacture may vary slightly among producers. The main types or geometry of fibers currently available from most producers are monofilament and fibrillated. The fibrillated fibers are usually manufactured in bundles or collated together and come in lengths of 1/2, 3/4, 1-1/2, or 2 inches. One manufacturer is producing a twisted collated fibrillated fiber and another is producing a blended collated fibrillated fiber consisting of fibrillated fibers blended together in various lengths from 3/4 to 2 inches. The monofilament fibers are described by length in inches and also either by miles**(1/1000** inch) or by denier's (unit of fineness equal to the fineness of a 9,000-meter fiber that weighs one gram) in diameter'. The term denier comes from the textile industry. The term fibrillated (screen) fiber derives from the manufacturing method used. The term collated means that the fibrillated fibers are bundled together, usually with some type of water soluble glue which will break up or dissolve in the fluid concrete mixture. Another method of packaging the fibers used by one manufacturer was in twisted collated fibrillated fibers, for a claimed better 3-dimensional distribution throughout the mixture.


Figure2.1: Twisted wave geometry


Figure2.2: Mesh geometry


Figure2.3: Polypropylene fibre

Table no.3.2 Properties of polypropylene fibres

Properties	Test data
Diameter(D) ,mm	0.0445
Length (l),mm	6.20
Aspect Ratio (l/D)	139.33
Tensile strength Mpa	308
Specific gravity	1.33

2.3 Mix Design

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.

III. To Find Optimum Polypropylene Fibre Content

This section focuses on the experimental results obtained from each test and analysis of the test results. The experimental tests were carried out to obtain the mechanical properties and behavior of polymer fibre reinforced concrete. The comparisons of mechanical properties and behavior include the workability, compressive strength, tensile strength, flexural strength. Effect of increase in polymer fibre percentage by volume of cement and at same time reducing the same quantity of cement in the polypropylene fibre reinforced concrete (PFRC) was studied. Observation for 7, 14 & 28 days curing as well as exposure period were recorded and presented in the form of tables and graph. While the flexural strength and tensile strength graph were measured and plotted only for 28 days in curing & exposure conditions. We have defined the specimens which were exposed to surrounding environment as irregular curing.

3.1 Cube crushing strength results

1. For normal mix M30 and M40 subjected to control curing and Irregular curing conditions (Exposed).

From the above fig. 3.1 ,it can be seen the initial strength of mixes(M30 & M40) have found to be satisfying the nominal criteria that 7 days strength shall be 1/3rd of the mix proportion(65% of grade of concrete), which is been satisfying for both curing & exposed conditions of concrete. As the days of curing advances a slight drop in strength is observed for both the mixes (M30 & M40). But as the curing reaches to 28 days, the gain in strength is observed which satisfied the target strength. Also it has been observed that M30 mix under regulated curing conditions shows linear increased in strength as in comparison to other mixes.

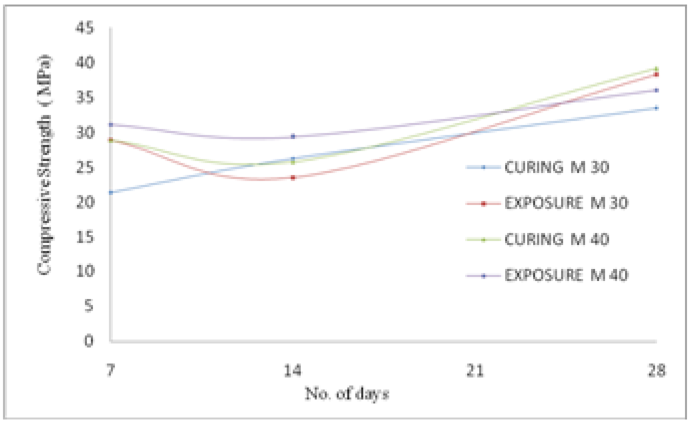

Figure3.1: For normal mix M30 and M40

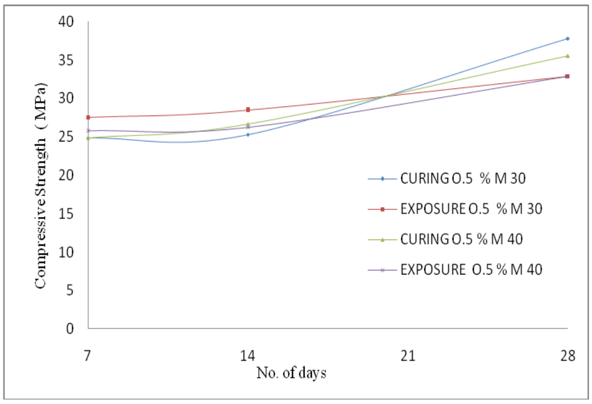

Figure 3.2: For 0.5 % fibre mix M30 & M40

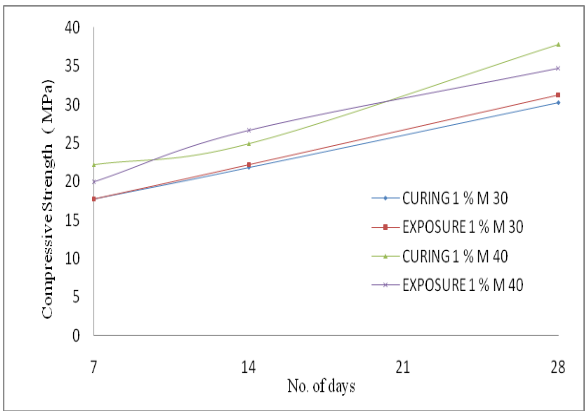

Figure 3.3: For 1 % fibre mix M30 & M40

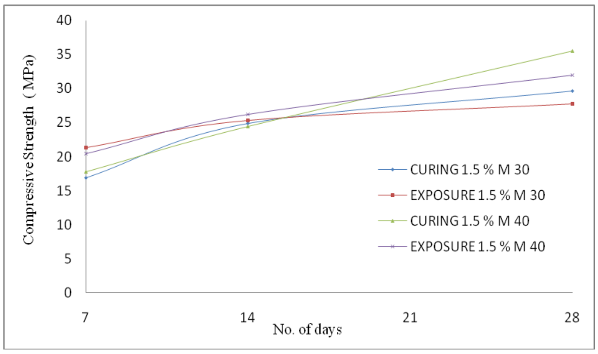

Figure3.4: For 1.5 % fibre mix M30 & M40

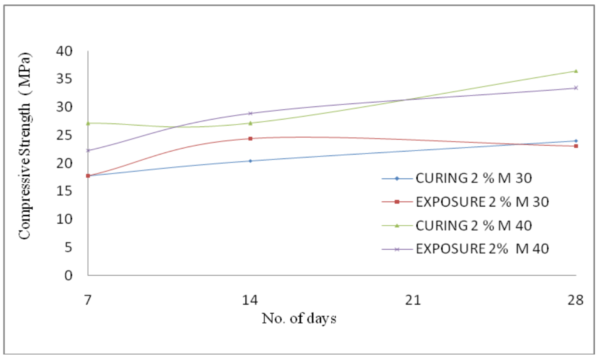

Figure 3.5: For 2 % fibre mix M30 & M40

From the above graph 3.2, it can be seen that the compressive strength of mixes (M30 & M40) are satisfying the nominal criteria that 7 days strength shall be 1/3rd of the mix proportion (65% of concrete grade), which is been satisfying for both curing & irregular curing conditions of concrete. As the days of curing advances to 14 days a continuous increase in strength was observed for both the mixes (M30 & M40). But as the curing reaches to 28 days, the gain in strength was observed to satisfy the target strength. Also it has been observed that M40 mix under regulated curing conditions shows linear increase in strength as in comparison to other mixes.

From the above figure 3.3, it can be seen clearly that linear variation in strength gain was observed in M30 mix for both curing and irregular curing conditions. The strength built up walks hand in hand till the end of the curing period. Whereas M40 complement each other in the pace of strength built up starting from 7, 14 and ends at 28 days. The compressive strength of mixes (M30 & M40) was not found to be satisfying the nominal criteria of 7 days strength for both curing & irregular curing of concrete. As the days of curing & irregular curing conditions advances to 14 days a slight increase in strength was observed for M40 mix. But for M30 mix it nearly coincide with each other for curing conditions and irregular curing condition. Also it was observed that M30 mix under curing conditions and irregular curing condition shows simultaneous linear increase in strength as in comparison to other mixes. But as the curing reaches to 28 days, the target mean strength was not achieved by the mixes.

From the figure 3.4, graph plotted for 1.5% mix proportion for both mixes it can be seen clearly that 7 days strength calculated has come out to be lesser as per the 1/3rd mix proportion criteria . A slight increase in strength was observed after 14 days curing. But as the period of curing advances a sudden drop in strength was observed throughout. The compressive strength of M30 mix for irregular curing condition was notice to be satisfying the nominal criteria for 7 days strength which is 1/3rd of the mix proportion (65% of concrete grade) but the curing condition of M30 mixes give abnormal strength. For M40 mix, the 7days strength for curing condition is less than irregular curing condition. As the days of curing & exposure conditions advances to 14 days a slight increase in strength is observed for M40,but it is found to be little more than irregular curing condition for M30 grade. But as the curing reaches to 28 days, the gain in strength is observed which satisfies the target strength. Also it has been observed that M40 mix under regulated curing conditions shows linear increased in strength as in comparison to other mixes.

From the above figure 3.5, graph plotted for 2% fibre content, it is observed that the initial strength for 7 days was found to be unsatisfactory for some of the mixes (M30), whereas in case of M40 initial strength has just fulfilled the criteria. For total period of curing the strength gain does not shows a linear variation in both the mixes (M30 and M40). As the days of curing & irregular curing condition advances to 14 days a slight increase in strength was observed for irregular curing while curing conditions shows linear increase in strength. In M40, the curing and irregular curing condition the compressive strength was nearly satisfactory for 28 days.

3.2 Flexural strength for normal, 0.5%, 1%, 1.5%, 2% fibre mix (M30 & M40) subjected to control curing and irregular curing conditions for 28 days.

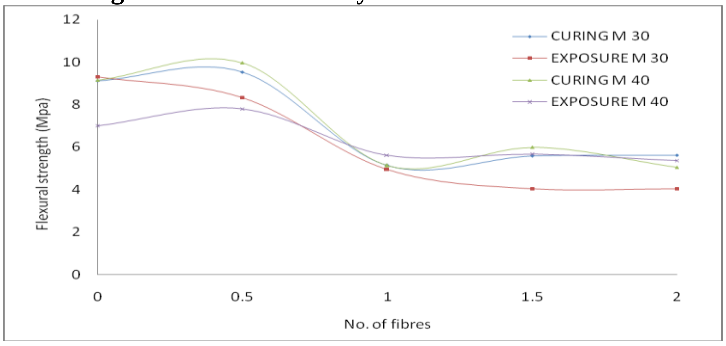

Figure 3.6:.Flexural strength for normal, 0.5%, 1%, 1.5%, 2% fibre mix M30 and M40

From above graph plotted for variation flexural strength of both mixed proportion (M30 & M40) with respect to varying fibres content (0%, 0.5, 1%, 1.5%, 2%) shows continuous drop of strength after 0.5% fibre content. Flexural strength has come out to be more only for 0.5% fibre content in both mixes and as the fibres content are increased the continuous drop was observed for increase fibre content. Hence we may conclude that the optimum value of fibre content is 0.5% for tensile strength in both mixes. Also the flexural strength of both mixes (M30 & M40) has found to be satisfying the maximum strength criteria i.e. 0.7√fck for 28 days curing and irregular condition.

IV. Effects of Curing

For analysing effect of curing Mix M30 and M40are used.

4.1 Compressive strength for normal, 0.5%, 1, %, 1.5%, 2 % fibre mixM30 & M40

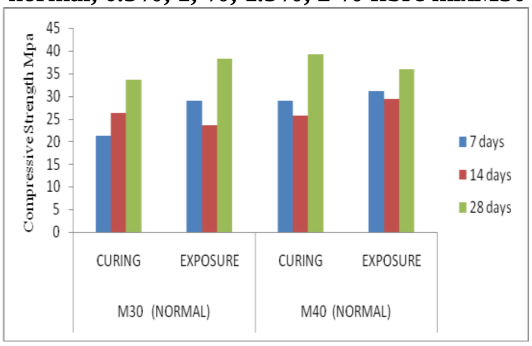

Figure 4.1: For normal mix M30 & M40

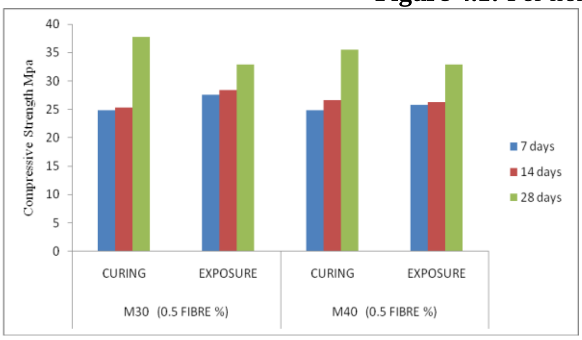

Figure 4.2: For 0.5 % fibre mix M30 & M40

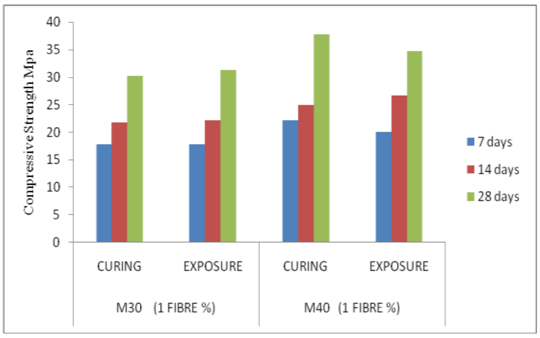

Figure 4.3: For 1 % fibre mix M30 & M40

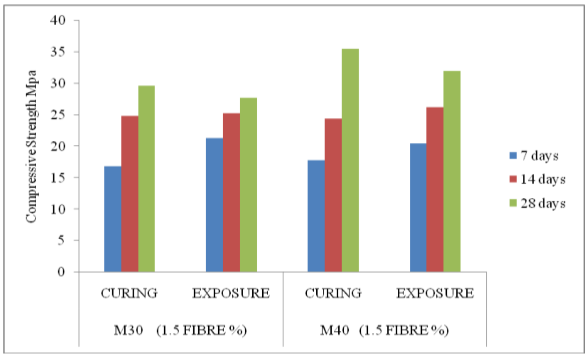

Figure 4.4: For 1.5 % fibre mix M30 & M40

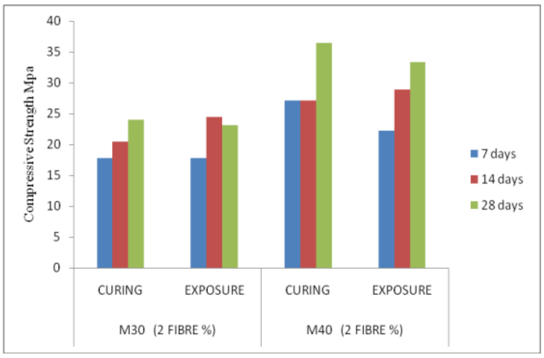

Figure 4.5: For 2 % fibre mix M30 & M40

From the above figure 4.1, it can be seen clearly that initial strength i.e. 7 days strength for both grade of concrete for curing condition was observed less than irregular curing condition. But at 14 days the strength for curing condition was observed more than irregular condition. Finally it was seen that i.e. 28 at the maximum strength was obtained for curing condition. So from this it was concluded that initially for irregular condition the strength may get more than curing condition but after the 28 days most strength was obtained for curing condition.

From the above figure 4.2, it can be clearly seen that for 7 days & 14 days strength for both grade of concrete for curing condition as well as irregular curing condition there is a linear variation in strength. Finally it was seen that for 28 days the maximum strength was obtained for curing condition for M30 grade of concrete and also for this volume contain of fiber (0.5%) the greatest compressive strength is obtained.

From the above figure 4.3, it has been seen that the compressive strength for M30 (1%fibre) grade of concrete at 7, 14 & 28 days for curing condition as well as for irregular curing condition was observed nearly same. For M40 grade of concrete compressive strength at 28 days for curing condition was more as compare to the irregular curing condition.

From the above figure 4.4, it has been seen that the compressive strength for M30 (1.5%fibre) grade of concrete at the 28 days for curing condition is getting more as compared to the irregular curing condition and also for M40 grade of concrete the compressive strength of curing condition is more than the strength of irregular curing condition.

From the above figure 4.5, plotted for 2% fibre content, it is observed that the initial strength for 7 days was found to be unsatisfactory for some of the mixes (M30), whereas in case of M40 initial strength has just fulfilled the criteria. As the days of curing & irregular curing condition advances to 14 days a slight increase in strength was observed for irregular curing while curing conditions shows linear increase in strength. In M40, the curing and irregular curing condition the compressive strength was nearly satisfactory for 28 days.

4.2 Tensile strength for normal, 0.5%, 1, %, 1.5%, 2 % fibre mixM30 & M40

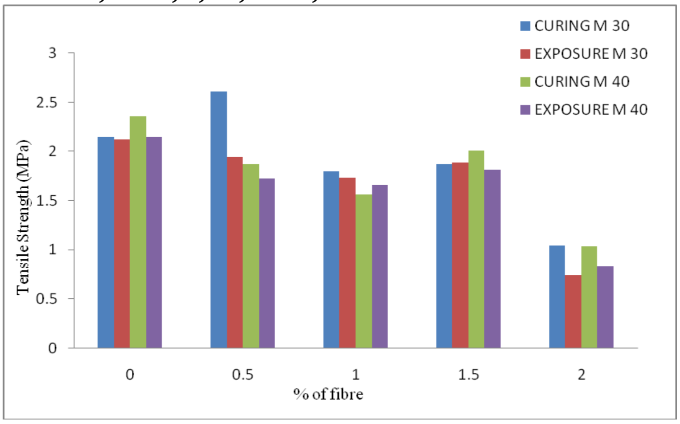

Figure 4.6: Tensile strength for normal, 0.5%, 1, %, 1.5%, 2 % fibre mix M30 & M40

From above bar graph plotted for variation tensile strength of both mixed proportion (M30 & M40) with respect to varying fibres content (0%, 0.5, 1%, 1.5%, 2%) shows continuous drop of strength after 0.5% fibre content. Tensile strength has come out to be more only for 0.5% fibre content in both mixes and as the fibres content are increased the continuous drop was observed for increase fibre content. Hence we may conclude that the optimum value of fibre content is 0.5% for tensile strength in both mixes.

4.3 Flexural strength for normal, 0.5%, 1%, 1.5%, 2 % fibre mix M30 & M40

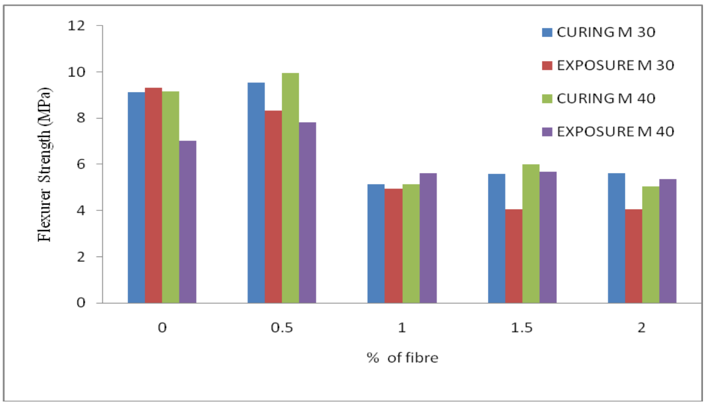

Figure 4.7: Flexural strength for normal, 0.5%, 1%, 1.5%, 2 % fibre mix M30 & M40

From above bar graph plotted for variation flexural strength of both mixed proportion (M30 & M40) with respect to varying fibres content (0%, 0.5, 1%, 1.5%, 2%) shows continuous drop of strength after 0.5% fibre content. Flexural strength has come out to be more only for 0.5% fibre content in both mixes and as the fibres content are increased the continuous drop was observed for increase fibre content. Hence we may conclude that the optimum value of fibre content is 0.5% for tensile strength in both mixes.

V. Conclusions

From the tests that I have performed I came to the following conclusions:

1. We have done different test on concrete for different conditions like control curing & irregular condition, from this it has been seen that for the irregular condition initially have more compressive strength than control curing condition but as the days advances it loses its strength or do not give satisfactory strength as compare to curing condition . Hence for a better strength we may conclude that the curing is an essential parameter.
2. The polypropylene fibers (PPF) reduce early age shrinkage and moisture loss of the concrete mix even when low volume fractions of PPF are used.
3. From the result of this research, it was found that the use of fiber in the concrete decreases the workability of the fresh concrete Evidence of low workability was shown through the results of workability test obtained in standard slump test. It was concluded that the increasing percentage volume of fiber added into the concrete would lead the workability decreased. High volume dosage rate above 1.0% showed that the concrete was significantly stiff and difficult to compact. However it also reduced the bleeding and segregation in the concrete mixture.
4. It was also seen that the loss in weight and loss/gain in compressive strength of the cube specimens improved with age. Compressive strength of concrete increases with increase in fiber dosage up to 0.5%, then it starts decreasing. So the optimum percentage fiber found from research is found out to be 0.5%.
5. In splitting tensile strength test, it was found that tensile strength was significantly improved only for 0.5% of fiber dosage and as the percentage of fiber volume dosage increases a continues drop of strength was observed.
6. In flexure strength the improvement in the behavior due to the addition of the PPF is the similar to that in tensile strength. Hence we may conclude that the optimum value of fibre content is 0.5% for both tensile strength and flexural strength.
7. As per the current demand of construction industry new types of concrete are to be invented, which will satisfy the problems observed in traditional concrete. In this approach PPFRC will be a good substitute to meet the present demand of construction industry.

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