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Experimental Study on the Mechanical Properties of Polypropylene Fibre Reinforced Self Compacting Concrete with Portland Slag Cement

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STRUCTURAL ENGINEERING

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ABSTRACT

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, where tensile strength is only approximately one tenth of its compressive strength. As a result for these characteristics, concrete member could not support such loads and stresses that usually take place on concrete beams and slabs. Historically, concrete member reinforced with continuous reinforcing bars to withstand tensile stresses and compensate for the lack of ductility and strength. Furthermore, steel reinforcement adopted to overcome high potential tensile stresses and shear stresses at critical location in concrete member. The inclusion of steel reinforcement significantly increases the strength of concrete, but to produce concrete with homogenous tensile properties, the development of micro cracks is a must to suppress. The introduction of fibres was brought in as a solution to develop concrete in view of enhancing its flexural and tensile strength. It is a new form of binder that could combine Portland cement in the bonding with cement matrices. Fibres are generally discontinuous, randomly distributed throughout the cement matrices. Fibre reinforced self-compacted concrete‟ (FRSCC) is formed from cement, various sizes of aggregates, which incorporate with discrete, discontinuous fibre

Self–compacting concrete (SCC) is the concrete that is able to flow under that is able to flow in the interior of the formwork, filling it in a natural manner and passing through the reinforcing bars and other obstacles, flowing and consolidating under the action of its own weight. These properties enable the SCC to be an excellent material for constructions with complicated shapes and congested reinforcement. One of the main advantages in using SCC is the minimization of skilled labour needed for placing and finishing the concrete. All these benefits decrease the costs and reduce the time of the building process over constructions made from traditionally vibrated concrete. However, hardened self-compacting concrete is still as brittle as normal concrete and has a poor resistance to crack growth.To improve the post-peak parameters of SCC, polypropylene (Recron fibres) are added.

As self-compacting concrete offers several economic and technical benfits the use of polypropylene, polyester and glass fibres extends its possibilities. Polypropylene fibres bridge cracks, retard their propagation, and improve several characteristics and properties of the SCC. The purpose of thesis is to investigate the effects of weight fraction of polypropylene on the compressive strength, split tensile strength, and modulus of elasticity of polypropylene fibre reinforced self-compacting concrete. For this purpose, Recron fibres were used. Four different fiber volumes were added to concrete mixes at 0.1, 0.2, 0.3and 0.4 percent by weight of cement. Four different mixes were prepared. After 28 days of curing, compressive strength, split tensile strength and modulus of elasticity were determined. It was found that, inclusion of polypropylene fibres significantly affect the compressive strength, split tensile strength and modulus of elasticity of self-compacting concrete.

CHAPTER - 1

INTRODUCTION

1.1 General Theory

Concrete is an artificial stone and its excellence resistance to compression resembles the properties of natural stone. It is a pseudo fluid for a part of its early age. It's Strength and other properties can be regulated to some extent during its manufacture. The key to achieving a strong, durable concrete rests in the careful proportioning and mixing of the ingredients. Portland cement's chemistry comes to life in the presence of water. Cement and water form a paste that coats each particle of stone and sand the aggregates. Through a chemical reaction called hydration, the cement paste hardens and gains strength.

The quality of the paste determines the character of the concrete. The strength of the paste, in turn, depends on the ratio of water to cement. The water-cement ratio is the weight of the mixing water divided by the weight of the cement. High-quality concrete is produced by lowering the water-cement ratio as much as possible without sacrificing the workability of fresh concrete, allowing it to be properly placed, consolidated, and cured.

A mixture that does not have enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough surfaces and porous concrete. A mixture with an excess of cement paste will be easy to place and will produce a smooth surface; however, the resulting concrete is not cost effective and can more easily crack. A properly designed mixture possesses the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Typically, a mix is about 10 to 15 percent cement, 60 to 75 percent aggregate and 15 to 20 percent water. Entrained air in many concrete mixes may also take up another 5 to 8 percent. The approximate percentages of the nominal mix are as shown in fig.1.1

The longer the concrete is kept moist, the stronger and more durable it will become. The rate of hardening depends upon the composition and fineness of the cement, the mix proportions, and the moisture and temperature conditions. Concrete continues to get stronger as it gets older. Most of the hydration and strength gain take place within the first month of concrete's life cycle, but hydration continues at a slower rate for many years.

Fig.1.1 Proportions of ingredients of Nominal concrete mix

The durability of concrete is ability to withstand the environmental conditions to which it is exposed. It is necessary to emphasize durability in the construction of structures. Hence either in early stage of concrete or after some years some aspects will influence the concrete. Main requirements of durability are:

- An upper limit to the w/c ratio without lowering flow.

- Good compaction with a lower limit of cement content.

When large quantities of heavy reinforcement is to be placed in a member it is difficult to ensure that the formwork gets completely filled by concrete without voids or honeycombs. Compaction by mechanical vibrator is very difficult in this situation. Such problems can be avoided using self-compacting concrete.

Self-compacting concrete describes a concrete with ability to compact itself by means of it weight without requirement of vibration. It is placed in the same way as ordinary concrete without vibration. It is very fluid and can pass through passed around obstructions and fill all round and corners of the structure which saves labour time and energy. It gives placement efficiency of 300% and labour can be reduced by 70%. The guiding principle involved in this self-compacting concrete is that sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exists. The difference in ingredients of SCC and nominal mix in terms of proportions are shown in fig.1.2. SSC is an increasingly attractive choice for optimizing site man power(by lowering skill power), allowing safer working environment.

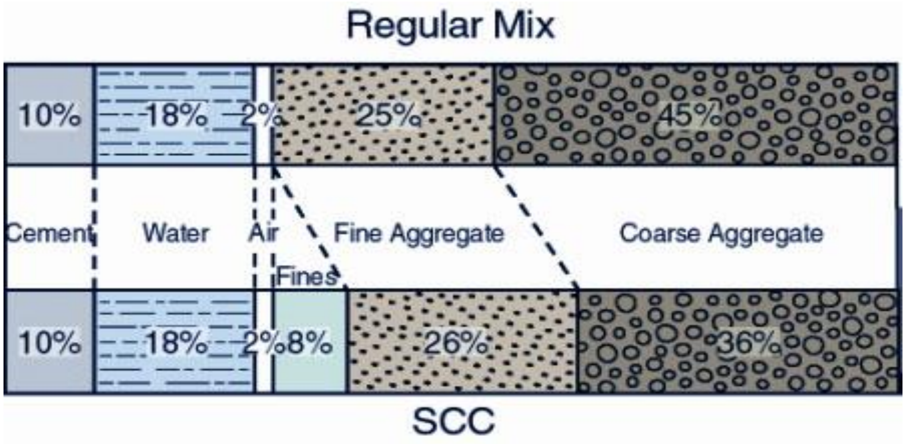

Fig.1.2 Difference between Nominal mix and SCC

SSC allows easier pumping, flows into complex shapes, minimizes voids to produce a high degree of homogenity and uniformity. Hence SCC allows for denser reinforcement, optimized sections. Two important properties specific to SCC in its plastic state are its flow ability and stability. The high flow ability of SCC is generally attained by using high range water reducing (HRWR) admixtures and not by adding extra mixing water.

The stability or resistance to segregation of the plastic concrete mixture is attained by increasing the total quantity of fines in the concrete and/or by using admixtures that modify the viscosity of the mixture. Increased fines contents can be achieved by increasing the content of cementitious materials or by incorporating mineral fines

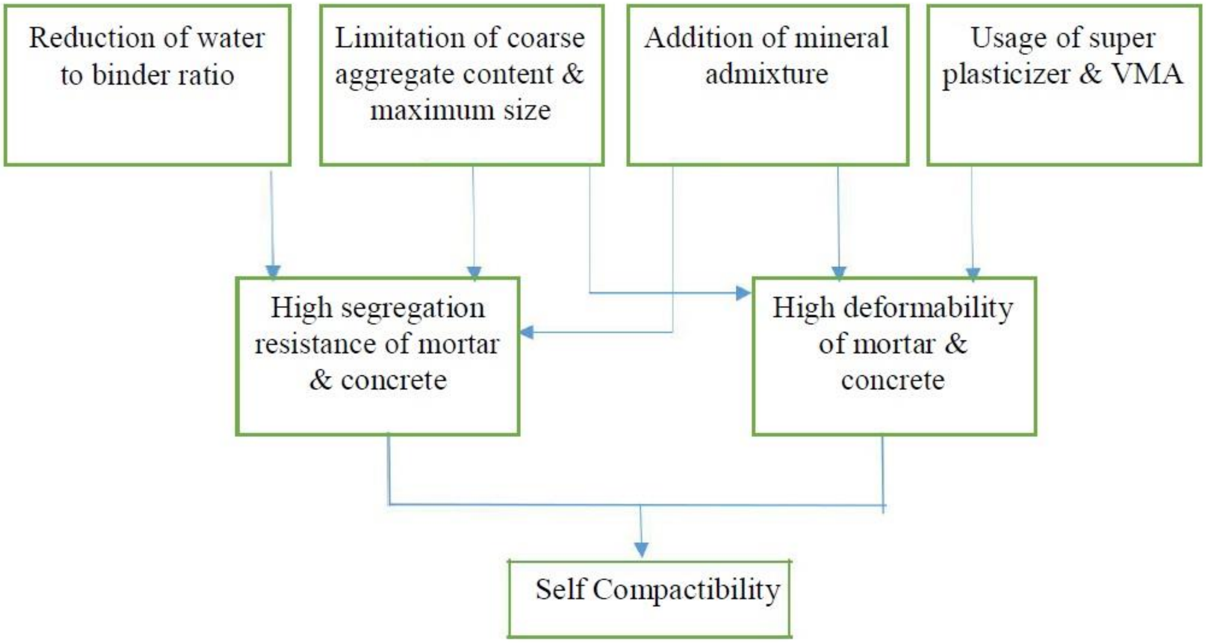

Fig.1.3 Flow chart for achieving Self Compactibility

Control of aggregate moisture content is also critical to producing a good mixture. SCC mixtures typically have a higher paste volume, less coarse aggregate, and higher sand to coarse aggregate ratio than typical concrete mixtures. Fig.1.3 shows a flow chart which indicates the steps to achieve the self Compactibility. SCC mixtures can be designed to provide the required hardened concrete properties for an application, similar to regular concrete. If the SCC mixture is designed to have a higher paste content or fines compared to conventional concrete, an increase in shrinkage may occur.

Regular concrete with vibration:

Self-Consolidating Concrete:

Fig.1.4 Comparison between Regular concrete with Vibration and SCC

1.1.1 Applications of SCC in Present Use

- The highest use of SCC was done at Delhi Metro project, about $10000m^3$ was used.
- Burj Khalifa, the tallest building in the world, used the SCC throughout the building.
- The Kesar Solitaire, a land mark in Palm Beach Road in Navi Mumbai, used M40 grade SCC for the triple basement structure, which was 10 meters below the ground level.
- Arianda airport in the Sweden used the SCC to avoid nuisance of vibration so that they can work in night.
- The MAXXI, National Museum of the 21st Century Arts in Rome, is composed of curved side walls made in SCC.

1.1.2 Advantages of SCC

- Improved constructability
- Bond to reinforced steel
- Flows into complex forms

- Minimizes voids on highly reinforced areas
- Produces superior surface finishes as shown in fig 1.4
- Lowering noise levels produced by mechanical vibrators
- Reduces skilled labour

1.2 Materials

The constituent materials should be selected to satisfy technical and health and safety criteria. Strength requirements as well as any other requirements concerning mechanical characteristics, thickness, shape, finishing, etc. should be described.

1.2.1 Cement

The type and content of cement should be selected to meet the specified requirements for concrete strength and durability. The cement content should be normally between 350 and 450 kg/m^3. Cement should be fresh and stored in a dry area and/or in a suitable silo.

1.2.2 Aggregates

The quality of the aggregates is of major importance, in relation to the performance of both the fresh and the hardened concrete. Their angular shape may adversely influence the pump ability of the fresh concrete. The moisture content should be taken into consideration when determining the water demand of the concrete mix. It is observed from the studies that self-compacting concrete is achievable at lower cement content when round aggregates are used in comparison with angular aggregates.

1.2.3 Admixtures

The organic substances or combinations of organic and inorganic substances, which allow a reduction in water content for the given workability, or give a higher workability at the same water content, are termed as plasticizing admixtures. A good plasticizer fluidizes the mortar or concrete in a different manner than that of the air entraining agents. Some of the plasticizers, while improving the workability entrains air also. Super plasticizers are more powerful agents dispersing agents and hence as high water reducers. Plasticizers and retarders should be checked regularly or as required, for setting time, water reduction and development of strength as compared with the reference concrete. Acrylic polymers and polycarboxylate ethers are effective at lower dosages compared to sulfonated condensates.

1.2.4 Fibres

Plain concrete possess a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. Although every type of fibre has been tried out in concrete not all of them can be effectively and economically used. Steel fibre is the one of the most commonly used fibre which improves flexural impact and fatigue strength of concrete. Polypropylene is good and increasing impact strength unlike that of flexural strength. Carbon fibres makes the concrete high modulus of elasticity and flexural strength.

1.2.4.1 Recron3S fibres

Concrete is widely recognized as a cost-effective, versatile construction material. Yet it is also best with a number of drawbacks that are inherent to its composition. By generally accepted engineering standards, concrete is relatively brittle and lacks flexural strength. Intertwined with these problems is concrete’s propensity to crack in both its plastic (early-age) and hardened (long-term) state. Early-age cracks are microscopic fissures caused by the intrinsic stresses created when the concrete settles and shrinks over the first 24 hours after being placed. Long-term cracking is in part caused by the shrinkage that transpires over the months, perhaps years, of drying that follow. In either case, these cracks can jeopardize the overall integrity of the concrete and not allow it to maintain – or possibly ever attain – its maximum performance capability.

Recron3S Fibre Reinforcement Systems can provide a solution to Recron fibres are engineered micro fibres with a unique "triangular" cross-section, used in secondary reinforcement of concrete. It complements structural steel in enhancing concrete's resistance to shrinkage cracking and improves mechanical properties such as flexural/split tensile and transverse strengths of concrete along with the desired improvement in abrasion and impact strengths. The Recron Polypropylene fibres are as shown in fig.1.5.

Fig.1.5 Polypropylene Fibres

1.2.4.2 Advantages of Recron3S fibres

- improves resistance to plastic & drying shrinkage cracking
- inhibits growth of cracks-bridges micro-cracks and provides stability to concrete
- improves flexural toughness/increases split tensile strength
- enhances abrasion resistance and increases absorption of concrete thereby improving impact resistance

- acts as a pumping aid in making concrete more homogenous
- reduces surface water absorption/permeability in concrete
- improves durability and enhances longevity of concrete structure

1.3 Necessity of the work

For several years the problem of durability was a major topic of interest. One solution to overcome this problem is to switch over ordinary concreting methods to self-compaction concrete which can be compacted to every corner of formwork without the means of vibrator.

1.4 Objective of Present Work

The main objective of the present work is to study the workability and mechanical properties of self-compacting concrete by adding different percentages of Recron fibres by weight of cement.

CHAPTER - 2

LITERATURE REVIEW

2.1 Introduction

This chapter deals with literature review concerning with the work done by different authors with regard to Polyester fibres and self-compacting concrete. Few of them are mentioned below:

2.2 Literature survey

Shrikant M. Harle (2014) said that concrete is most widely used construction material in the world. Nowadays the world is witnessing the construction of more and more challenging and difficult Engineering structures. So, the concrete need to possess very high strength and sufficient workability. Researchers all over the world are developing high performance concrete by adding various fibers, admixtures in different proportions. Various fibers like glass, carbon, Poly propylene and aramid fibers provide improvement in concrete properties like tensile strength, fatigue characteristic, durability, shrinkage, impact, erosion resistance and serviceability of concrete. Because of such characteristics Fiber Reinforced Concrete has found many applications in civil engineering field. Glass Fiber Reinforced Concrete (GFRC) is a recent introduction in the field of concrete technology. GFRC has advantage of being light weight, high compressive strength and flexural strength. To improve the long term durability an Alkali resistance glass fiber reinforced concrete is also invented. The aim of the work is to study the properties of the effect of glass fibers as reinforcement in the concrete for different proportions from the research work which is already carried out by the researchers

C Selin Ravikumar and T S Thandavamoorthy (2013) over the decades, there has been a significant increase in the use of fibres in concrete for improving its properties such as tensile strength and ductility. The fibre concrete is also used in retrofitting existing concrete structures. Among many different types of fibres available today, glass fibre is a recent introduction in the field of concrete technology. Glass fibre has the advantages of having higher tensile strength and fire resistant properties, thus reducing the loss of damage during fire accident of concrete structures. In this investigation glass fibres of 450 mm length are added to the concrete by volume fraction of up to 1% to determine its strength and fire resistant characteristics. Comparison of the strength and fire-resistance performance of conventional concrete and glass fibre concrete was made. The paper presents the details of the experimental investigations and the conclusions drawn there from.

Grover Rakesh(2013) given comparative study of polypropylene fibre reinforced silica fume concrete with plain cement concrete showing that Silica fume appeared to have an adverse effect on the workability of fibre concrete. Concretes PF0S0 to PF0.6S15 having different flexural strength could be prepared by different combination of cement, polypropylene fibre and silica fume with keeping the aggregate and super plasticizer content constant. It is observed from slump test results of PF0S0 to PF0.6S15 that there is continuous decrease in workability of concrete with increase in polypropylene fibre content. The increase in flexural strength was found to be around 40% with the use of polypropylene and silica fume compared to the reference c─oncrete. Flexural strength was found out to be optimum for a mix of 0.4% PP and 10% SF. Silica fume has no significant effect on flexural strength of concrete.

Kolli.Ramujee (2013) noticed the Reduction of slump with increase in fibre content, especially beyond 1.5% dosage, the mix becomes fibrous which results in difficulty in handling. The Compressive strength and splitting tensile strength tests reveals that, the strengths were increased proportionately with the increase in volume ratios of Polypropylene Fibres with reference to the controlled mix without fibres. The maximum increase in Compressive strength was 34% and split tensile strength was 40% compared to the mix without fibres. The samples with fibres content of 1.5 % showed optimum results in Comparison with other samples.

K.Murahari, Rama mohan Rao P (2013) studied the effects of polypropylene fibers on the strength properties of fly ash based concrete, Compressive strength of concrete increases gradually by addition of Polypropylene fiber from 0.15% to 0.30%. There is increase in compressive strength as compared with normal plain concrete (without fibers) Splitting tensile strength of concrete increases gradually by addition of Polypropylene fiber from 0.15% to 0.30%. There is increase in splitting tensile strength as compared with normal plain concrete (without fibers). Flexural test of concrete gradually increases with the addition of Polypropylene fiber. There is increase in Flexural test as compared with normal plain concrete (without fibers).

Indrajit Patel, C D Modhera(2011) studied the effect of polyester fibres on engineering properties of high volume fly ash concrete as The compressive strength gaining is comparatively slower at 3 and 7 days for all mix particularly for high 60% of fly ash and higher mix M35 and M40. Targeted values at 7 days for plain HVFA concrete is of the 72% to 78% which is as better as normal concrete without fly ash. Beyond 7 days the increase in strength is of order 65 to 76% and all mix shows satisfactory values at age of 28 days. Inclusion of fibre at the rate of 0.25%
by mass of the cementitious material does not have much effect on the w/c ratio and 60 min. slump values as well. For higher proportion of cementing material in higher concrete grade the dosage of plasticizer was increased to 1.00% to achieve desired slump and workability. Increase in compressive strength at 7 days age for all mix with fibre varies between 7.00 to 9.50% Increase in 28 days compressive strength as compared to plain HVFA concrete is of the order 9.75 to 15 %. All sample shows required flexural strength at 14, 28 and 56 days age. Increase in strength between 14 to 28 days is of order 22 to 30% and 28 to 56 days is 7.50 to 13.5%. 55% cement replacement shows optimum gain of compressive and flexural strength for all grade of plain and fibre reinforced HVFA concrete. With considerable reduction in cost of cementing material and including marginal proportion of polyester fibre strong and durable eco-friendly concrete can be produced and applied in the construction sectors like pavement, foundations, mass concrete and gravity structures.

B. Krishna Rao et. al. (2009) proved that Self-compacting concrete (SCC) offers several economic and technical benefits; the use of steel fibers extends its possibilities. Steel fibers acts as a bridge to retard their cracks propagation, and improve several characteristics and properties of the concrete. Fibers are known to significantly affect the workability of concrete. Therefore, an investigation was performed to compare the properties of plain normal compacting concrete (NCC) and SCC with steel fiber. Ten SCC mixtures and one NCC were investigated in this study. The content of the cementitious materials was maintained constant (600 kg/m3), while the water/cementitious material ratio is kept constant

0.31. The self-compacting mixtures had a cement replacement of 35% by weight of Class F fly ash. The variables in this study were aspect ratio (0, 15, 25 and 35) and percentage of volume fraction (0, 0.5, 1.0 and 1.5) of steel fibers. Slump flow time and diameter, J-Ring, V-funnel, and L-Box were performed to assess the fresh properties of the concrete. Compressive strength, splitting tensile strength and flexural strength of the concrete were determined for the hardened properties. A marginal improvement in the ultimate strength was observed. The addition of fiber enhanced the ductility significantly. The optimum volume fraction (V) and aspect ratio (A) of fiber for better performance in terms of strength was found to be 1.0 percent and 25. The results indicated that high-volume of fly ash can be used to produce Steel fiber reinforced self-compacting concrete, even though there is some increase in the concrete strength because of the use of steel fiber and high-volume of fly ash.

D.L. Shah and C.D. Modhere, Ph.D. (2009) studied the Influence of Steel and Polyester Fibres in the Self-Compacting Concrete. The workability requirements for successful placement of SCC necessitate that the concrete exhibits excellent deformability and proper stability to flow under its own weight without segregation and blockage. It was observed that there were no problems in mixing of SCC with 0.5% hooked end steel fibres and 0.1% polyester fibres. The fibres distribution was uniform. However, SCSFRC mix exceeded the upper limits suggested by EFNARC. All mixtures had a good flow ability and possessed self-compact ability characteristics. In conclusion, the fibre length, geometry and dosage play an important role in SCC. In hardened state, polyester fibres did not increased strengths much but reduce micro cracks, and crack propagations. SCC with hooked end steel fibres increased compressive strength 25 %, tensile strength 40% and flexural strength 65 % at 28 days. To use the advantages of SCFRC efficiently, all parameters affecting the properties of concrete in respect of the production and the durability of concrete structures should exactly be known. In this way SCFRC can be designed optimally. Finally, it was found that a considerable amount of fibres allowed in self-compacting concrete.

Hajime Okamura and Masahiro Ouchi (2003) given a rational mix design method and an appropriate acceptance testing method at the job site have both largely been established for self-compacting concrete can be considered to have been solved. The next task is to promote the rapid diffusion of the techniques for the production of self-compacting concrete and its use in construction. Rational training and qualification systems for engineers should also be established. In addition, new structural design and construction systems making full use of self-compacting concrete should be introduced.

Nan-Su et al. (2001) proposed a new mix design method for self-compacting concrete. In this method first the amount of aggregates required is determined and the paste of binders is then filled into the voids of aggregates to ensure that the concrete thus obtained has flow ability. The principle consideration of the proposed method is to fill the paste of binders into voids of the aggregate frame work piled loosely. The amount of aggregates, binders, mixing water as well as the quality and type of super plasticizer are the major factors which influence the SCC. Compared to the method developed by the Japan ready-mix concrete association, this method is simpler, easier and less time consuming requires less amount of binder and hence reducing the cost.

Seyed Hamed Ahmadipourinaeim and Younes Saberi (2000) studied the properties of polypropylene fibres, the use of fibre reinforced high-strength concrete to eliminate some defects have been increased. Moreover, the addition of small amounts of polypropylene fibres to concrete improvements its mechanical properties. Due to the high tensile strength of these fibres we can improve the capacity of the concrete and control the volume changes with the lapse of time compressive strength. According to the results, fibres, with the equivalent weight and different length have different strength verses the pressure. The presence of fibres in concrete improves heat resistance and prevents the destruction of the structure due to water vapour pressure.

CHAPTER – 3

METHODOLOGY

Self-compacting concrete is the current research area today. The present study is utilization of Portland Slag cement with chemical admixtures. Therefore an attempt was made to investigate the mechanical properties of self-compacting using the Portland Slag Cement and adding various percentages of Recron Polypropylene fibre. Each category of mix contains 4 mixes like PP01, PP02, PP03, and PP04.

The essential components of SCC is superplasticizer. It is to be ensure that dosage is sufficient to make the concrete flow under its own weight. Several trial mixes were conducted to determine the optimum dosage of SP in order to achieve the required properties. Fresh concrete properties were investigated and hardened concrete tests such as compressive strength for cube on 150×150×150 in mm, and split tensile strength for cylinders of size 150×300 mm were casted and tested for 7, 14 and 28 days.

The following specimens were casted for hardened concrete tests:

Number of cubes casted for compressive strength tests = 30 samples

Number of cylinders casted for split tensile strength and Young’s modulus tests = 30 samples

Total number of samples = 60 samples

CHAPTER – 4

EXPERIMENTAL INVESTIGATION

4.1 Introduction

This chapter deals with the experimental programme particulars. The materials used, concrete mix details, mixing procedure, casting, curing, and testing procedures are explained.

4.2 Materials

The specifications and properties of various materials used in the preparation of test specimens are as follows:

4.2.1 Cement

The cement used is the Portland Slag Cement which has similar properties that of ordinary Portland cement which has addition features like low heat of hydration and better resistant to chlorides. In this experiment ACC Portland Slag cement was used conforming to IS: 455-1989. The properties of the cement are as follows:

- Specific gravity : 2.92
- Standard consistency : 32%
- Initial setting time : 135 min
- Final setting time : 230 min
- Fineness of cement : 0.5%

4.2.2 Fine aggregate

The fine aggregate used in the present experiment is from Godavari river which is zone II conforming to IS: 383 -1970. The properties of the sand are as follows:

- Grade of sand : Zone II
- Specific gravity : 2.65
- Loose Bulk Density : 1508 kg/m^3

- Fineness Modulus : 2.67

The sieve analysis results are tabulated in table 4.1 and the particle size distribution are shown in fig.4.1

S.No.	IS Sieve Size	Weight Retained gm	Percentage Weight Retained	Cumulative Percentage Retained	Percentage Passing
1	4.75mm	10	1	1	99
2	2.36mm	45	4.5	5.5	94.5
3	1.18mm	175	17.5	23	77
4	600µm	260	26	49	51
5	300 µm	395	39.5	88.5	11.5
6	150 µm	115	11.5	100	0
Total		1000	FM	2.67	

Table 4.1 Sieve Analysis of Fine Aggregate

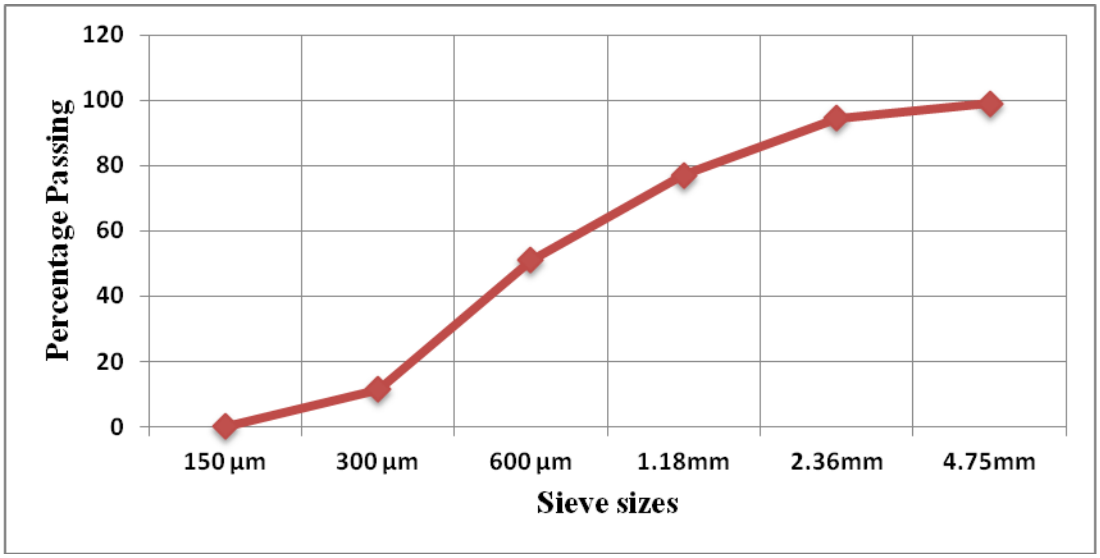

Fig. 4.1. Particle Size Distribution of Sand

4.2.3 Coarse aggregate:

The coarse aggregate used was from an established quarry satisfying the requirements of IS: 383-1970. In this mix the aggregate used a mixture of 60% by weight of total weight aggregates of 10mm sieve passing and 40% by weight of 10mm retained. The maximum size of aggregate used was 12.5 mm. Sieve analysis values are presented in table 4.2. The properties are as follows:

Specific gravity	:	2.78
Loose Bulk Density	:	1435 kg/m^3
Fineness Modulus	:	5.33

S.No.	IS Sieve Size	Weight retained gm	Percentage weight retained	Cumulative percentage retained	Percentage of fines
1	80 mm	0	0.00	0.00	100.00
2	40 mm	0	0.00	0.00	100.00
3	20 mm	0	0.00	0.00	100.00
4	10 mm	1.601	32.76	32.76	67.24
5	4.75 mm	3.286	67.24	100.00	0.00
6	2.36 mm	0	0.00	100.00	0.00
7	1.18 mm	0	0.00	100.00	0.00
8	600 µm	0	0.00	100.00	0.00
9	300 µm	0	0.00	100.00	0.00

Table 4.2 Sieve Analysis of Coarse Aggregates

Fineness modulus = (∑ cumulative percent retained)/ 100 = 532.76/100 = 5.3276

Fineness modulus = 5.33

4.2.4 Water

Water used for mixing is conforming to IS: 456- 2000 which is clean and free from injurious amounts of oils, acids, salts or any other foreign material which causes deterioration of steel or concrete

4.2.5 Super Plasticizer

Super plasticizer constitute a relatively new category and improved version of plasticizers which are chemically different from normal plasticizers. Use of super plasticizer reduces the water content up to 30 %. These are water soluble added to control primarily the flow and setting of the concrete.

In this procedure the chemical admixture used was MASTER GLENIUM SKY 8784. It is the super plasticizer based on second generation polycarboxylic ether polymers, developed by nanotechnology. The properties of the super plasticizer are as follows:

- Aspect : Light brown liquid
- Relative density : 1.10 +/- 0.01 at 25^0 C
- pH : >6
- Chloride ion content : <0.2%

4.2.6 Secondary Reinforcements

Ordinary concrete may not meet the long term requirements of large scale. Repeated stress, temperature variation and corrosion make them brittle, lacking tension and developing cracks. A secondary reinforcement additive that toughens and strengths the concrete, while helping resist shrinkage and cracking. It also bonds better with the mix, due to its dimensional stability. In this experiment RECRON fibres made by Reliance Industries in which Polypropylene fibres have been used. The properties are given in table 4.3.

S.No.	Properties	Polypropylene
1.	Shape	Triangular
2.	Cut length	6mm
3.	Effective Diameter	25-40µ
4.	Specific gravity	0.90-0.91
5.	Melting point	160-165^{0}C
6.	Elongation	60-90%
7.	Young’s modulus	>4000 MPa

Table 4.3 Properties of Polypropylene Fibre

4.3 EXPERIMENTAL SETUP

4.3.1 Mixture proportions

The concrete mixture proportions are given in Table 5.1. The mixture proportions were calculated by using the guidelines of EFNARC 2005 and using Nan-Su method without Polypropylene as additive. The water binder ratio for all the mixes was kept constant at 0.35. Several trail mixes were conducted to determine the optimum dosage of super plasticizer in order to achieve the required self-compacting properties as per EFNARC standards. The dosage of super plasticizer was carefully selected as over dosage may induce bleeding and strength retardation.

4.3.2 Mixing procedure

Mixing of ingredients in pan mixer with the maximum capacity of 80 litres. The materials were fed into the mixture in the order of coarse aggregate, sand and PSC. The materials were mixed in dry condition for 1.5 minutes. Subsequently three quarters of water was added with Polypropylene followed by the super plasticizer and the remaining water while mixing continued for 6 minutes in order to obtain homogeneous mixture. Upon discharging from the mixture the self-compatibility tests were conducted on the fresh properties of each mixture. The fresh concrete was placed into steel cubes, cylinders and prism moulds then compacted without vibration. Finally surface finishing was done carefully to obtain a uniform smooth surface.

4.3.3 Casting

The cubical specimens of standard size 150mm*150mm*150mm were casted for compressive strength and tested for 7, 14 and 28 days. The cylindrical specimens of standard size 150mm diameter and 300mm height were casted for split tensile strength test for 7, 14 and 28 days and Young's modulus test for 28 days.

Following specimens were casted for hardened concrete tests:
Number of cubes casted for compressive strength tests =30 samples
Number of cylinders casted for split tensile strength and Young's modulus tests=30 samples
Total number of samples = 60 samples

4.3.4 CURING

After casting, all specimens were covered with plastic sheets and water saturated burlap and left at room temperature for 24 hours. The specimens were demoulded after 24 hours and placed in curing tank filled with water at 27^{0}C until the tests were carried out at 7,14 and 28 days respectively.

4.3.5 TESTING

4.3.5.1 Fresh concrete test

Slump flow test is the one which is used to measure the flow ability in the absence of obstructions. It does not measure all factors contributing to workability nor is it always representative of the placability of the concrete. However it is used conveniently as a control test and give indication of the uniformity of concrete. The higher the flow value the greater its ability to fill form work under its own weight. Fig.4.2 depicts the procedure to measure the slump flow value in laboratory. Also the time required for concrete to reach 500 mm mark, known as T50 time can also be measured.

Fig. 4.2 Slump Flow test of SCC Mix

4.3.5.2 Hardened concrete

One of the purposes of testing hardened concrete is to confirm that the concrete used at site has developed the required strength. The results of the test on hardened concrete helps to reveal the quality of concrete. Tests are made by casting cubes or cylinder from the concrete.

4.3.5.2.1 Compression Test

It is the most common test conducted on hardened concrete because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. Tests shall be carried at recognized ages of the test specimens, the most being 7, 14 and 28 days. The cubes are placed in the machine such that load shall be applied to opposite sides of cast. Fig.4.3 shows the testing process of a cube of size 150mm in compression testing machine.

The load shall be applied at rate of 140 kg/sq. cm/min.

$$\text{Compressive strength} = \frac{P}{A}$$

Where A is the cross section of cube

Fig 4.3 Testing of Cubes – Compressive Strength

4.3.5.2.2 Split Tensile Test

Concrete is not normally designed to resist direct tension. However tensile stress do develop in concrete members as a result of flexure, shrinkage and temperature changes. It is very difficult to perform a direct tension test on a concrete specimen as it requires a purely axial tensile force is to be applied. Hence indirect tension test are used usually cylinder split tensile strength. In this test a standard plain concrete cylinder is loaded in compression on its side along a diametral plane as shown in fig.4.4 and the failure occurs by splitting of the cylinder along the loaded plane. The tensile strength fcr is obtained as:

$$fcr = \frac{2P}{\pi dl}$$

Where P is the maximum load, d is the diameter and l is the length of the cylinder.

Fig.4.4 Testing of Cylinders- Split Tensile strength

4.3.5.2.3 Elastic modulus Test

The modulus of elasticity, denoted as E, is defined as the ratio between normal stresses to strain below the proportional limit of concrete specimen. When concrete is subjected to loading, it exhibits a linear stress-strain relationship in the elastic range. The elastic limit is “the greatest stress which a material is capable of sustaining without any deviation from proportionality of stress to strain (Hook’s law).”

The test specimens consist of concrete cylinders 150 mm in diameter and 300 mm long. The specimen is tested at the age of 28 days. The longitudinal compress meter is mounted on the cylinder specimen such that measuring positions shall be equally spaced around the circumference of the cylinder close to the mid height. A typical cylinder specimen being tested was shown in fig.4.5.They should not fall within D/2 of the cylinder ends, where D is the diameter. The cylinder along with longitudinal compress meter shall be kept on the lower disc of the compression testing machine. The axis of the cylinder shall be aligned with the centre of the thrust of the spherical seat.

Fig 4.5 Testing of Cylinders-Modulus of Elasticity

Load on the specimen shall be applied continuously at a rate of 140 kg/sq.cm/min and is measured frequently at evenly spaced intervals of the longitudinal compress meter. Axial deformations or strains are determined from the data obtained by longitudinal compress meter. Stress is obtained by calculating load for area.

$$\text{Young's modulus, } E = \frac{\text{Stress},\sigma}{\text{Strain},\varepsilon}$$

CHAPTER - 5

RESULTS & DISCUSSIONS

5.1 Introduction

In this chapter the results based on experimental work are presented in tables and the results were discussed. The details of mix proportions per cum are given in table 5.1 as follows:

S.No.	CONSTITUENTS	PP00	PP01	PP02	PP03	PP04
1	Cement	495	495	495	495	495
2	Coarse aggregate	792.15	792.15	792.15	792.15	792.15
3	Fine aggregate	975.15	975.15	975.15	975.15	975.15
4	Water	158.4	158.4	158.4	158.4	158.4
5	SP	3.96	3.96	3.96	3.96	3.96
6	Polypropylene	0	0.495	0.99	1.485	1.98

Table 5.1 Details of Mix Proportions in kg/m^3

5.2 Slump Flow

The slump flow values for various percentages of Polypropylene are shown in table 5.2 and a graph showing the slump flow vs percentage is shown in fig.5.1

S.No.	% of Polypropylene	Slump value in mm
1	0	610
2	0.1	570
3	0.2	530

4	0.3	495
5	0.4	490

Table 5.2 Slump Flow results for Percentages of Polypropylene

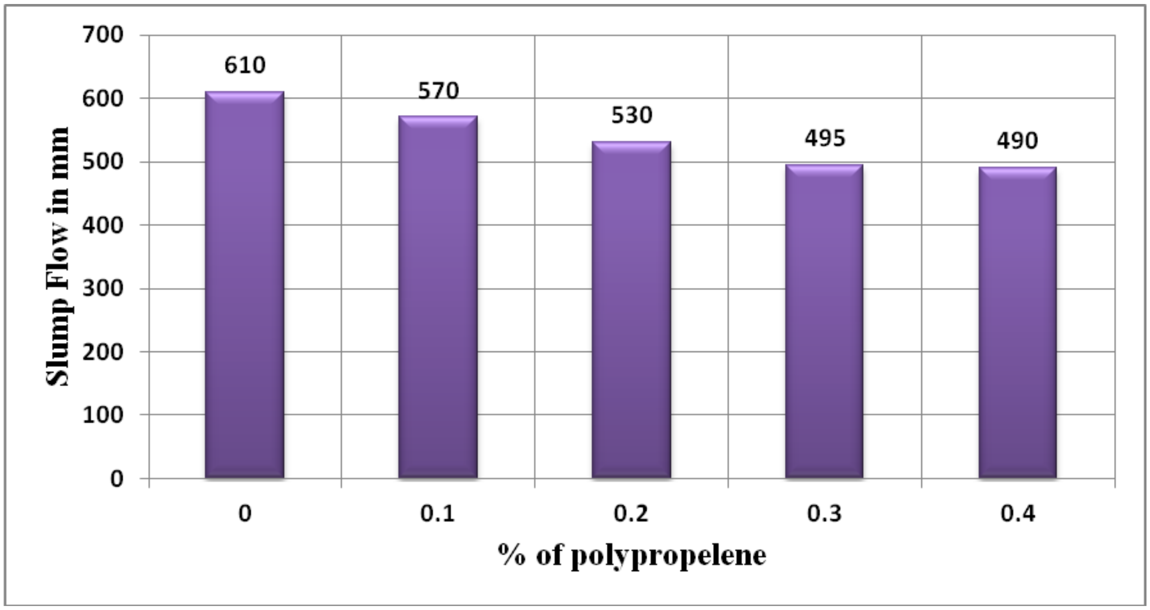

Fig.5.1 Slump Flow Vs % of Polypropylene

5.3 Mechanical properties

5.3.1 Compressive Strength of concrete

The cubes are casted with different percentages of Polypropylene and the same are tested in compression testing machine. The strength values of cubes with various percentages are shown in table 5.3 below.

S.No	Sample Designation	% of Polypropy Lene	7 days strength MPa	14 days strength MPa	28 days strength MPa	Ratio of 7 days to 28 days strength	Ratio of 14 days to 28 days strength

1	PP00	0	41.63	45.21	55.56	0.749	0.813
2	PP01	0.1	34.444	44.44	48.41	0.712	0.918
3	PP02	0.2	28.222	34.44	38	0.746	0.906
4	PP03	0.3	26	26.889	30.222	0.858	0.891
5	PP04	0.4	32	37.556	38.92	0.823	0.965

Table 5.3 Compressive Strength results

The graphs were drawn showing variation of strength against % of Polypropylene in figs. below.

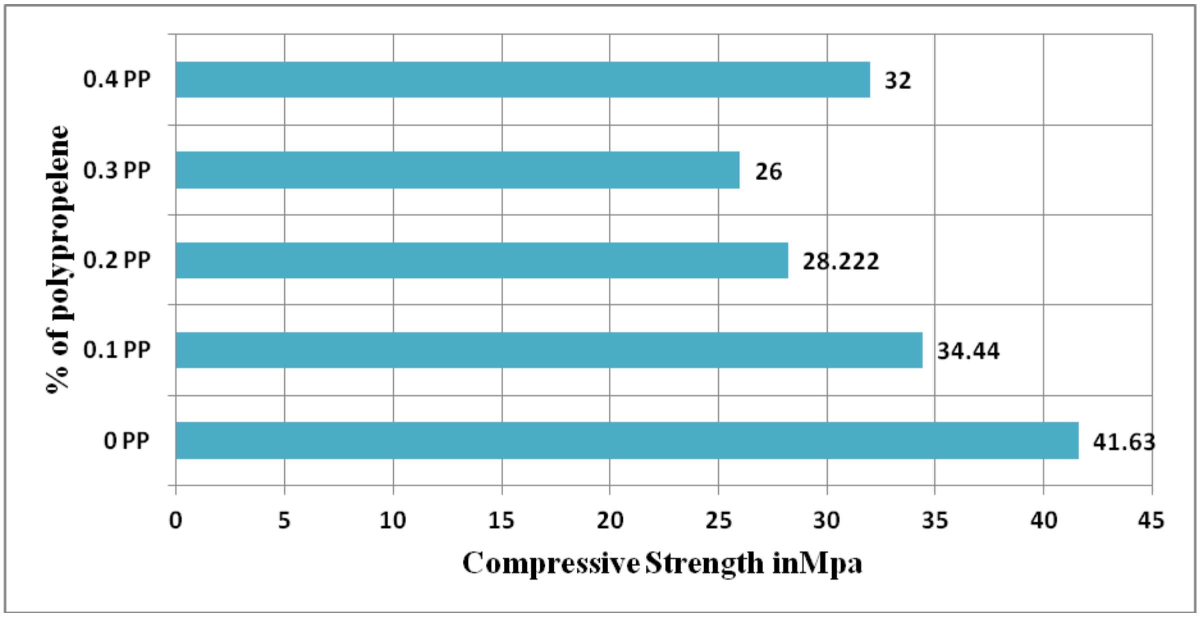

Fig.5.2 Compressive Strength for 7 days Vs % of Polypropylene

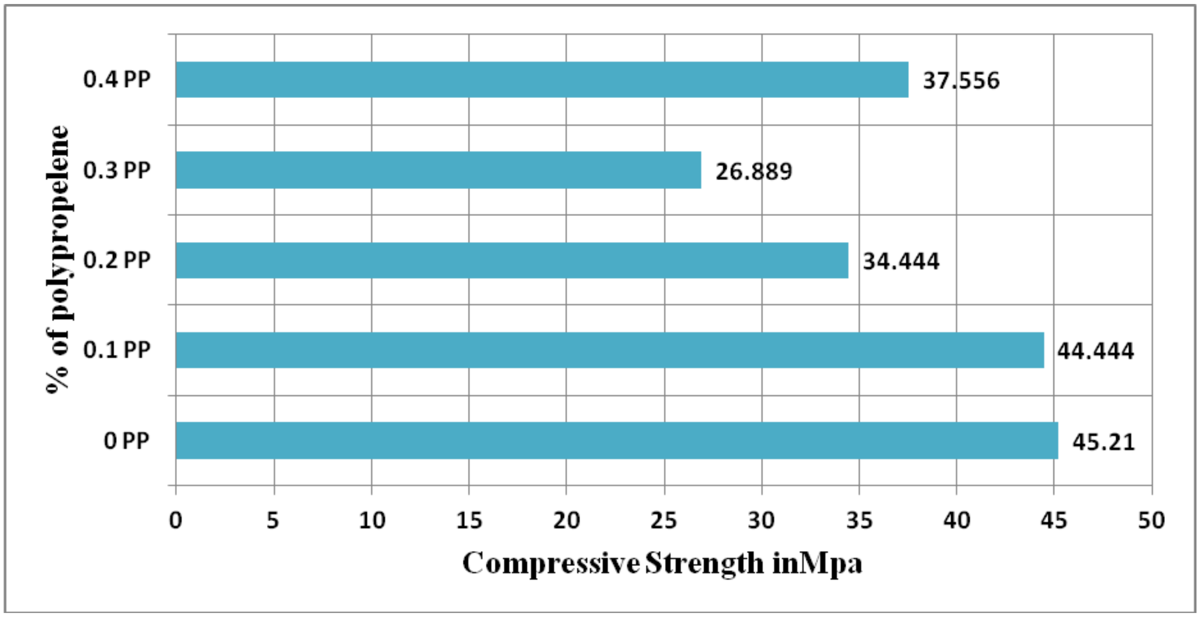

Fig.5.3 Compressive Strength for 14 days Vs % of Polypropylene

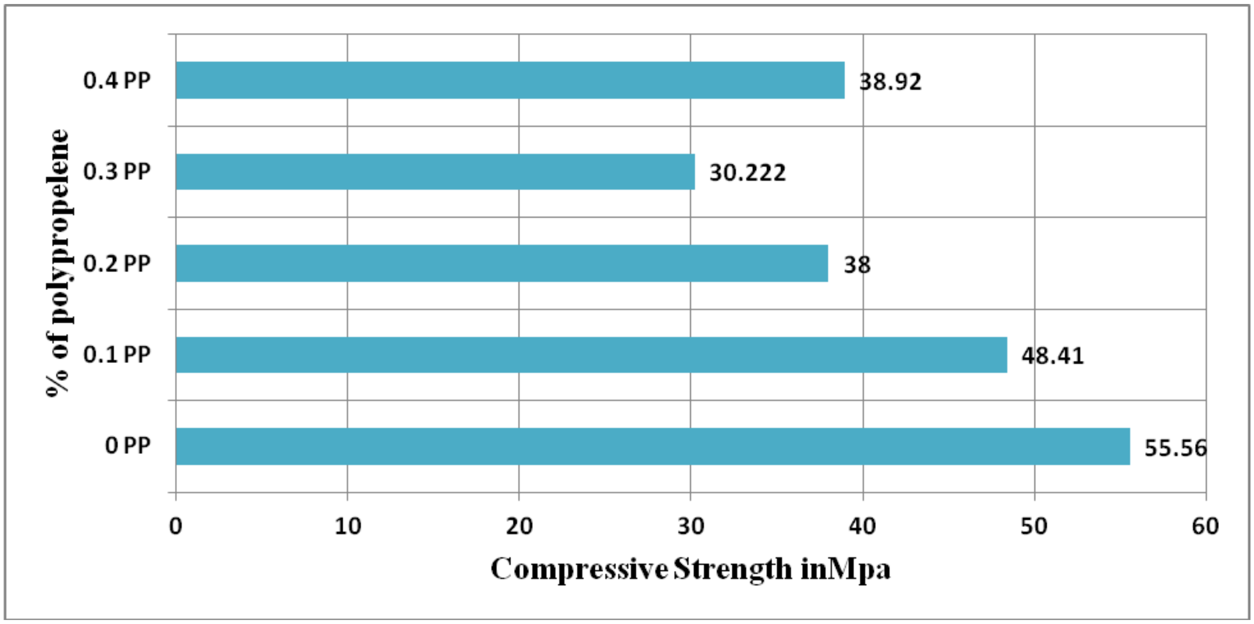

Fig.5.4 Compressive Strength for 28 days Vs % of Polypropylene

Fig.5.5 shows the value for every 0.1% increase of Polypropylene for 7, 14 and 28 days of curing period.

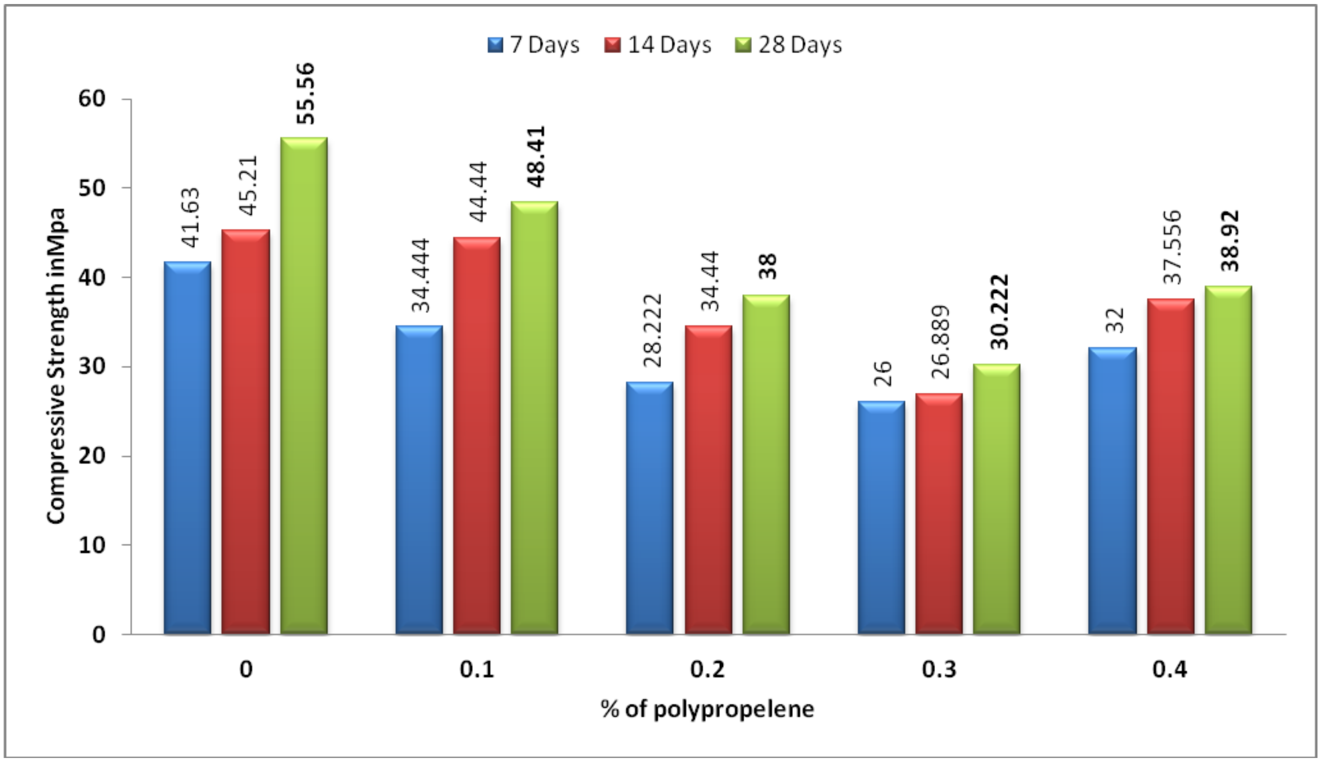

Fig.5.5 Compressive Strength Variation with % of Polypropylene

The graphs were drawn showing increase in strength against time for a given % of Polypropylene are shown in figs. below.

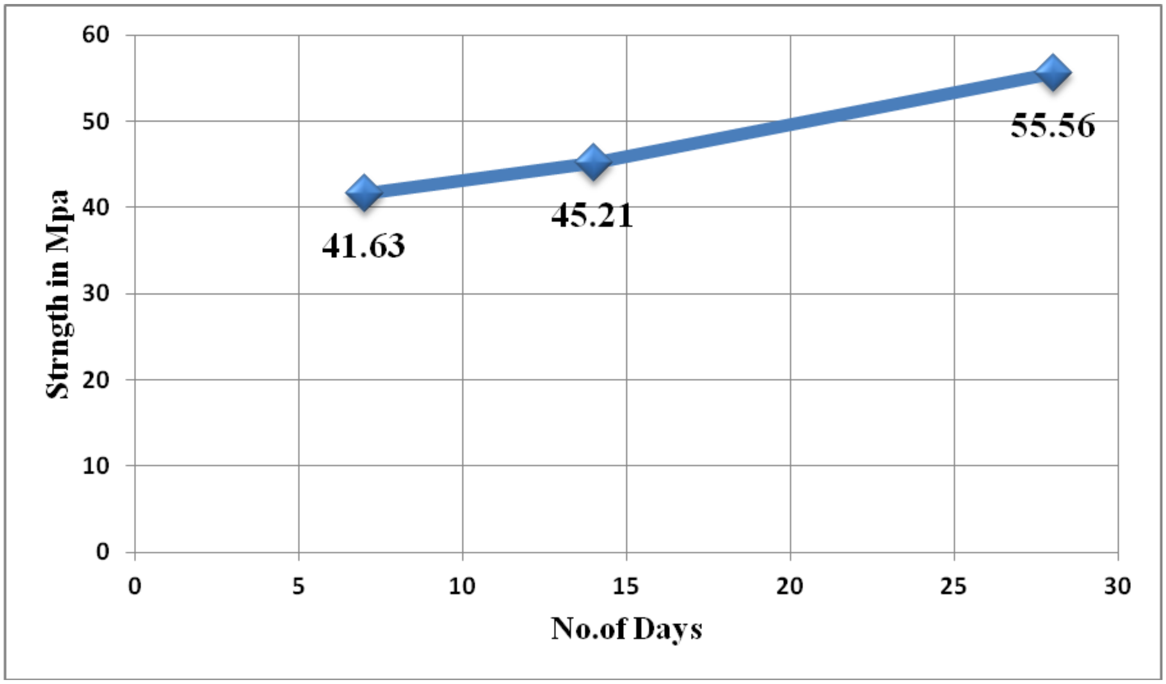

Fig.5.6 Compressive Strength Variation for 0 % Polypropylene

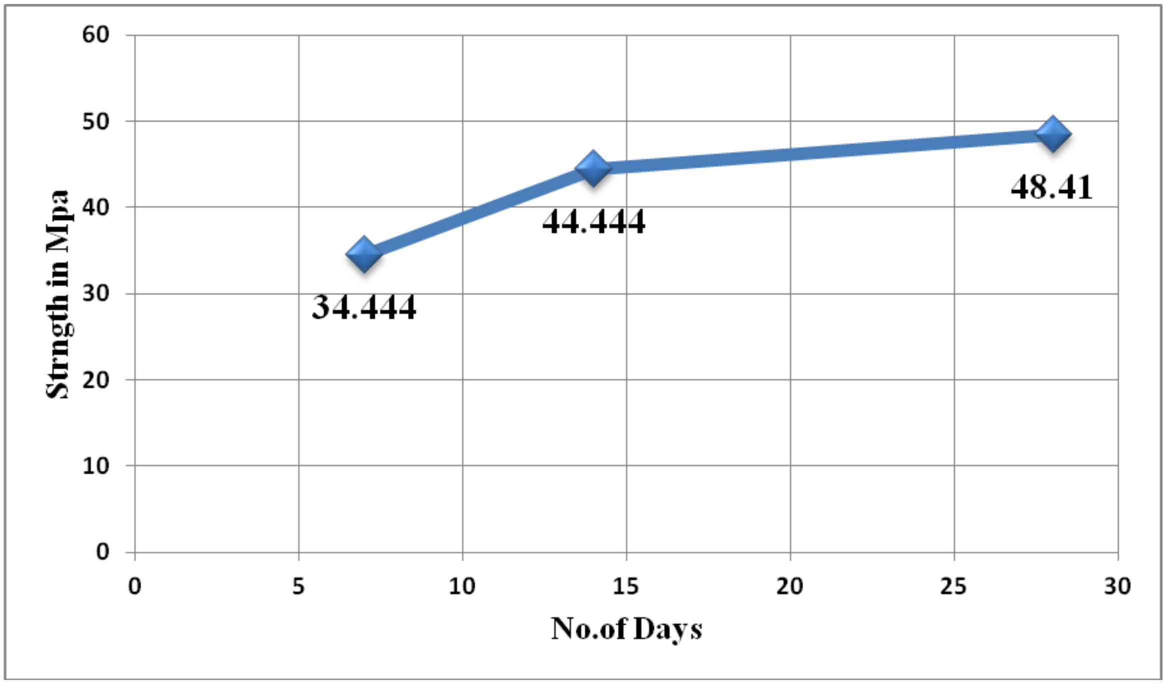

Fig.5.7 Compressive Strength Variation for 0.1% Polypropylene

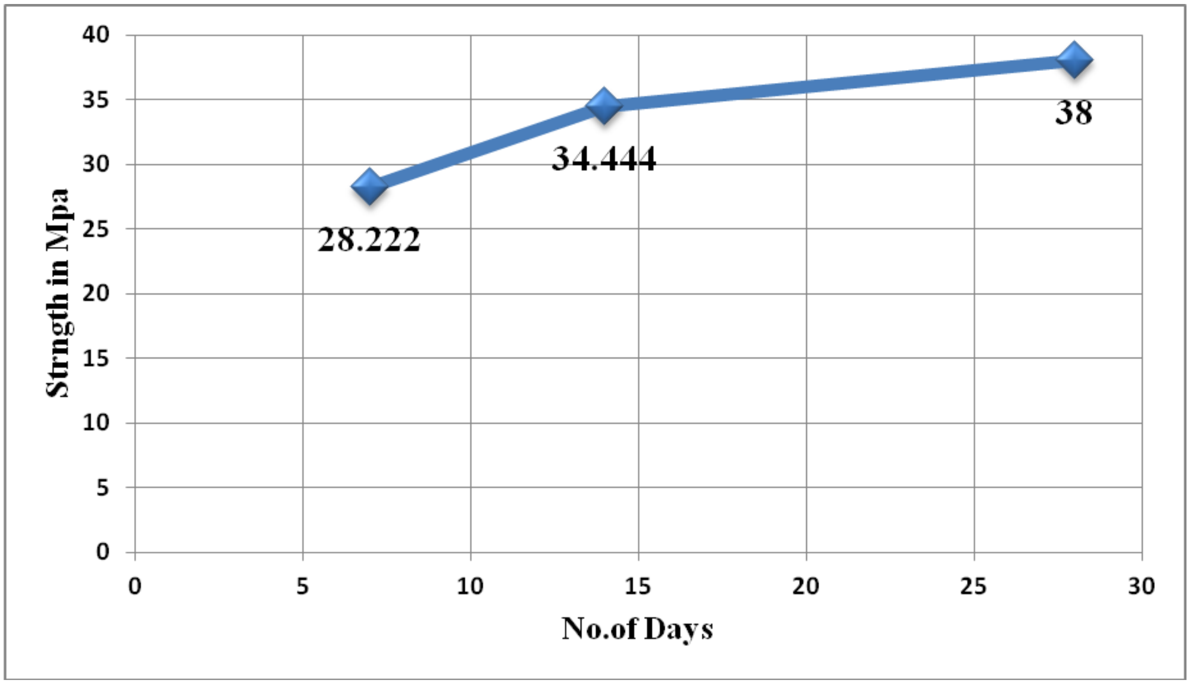

Fig.5.8 Compressive Strength Variation for 0.2% Polypropylene

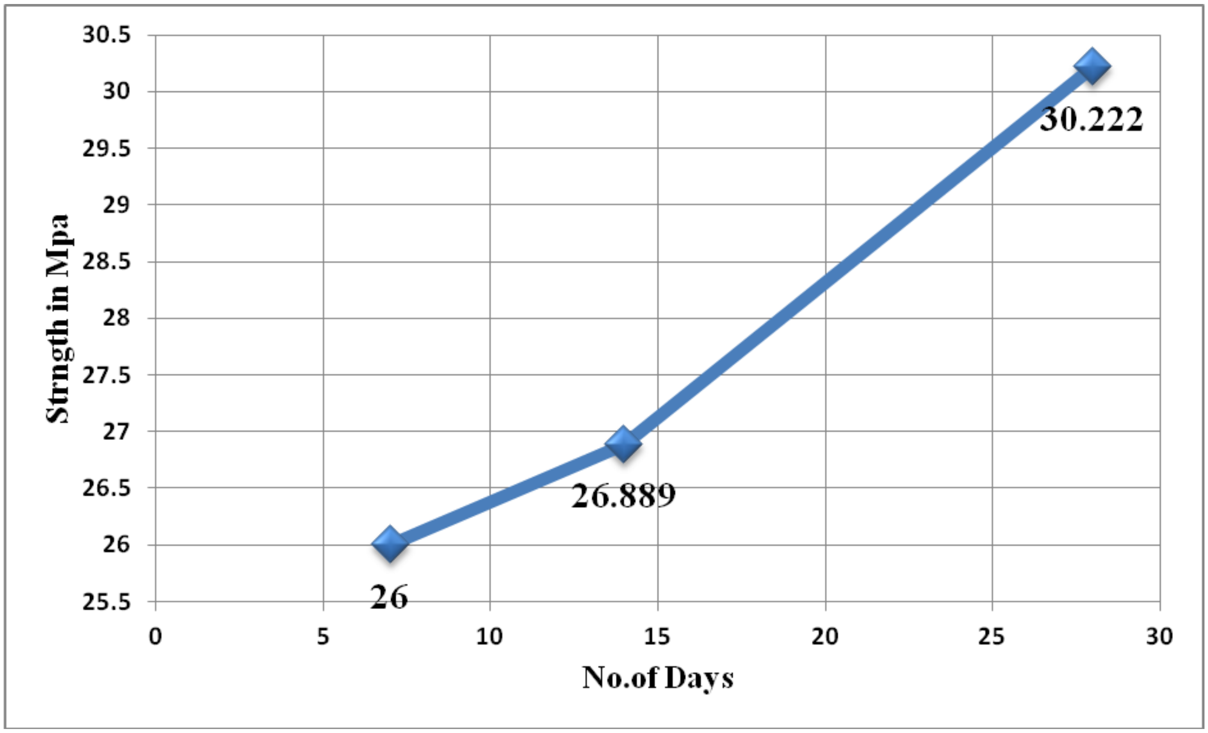

Fig.5.9 Compressive Strength Variation for 0.3% Polypropylene

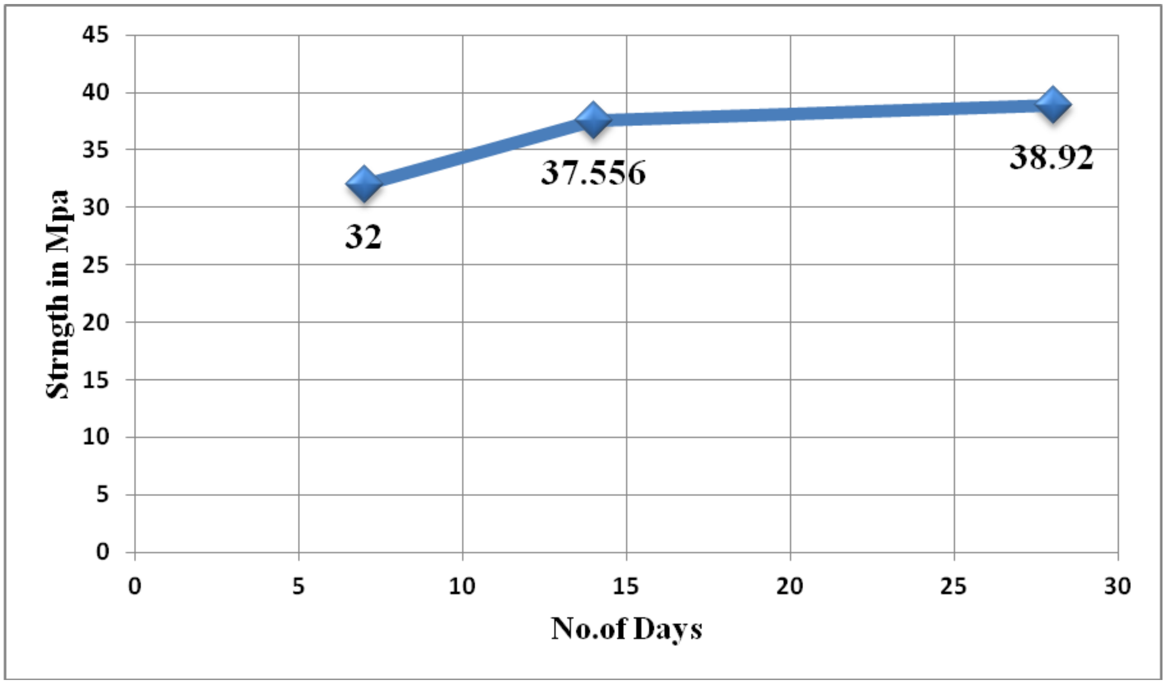

Fig.5.10 Compressive Strength Variation for 0.4% Polypropylene

5.3.2 Split tensile strength of concrete

The cylinders are casted with different percentages of Polypropylene and the same are tested in compression testing machine. The split tensile strength values with various percentages are shown in table 5.4 below

S.No	Sample Design Ation	% of Polypropy Lene	7 days Strength MPa	14 days strength MPa	28 days strength MPa	Ratio of 7 days to 28 days strength	Ratio of 14 days to 28 days Strength
1	PP00	0	2.203	2.312	2.825	0.778	0.819
2	PP01	0.1	2.934	3.005	3.25	0.905	0.925
3	PP02	0.2	1.98	2.051	3.04	0.654	0.675

4	PP03	0.3	1.909	2.687	3.32	0.578	0.805
5	PP04	0.4	2.121	2.581	3.53	0.6	0.735

Table 5.4 Split Tensile Strength results

The graphs were drawn showing variation of strength against % of Polypropylene in figs. below.

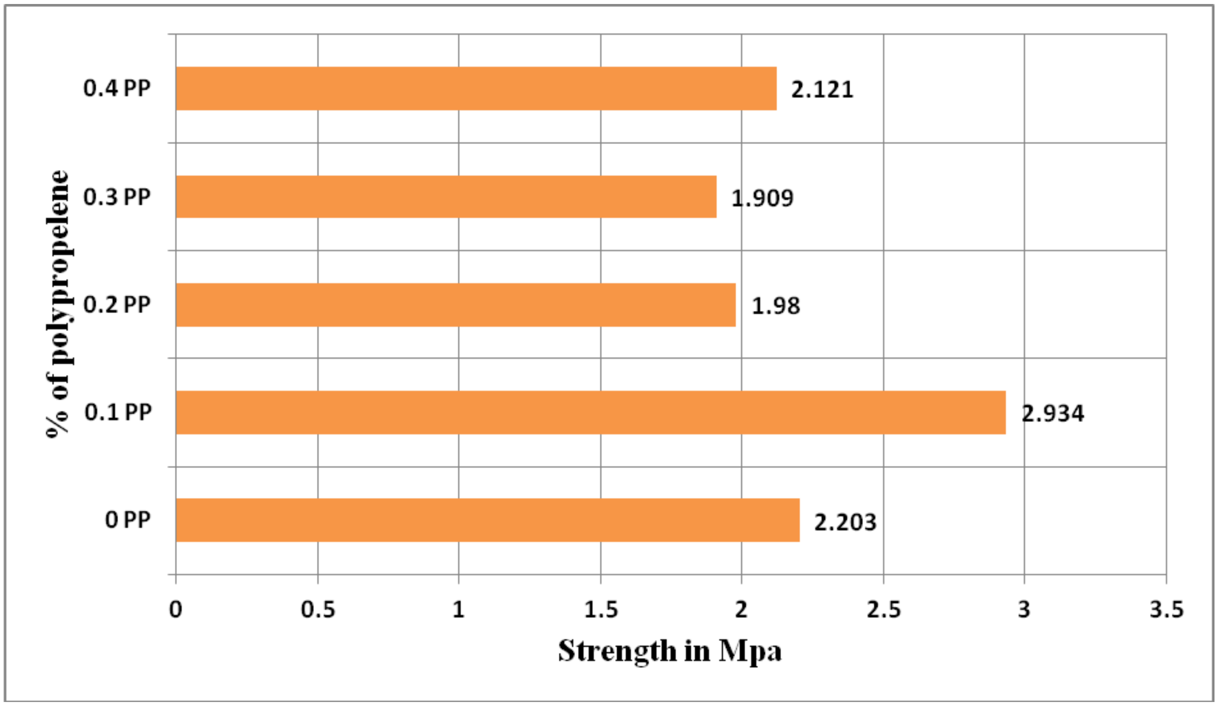

Fig.5.11 Split Tensile Strength for 7 days Vs % of Polypropylene

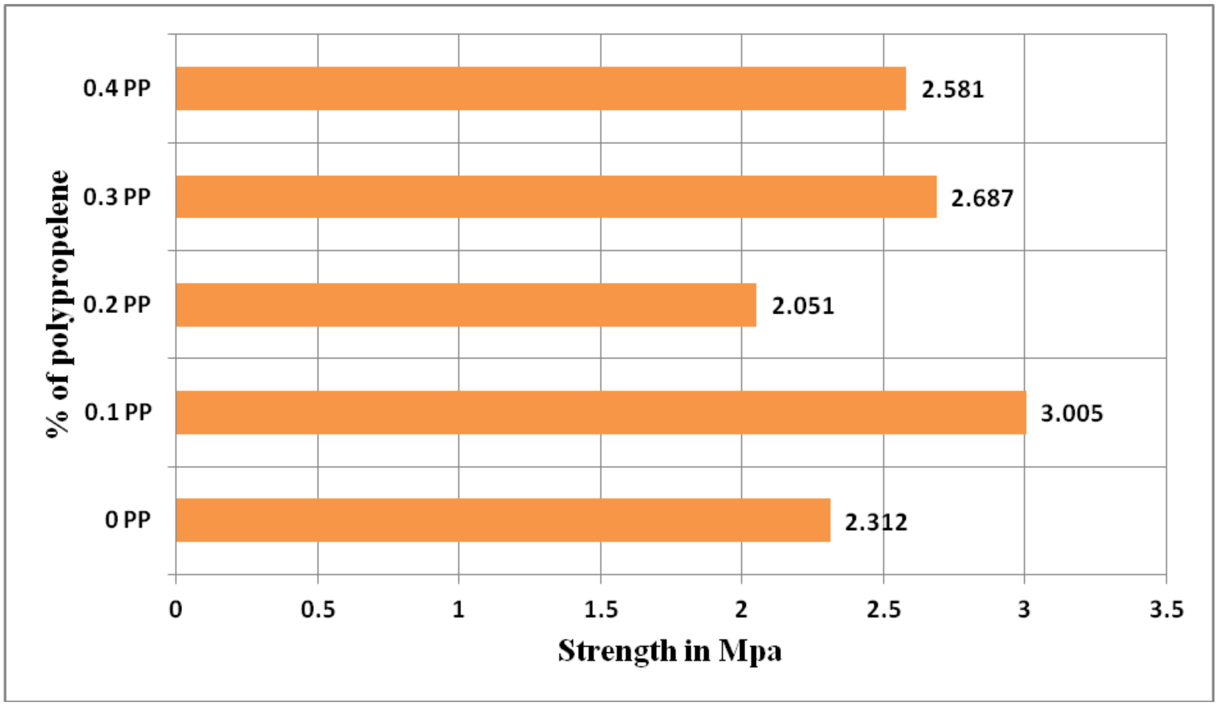

Fig.5.12 Split Tensile Strength for 14 days Vs % of Polypropylene

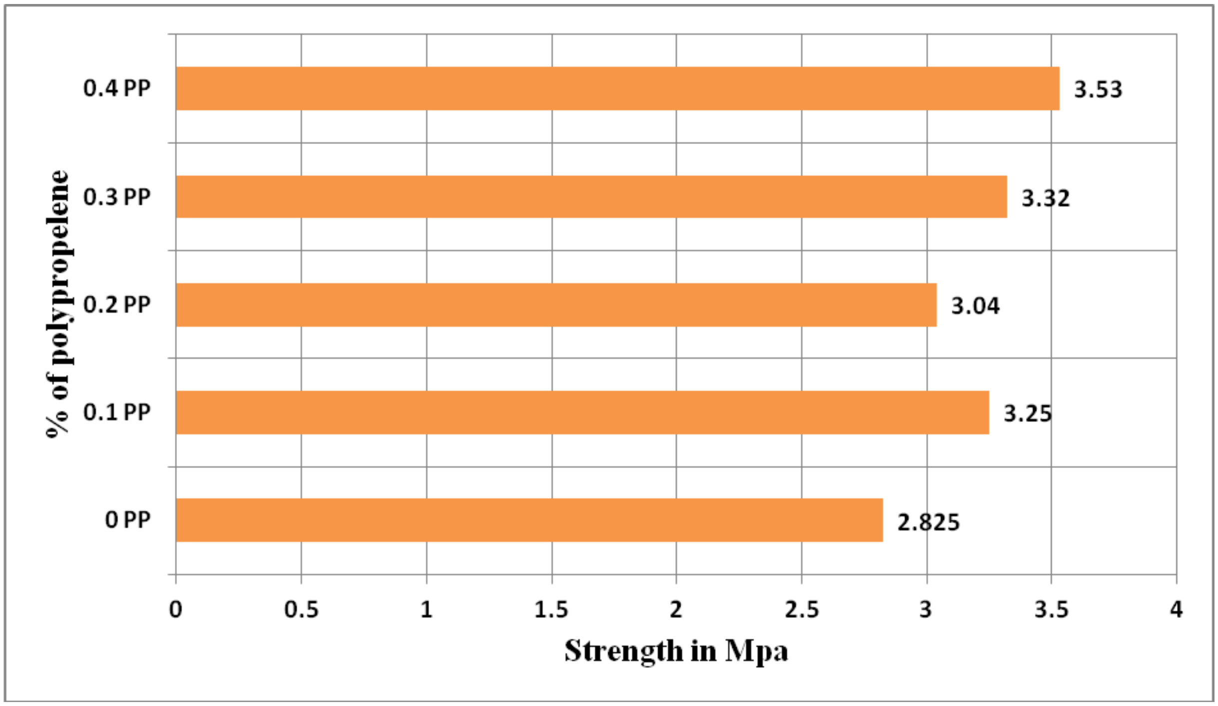

Fig.5.13 Split Tensile Strength of 28 days Vs % of Polypropylene

Fig.5.14 shows the value of compressive strength for every % of Polypropylene with increase in age.

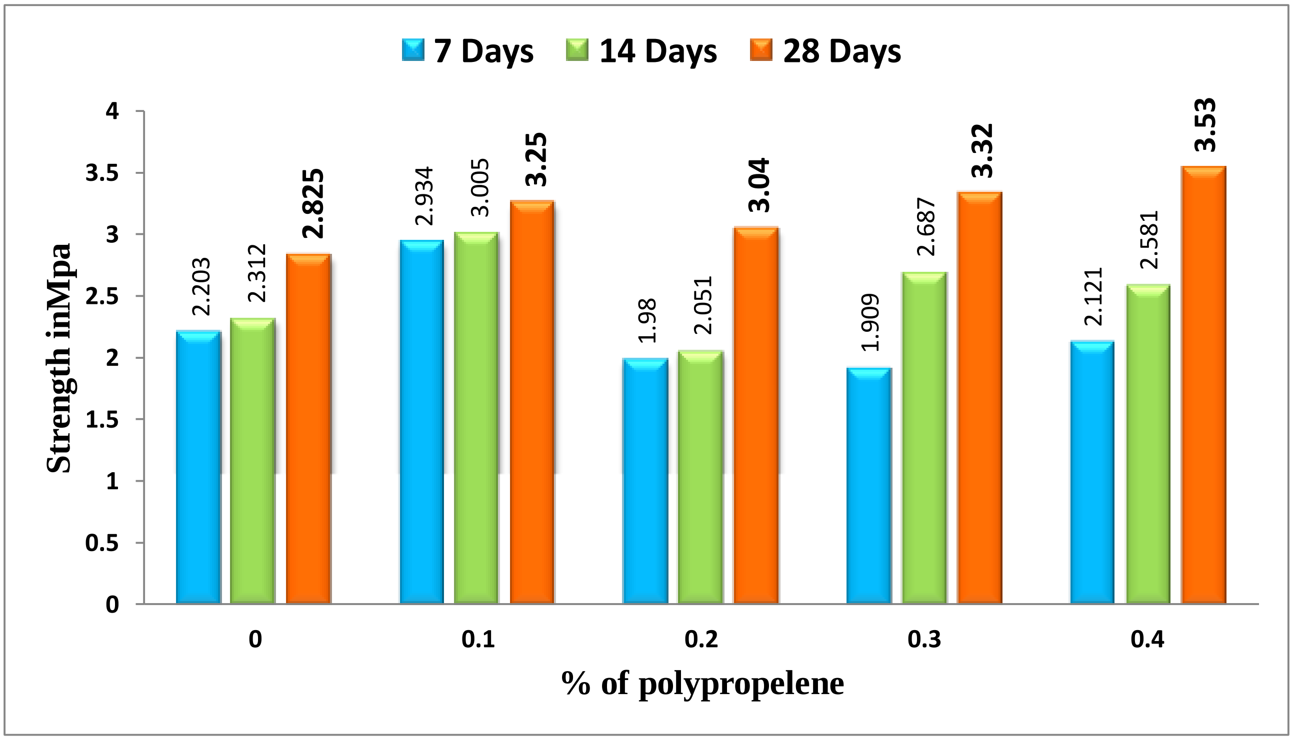

Fig.5.14 Split Tensile Strength Variation with % of Polypropylene

The graphs were drawn showing increase in strength against time for a given % of Polypropylene are shown in figs. below.

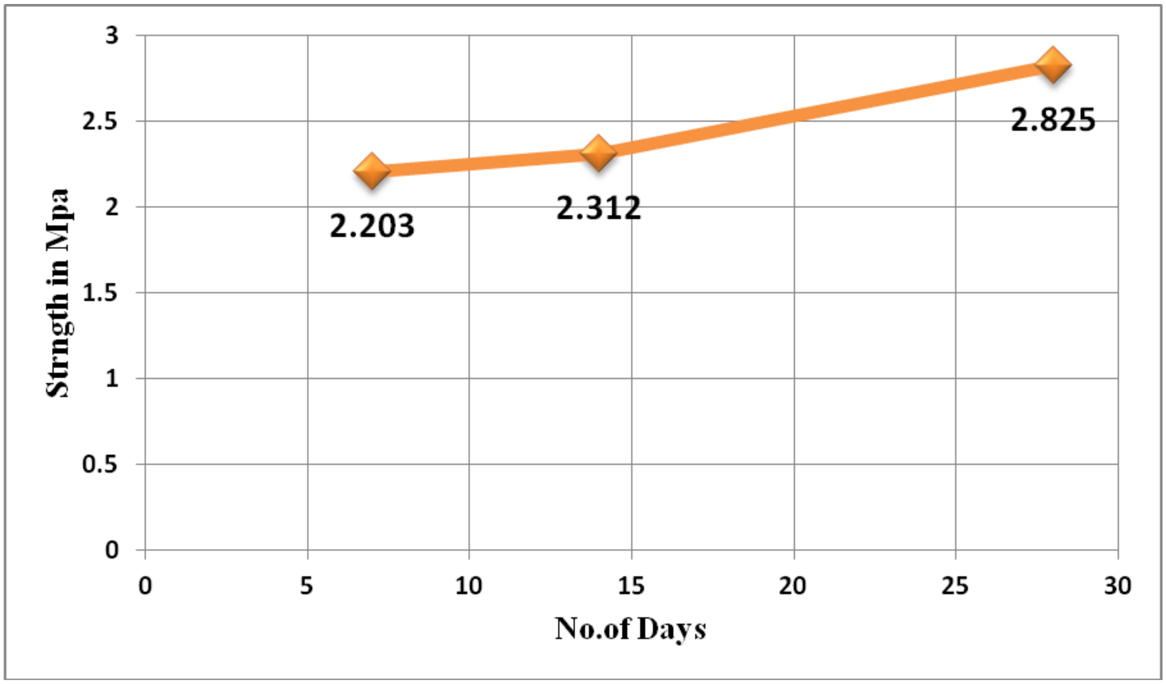

Fig.5.15 Split Tensile Strength Variation for 0 % Polypropylene

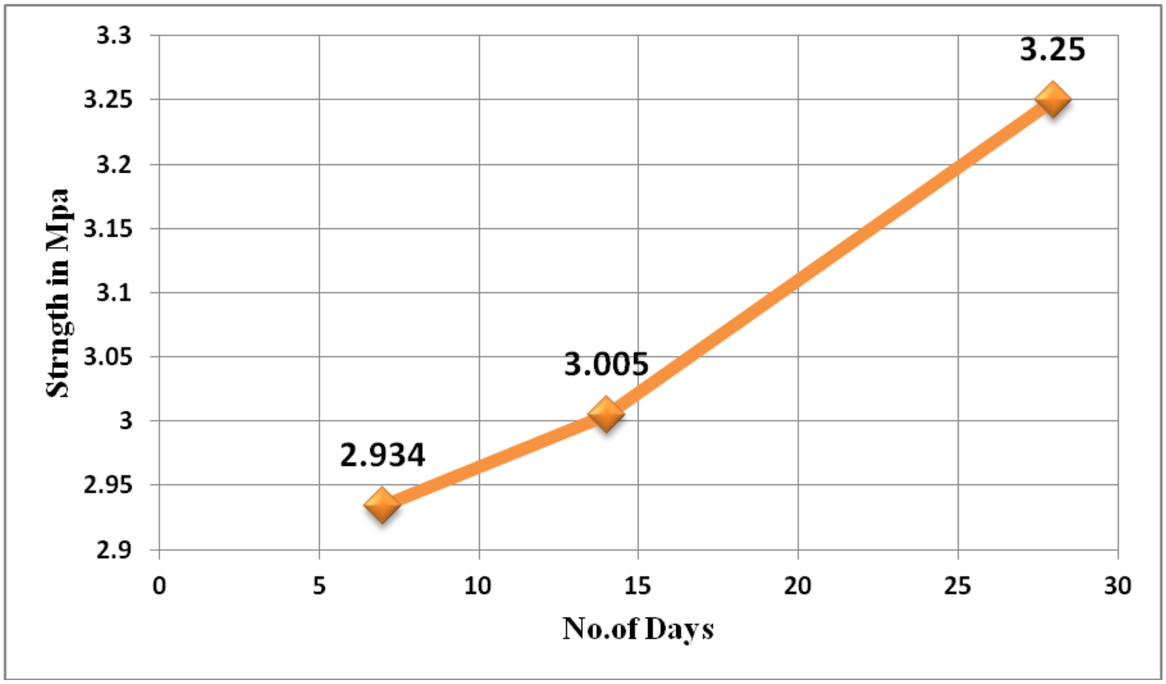

Fig.5.16 Split Tensile Strength Variation for 0.1% Polypropylene

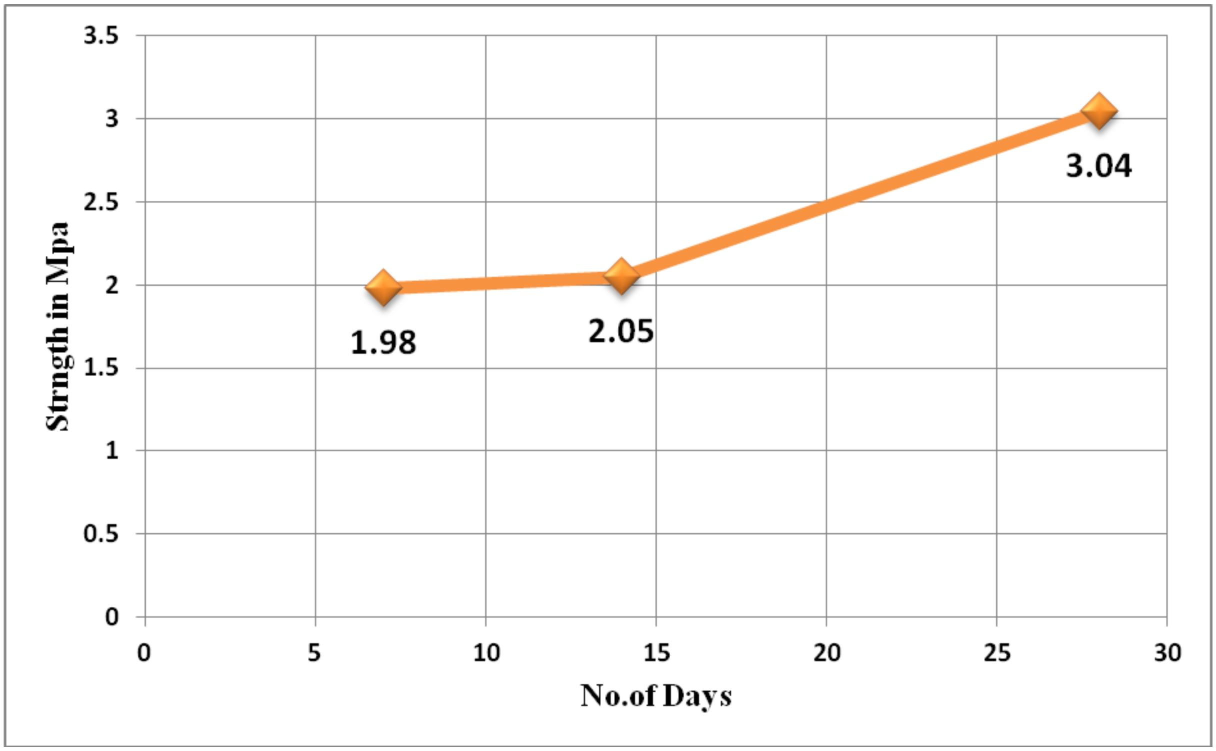

Fig.5.17 Split Tensile Strength Variation for 0.2% Polypropylene

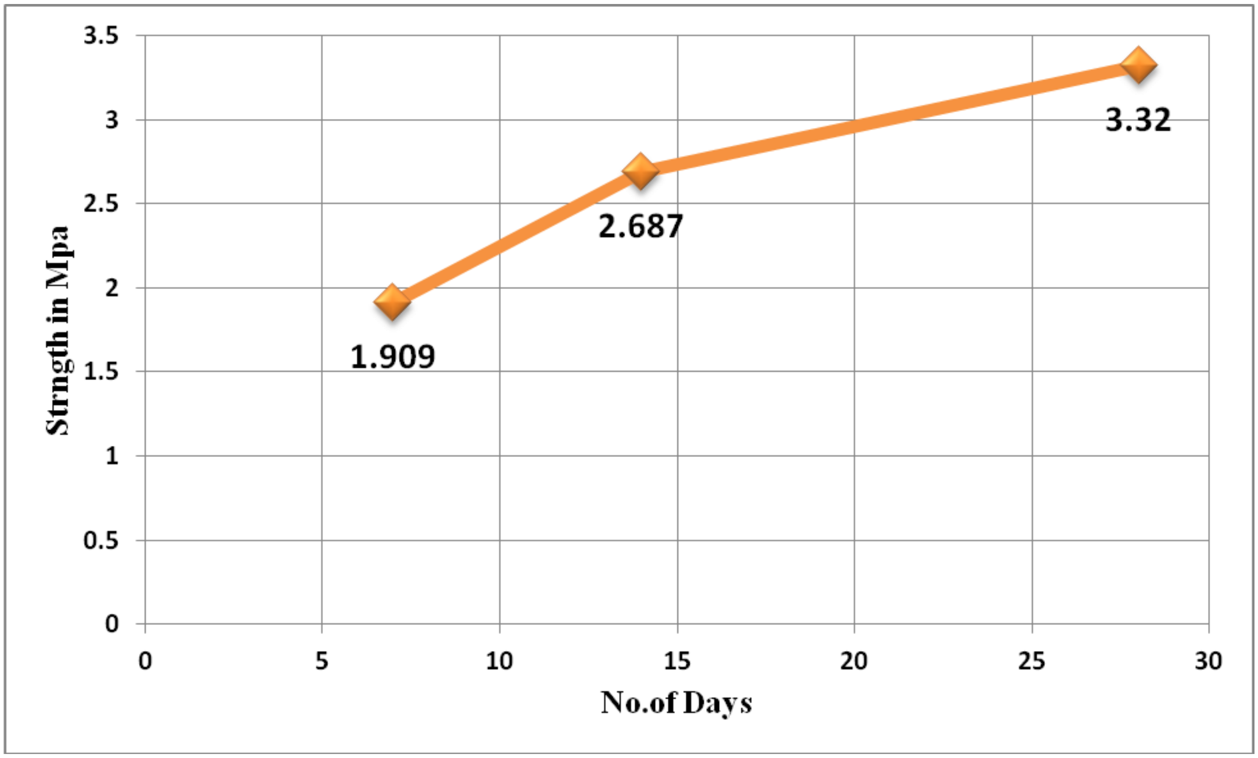

Fig.5.18 Split Tensile Strength Variation for 0.3% Polypropylene

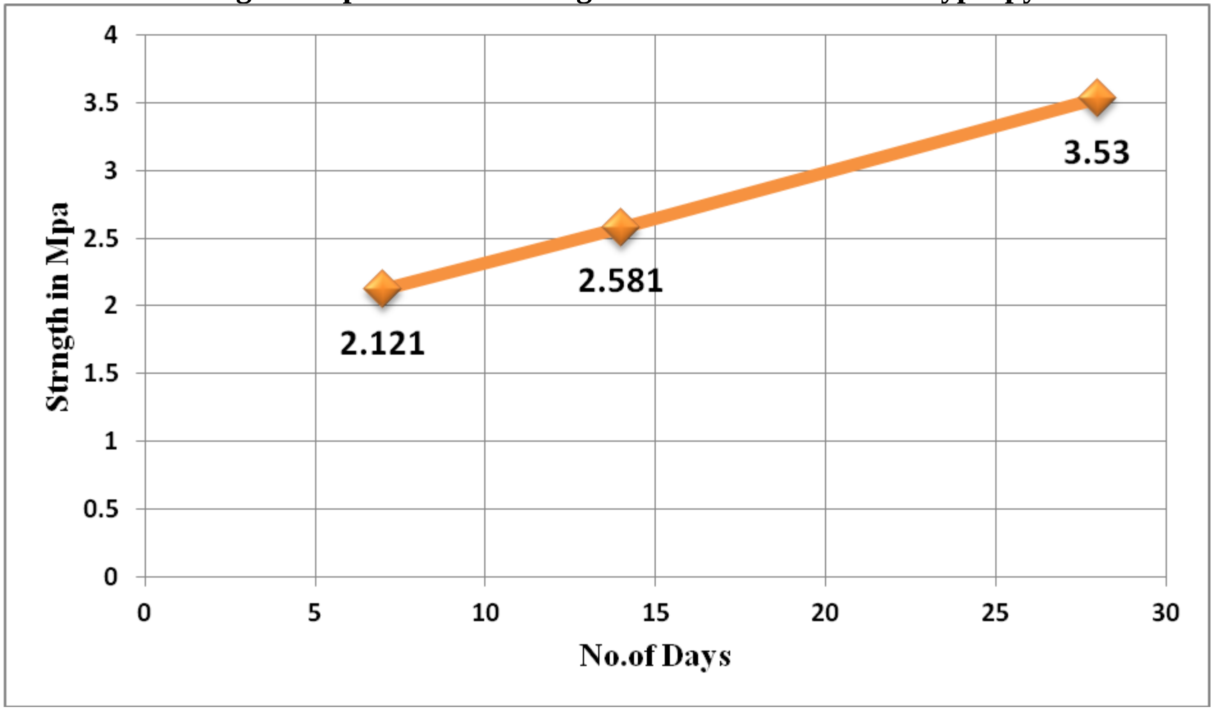

Fig.5.19 Split Tensile Strength Variation for 0.4% Polypropylene

5.3.3 Elastic modulus of concrete

The cylinders are casted with different percentages of Polypropylene and the same are tested in compression testing machine for elastic modulus and the values with various percentages are shown in table 5.5 below.

S.No	Sample Designation	% of Polypropylene	Stress in MPa	Strain	28 days strength MPa
1	PP00	0	15.05743	0.0006	25095.72
2	PP01	0.1	14.3205	0.0006	23867.5
3	PP02	0.2	13.4352	0.0006	22392
4	PP03	0.3	12.455	0.0006	20758.33

5	PP04	0.4	11.968	0.0006	19946.67

Table 5.5 Elastic modulus results

A plot was drawn between the elastic modulus values and the % of Polypropylene tested in 28 days shown in fig.5.20.

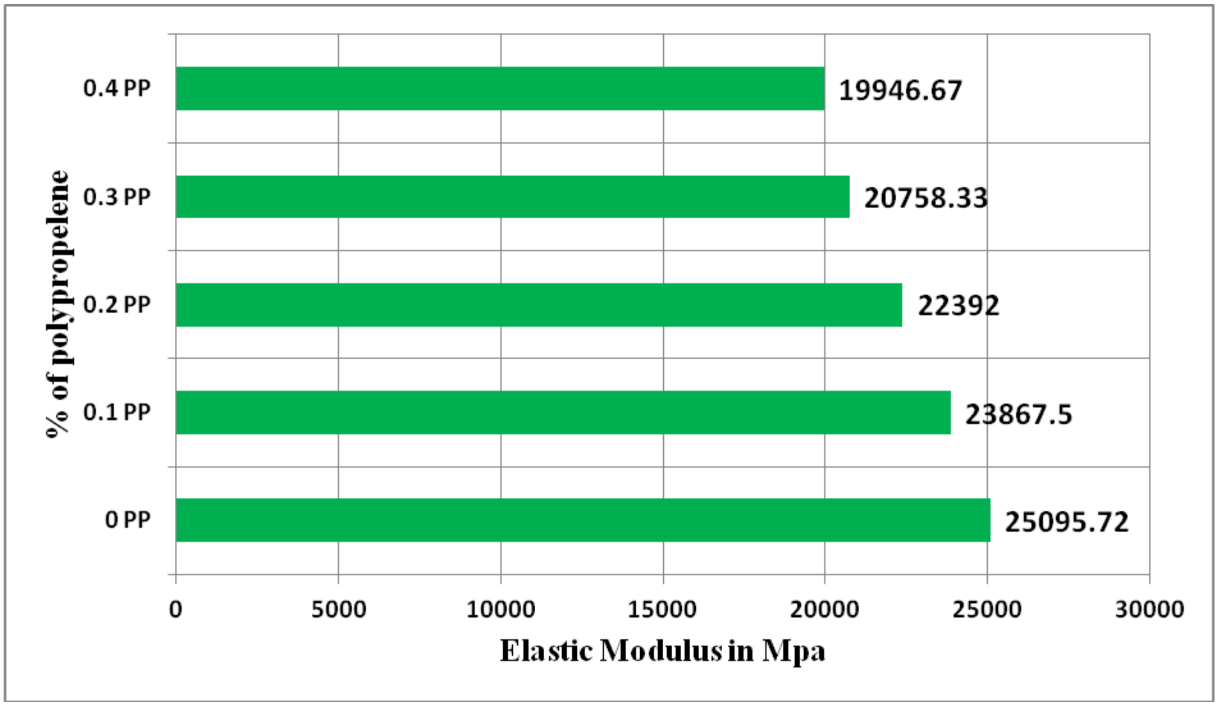

Fig.5.20 Elastic modulus for 28 days Vs % of Polypropylene

Load – deflection values are obtained from the longitudinal compressometer. The calculations of the Stress- Strain from the load and dial gauge readings values are shown in Appendix- III and the same stress and strain values computed are shown in table 5.6 and the stress- strain curve is drawn in fig. 5.21.

Table 5.6 Stress- Strain values for 0% Polypropylene

S.No	Strain	Stress in MPa
1	0.00017	4.52936
2	0.00033	8.77564
3	0.0005	13.5881
4	0.00067	16.702
5	0.00083	20.9483
6	0.001	23.4961

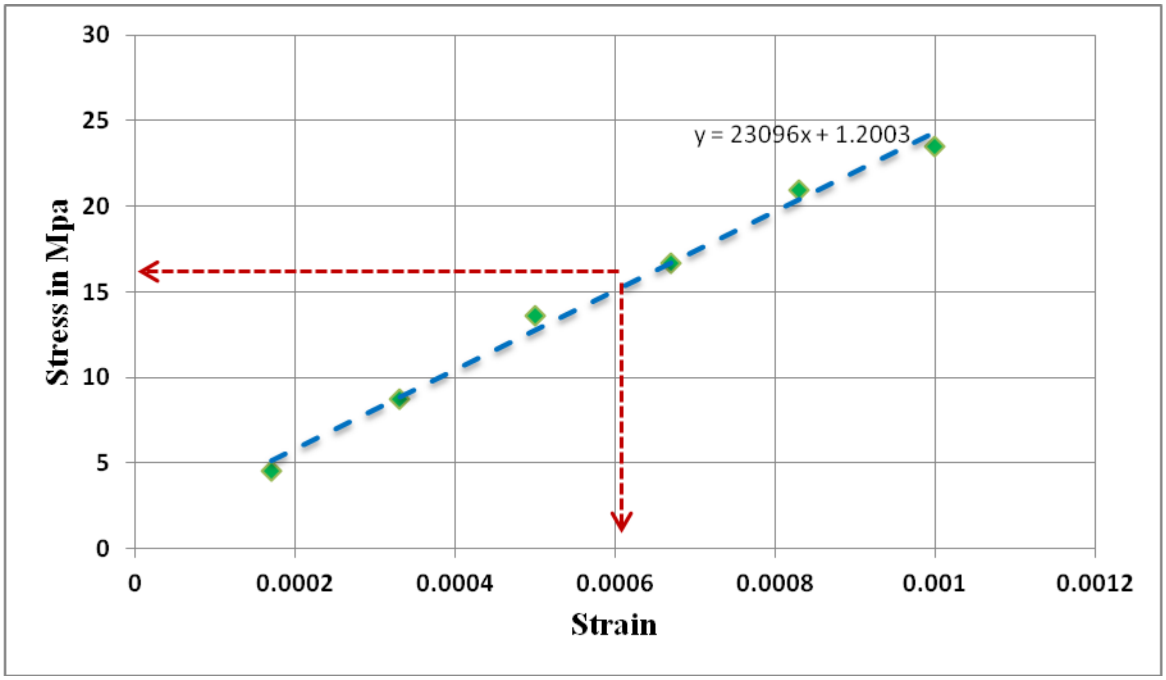

Fig. 5.21 Stress- Strain curve for 0% Polypropylene

Table 5.7 Stress- Strain values for 0.1% Polypropylene

S.No	Strain	Stress in MPa
1	0.00017	4.81245
2	0.00033	9.62489
3	0.0005	13.305
4	0.00067	16.702

5	0.00083	19.5329
6	0.001	21.2314
7	0.00117	23.4961
8	0.00133	25.1946
9	0.0015	25.7607
10	0.00167	26.61
11	0.00183	27.7423
12	0.002	28.3085

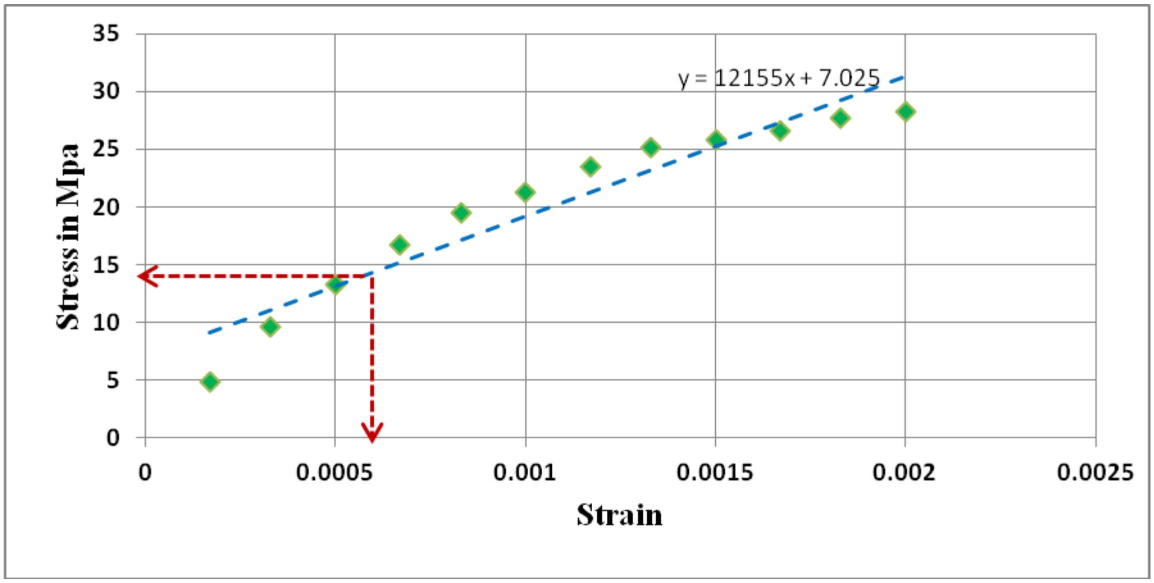

Fig. 5.22 Stress- Strain curve for 0.1% Polypropylene

Table 5.8 Stress- Strain values for 0.2% Polypropylene

S.No	Strain	Stress in MPa
1	0.00017	5.09553
2	0.00033	8.49255
3	0.0005	11.8896
4	0.00067	14.4373

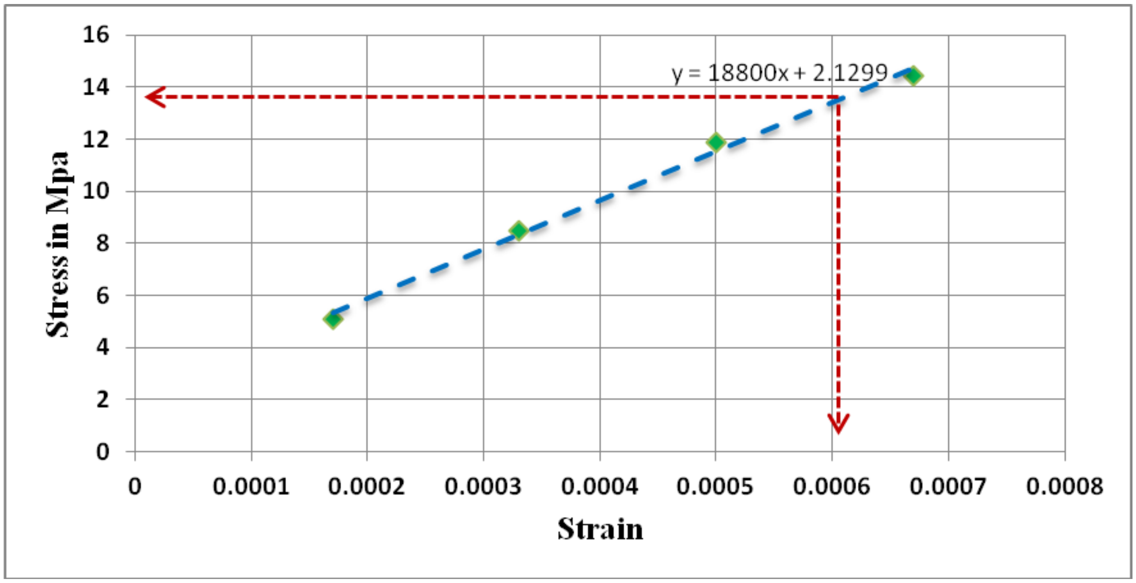

Fig.5.23 Stress-Strain curve for 0.2% Polypropylene

Table 5.9 Stress- Strain values for 0.3% Polypropylene

S.No	Strain	Stress in MPa
1	0.00017	3.96319
2	0.00033	8.49255
3	0.0005	11.8896
4	0.00067	14.7204
5	0.00083	16.9851
6	0.001	19.2498
7	0.00117	20.6652
8	0.00133	21.5145

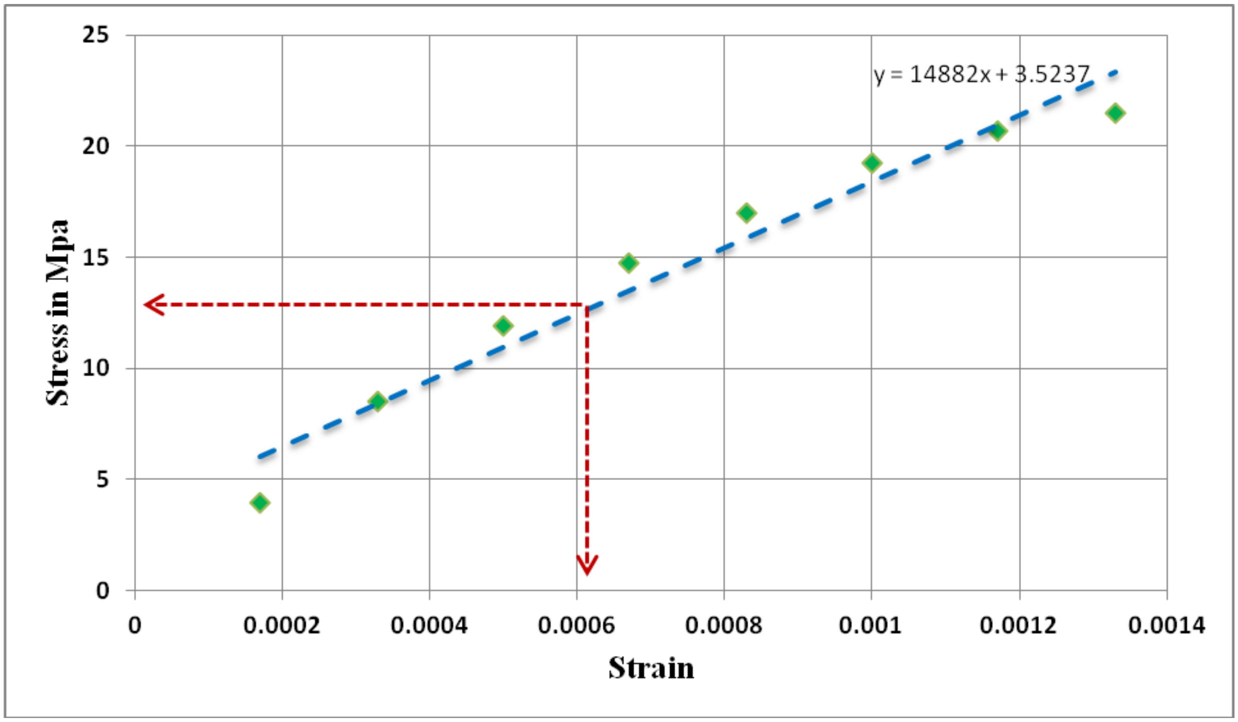

Fig.5.24 Stress-Strain curve for 0.3% Polypropylene

Table 5.10 Stress- Strain values for 0.4% Polypropylene

S.No	Strain	Stress in MPa
1	0.00017	5.09553
2	0.00033	8.49255
3	0.0005	11.3234
4	0.00067	13.8712
5	0.00083	15.5697
6	0.001	17.5513
7	0.00117	19.2498
8	0.00133	19.5329
9	0.0015	20.3821
10	0.00167	21.5145
11	0.00183	22.0806

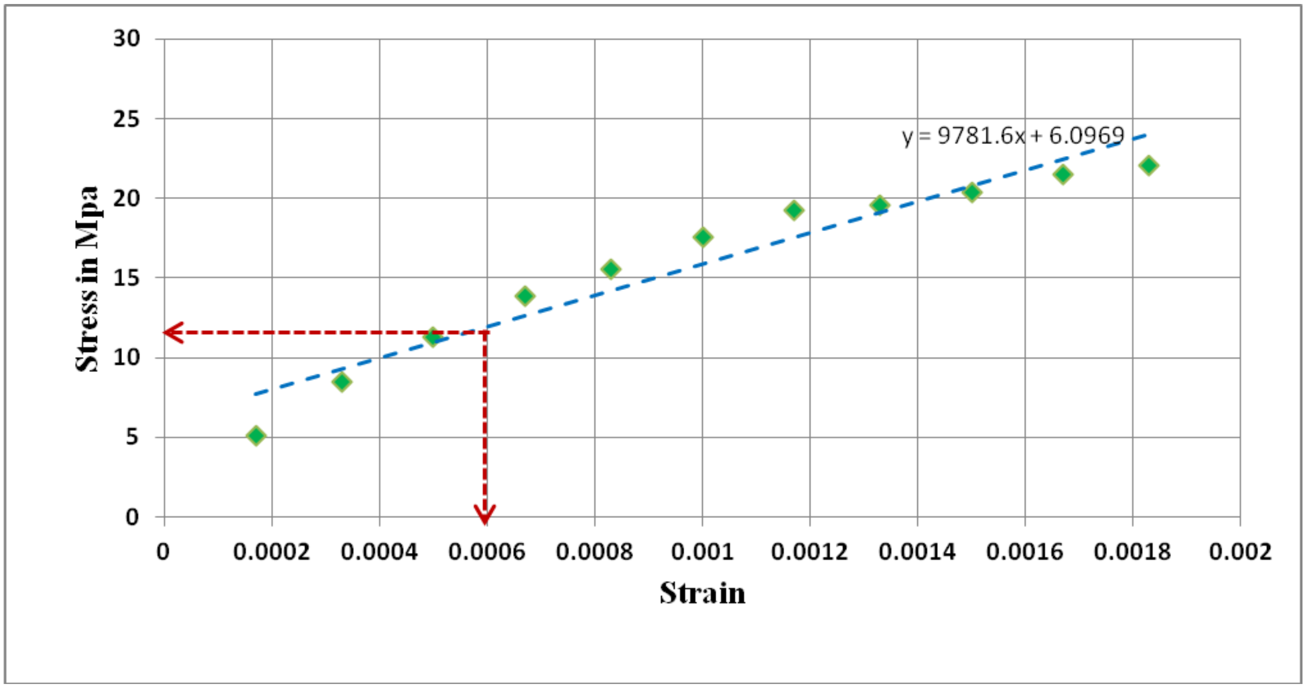

Fig.5.25 Stress-Strain curve for 0.4% Polypropylene

5.3.3.1 Comparison of Actual and Theoretical Elastic Modulus of concrete

Theoretical Elastic modulus of concrete = $5000\sqrt{fck}$ (as per IS 456:2000)

Where f_{ck} is the characteristic compressive strength of concrete

Theoretical values of Elastic modulus of concrete obtained from the above formula and the actual elastic modulus obtained from the experimental work are presented in Table 5.6 and comparison is represented as in fig. 5.21.

S.No.	% of PP	Elastic Modulus of concrete at 28 days in MPa	
		Theoretical value	Actual value
1	0	37269.29	25095.72
2	0.1	34788.648	23867.5
3	0.2	30822.07	22392
4	0.3	27486.36	20758.33
5	0.4	31192.948	19946.67

Table 5.11 Theoretical and Actual Values of Elastic modulus

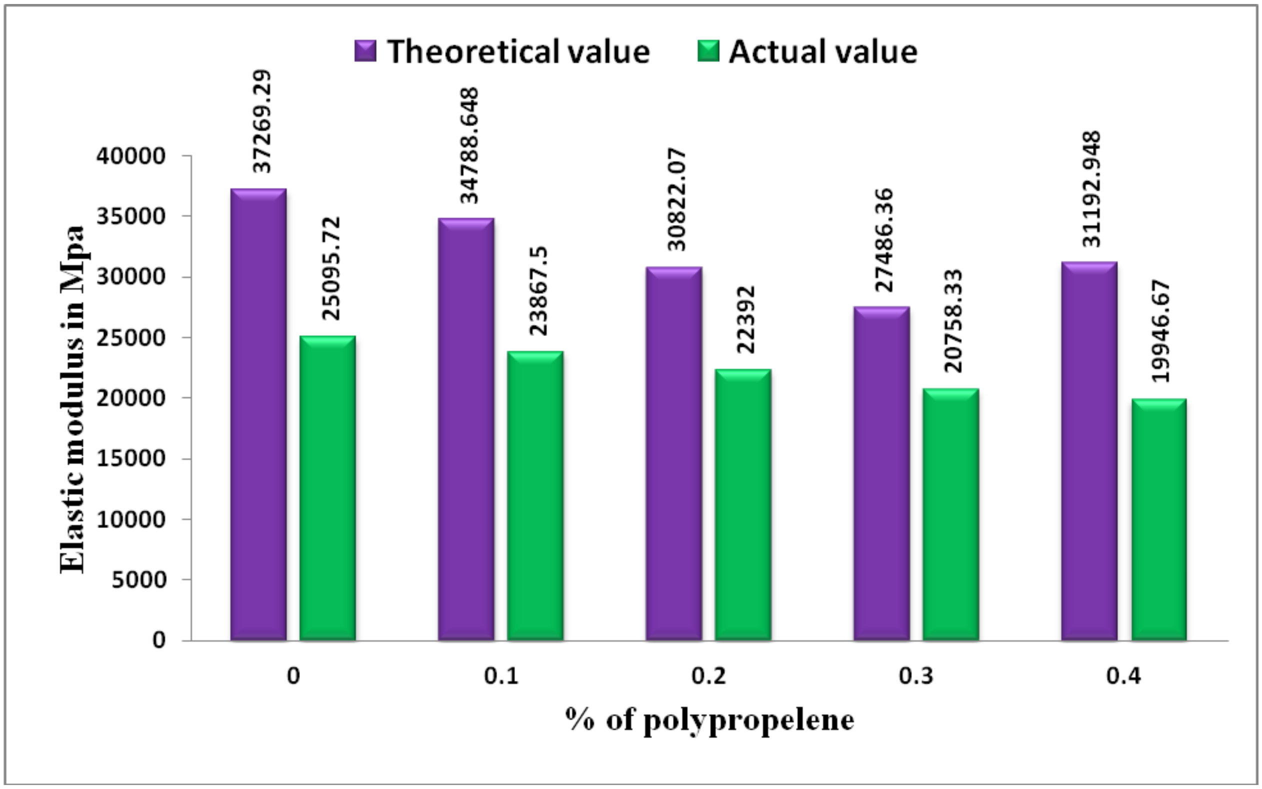

Fig. 5.26 Modulus of Elasticity Variation with % of Polypropylene

CHAPTER - 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This study discuss an experimental programme carried out to investigate mechanical properties of self-compacting concrete with different percentages of Polypropylene fibres.

6.2 Conclusions

The following conclusions can be drawn according to the results of the study

6.2.1 Slump flow Test: The workability tests on fresh concrete such as slump flow and T50 are measured. As the percentage of Polypropylenes fibre is increasing from 0 to 0.4 %:

i. The flow of the concrete gets reduced from 610mm to 490mm upon addition of fibres from 0 to 0.4%, also the time taken T50 increased. Hence it was observed that as percentage of fibre increases slump value decreases.

ii. As the percentage of fibres increases the velocity of flow decreases.

6.2.2 Tests on Hardened concrete: The tests on the hardened concrete such as compressive strength, split tensile strength and elastic modulus of concrete were measured. As the percentage of fibre increases from 0 to 0.4% :

1. **Compressive strength**
    i. As the percentage increases from 0 to 0.4% of Polypropylene, the strength was observed to be reduced from 55.56MPa to 30.22 MPa (i.e. by 45.6%) up to 0.3% of Polypropylene
    ii. But a sudden increase in strength value of 39MPa was observed at 0.4% Polypropylene.
    iii. The percentage of increase of the strength from 7 days to 28 days at all percentage was gradually reduced up to 0.3% Polypropylene but sudden increase in 0.4%.
2. **Split strength**
    i. The strength of concrete was increased by 15%, 7%, 17.5% and 24.9% at dosage rates of 0.1%, 0.2%, 0.3% and 0.4% percentages of fibre respectively.
    ii. The rate of increase in percentages of strength was reducing up to 0.2% of Polypropylene, but thereafter rate was increased.
    iii. Of the above percentages of Polypropylene, maximum value of strength is obtained at 0.4% Polypropylene.
3. **Elastic modulus of concrete**
    i. The elastic modulus of concrete was marginally reduced by increasing percentage of Polypropylene and also the variation was non uniform.
    ii. But the elastic modulus has its maximum value at 0% of Polypropylene having value of 25095.72 MPa

iii. Among the different percentages of Polypropylene 0.1% has maximum value of 23867.5MPa.
iv. The elastic modulus value was decreased as the percentage of Polypropylene was increased.

6.3 Recommendations

i. Studies on creep and shrinkage properties may be carried out.
ii. Studies on type and quantity of super plasticizer used, in order to achieve workability properties.

APPENDIX – I

CONCRETE MIX DESIGN

Mix Design Principle:

The flow ability and viscosity of the paste is adjusted by proportioning the cement and additives, water to the powder ratio and then by adding super plasticiser and VMA (if needed). The paste is the vehicle for the transport of the aggregates and hence volume of the paste should be greater than the volume of aggregates.

Mix Design:

In this experiment the mix was designed using Nan-Su method. In this method first the amount of aggregates required is determined and the paste of binders is then filled into the voids of aggregates to ensure that the concrete thus obtained has flow ability. The principle consideration of the proposed method is to fill the paste of binders into voids of the aggregate frame work piled loosely. The major factors which influence the properties of SCC are as follows:

- **Amount of aggregates, binders and mixing water:** when surface dry coarse and fine aggregates are loosely stacked together, the voids are lubricated which is obtained by adding water with binders, making the concrete more compact. And the Packing Factor which is defined as ratio of mass of aggregate of tightly packed state to that of loosely packed state plays an important role in the content of the aggregate. A higher value will impart more fine and coarse aggregate resulting in content of binder. On the other hand lower PF value will raise the cost of materials. The relation between water-cement ratio and compressive strength is similar that of ordinary concrete.

- **Cement based on the strength:** To secure good flow ability and segregation resistance the content of binder should not be low. Hence minimum amount of 290 kg/m^3 is recommended.
- **Type and dosage of superplasticizer:** An adequate quantity of SP can improve the flow ability, self-compatibility, and segregation resistance of fresh SCC. HRWRA helps in achieving the excellent flow rate at lower water content and VMA is used to arrest the bleeding if any.

The following are the various steps involved in the design process of mix.

Step 1: Calculation of Coarse and Fine aggregate contents;

The content of coarse aggregate is obtained as $W_g = PF\times W_{gl}\times (1-\frac{s}{a})$

The content of fine aggregate is obtained as $W_s = PF\times W_{sl}\times\frac{s}{a}$

Where,

W_g = content of coarse aggregate in kg/m^3

W_{gl} = unit weight of loose packed coarse aggregates in kg/m^3

W_{sl} = unit weight of loose packed fine aggregate in kg/m^3

S/a = volume of ratio of fine aggregates to total

aggregates PF = Packing factor

Step 2: Determine the cement content;

Assuming each kg of cement provide a strength of 20 psi for SCC Cement

needed per unit volume of concrete =C= target strength/20 kgs

Step 3: Determine the mixing water content required by cement;

Assuming water- cement ratio, W_{wc} = weight of cement * water-cement ratio

Step 4: Determine the dosage of SP;

Assuming the dosage of SP as percent by weight of cement, the weight of dosage is

W_{SP} = weight of cement * percent of dosage of SP

Assume PF= 1.2 and S/a = 0.54,

Loose bulk density of soil is 1508 kg/m^3 and coarse aggregate is 1435 kg/m^3

On substitution,

$$W_g = PF\times W_{gl}\times (1-\frac{s}{a})$$

$$= 1.2* 1435*(1-0.54) = 792.98 \text{ kg}$$

$$W_s = PF\times W_{sl}\times\frac{s}{a}$$

=1.2*1508*0.54 = 975.15 kg

For 1m^3 concrete mix proportions are:

Cement	:	495 kg
Coarse aggregate	:	792.98 kg
Fine aggregate	:	975.15 kg
Water	:	158.4 kg
SP	:	3.96 kg

Hence the ratio is given as

Cement : CA : FA : Water : SP = 1 : 1.602 : 1.97 : 0.32 : 0.008

APPENDIX - II

SAMPLE CALCULATIONS:

Sample calculations of the quantities required for the mix with 0.4% Polypropylene fibre.

Volume required:

For 6 Cubes = 6 x 0.15 x 0.15 x 0.15 = 0.02025 m^3

For 6 Cylinders = 6 x $(\pi/4)$ x $(0.15)^2$ x 0.30 = 0.03181 m^3

Add 20% extra (wastage) = 0.2 x 0.05207 = 0.01041 m^3

Total volume: = 0.06247 m^3

Quantity of cement required for 0.06247 m^3 of Concrete: = 495 x 0.06247

= 30.923Kg

Quantity of coarse aggregate required for 0.06247 m^3 of Concrete = 792.98 x0.06247

= 49.537kg

Quantity of fine aggregate required for 0.06247 m^3 of Concrete = 975.15x 0.06247

= 60.92 kg

Quantity of water required for 0.06247 m^3 of Concrete = 158.4 x 0.06247

= 9.895 kg

Quantity of super plasticizer required for 0.06247 m^3 of Concrete = 3.96 x 0.06247

= 0.2474Kg

Quantity of Polypropylene fibre required for 0.06247m^3 Concrete:

a) 0.1% of Polypropylene: = 495x 0.001 x 0.06247 = 30.92grms
b) 0.2% of Polypropylene: = 495x 0.002 x 0.06247 = 61.84grms
c) 0.3% of Polypropylene: = 495x 0.003 x 0.06247 = 92.76grms
d) 0.4% of Polypropylene: = 495x 0.004 x 0.06247 = 123.69grms

APPENDIX - III

STRENGTH CALCULATIONS

A. Compressive strength of cube:

Maximum load applied on the specimen P=1250kN

Cross sectional area of cube A = 150 x 150 mm^2

Compressive strength of cube = P/A = $\frac{1250 \times 1000}{150 \times 150} = 55.56$ N/mm^2

B. Split tensile strength of cylinder:

Maximum load applied on the specimen P = 250kN

Cross sectional area of cylinder d x l = 150 x 300 mm^2

Split Tensile strength of cylinder $= \frac{2*p}{\pi dl} = \frac{2X250X1000}{\pi X150X300} = 3.53$ N/mm^2

C. Young's Modulus of concrete:

Maximum load applied on the specimen P = 500kN

Length of the cylinder L = 300 mm

Cross sectional area of cylinder $A = \pi d^2/4 = \frac{\pi \, X \, 150^2}{4}$

Dial Gauge reading a = 60

Least Count LC = 0.01

Change in length Δl = a x LC = 60 x 0.01 = 0.6 mm

Stress σ = P/A $= \frac{(500X1000)X4}{\pi X150X150} = 28.31$ N/mm^2

Strain $\mathcal{E} = \Delta l/l = \frac{0.6}{300} = 0.002$

Young's Modulus of concrete $E = \frac{\sigma}{\varepsilon} = \frac{28.31}{0.002} = 14154.3\ N/mm^2$.

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