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Experimental Work on Performance of FRC by Partially Replacing Cement With Limestone

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Abstract*: Concrete consists of cement, sand, coarse aggregate and water. The critical factor that increases value to concrete is that it tends to be intended to withstand harsh conditions. The concrete industry is continually looking for supplementary cementitious material to reduce the substantial waste disposal problem and depletion of natural resources. The study is done to test the relevant properties using limestone as a partial replacement of cement, polypropylene fibre as an additive in concrete. Lime serves as a substitute for cement and enhances the compressive strength, split tensile strength and flexural strength of concrete. Also adding limestone powder increases the durability of concrete. Polypropylene fibres help in reducing the micro racks of concrete and also increasing the flexural and tensile strengths of concrete. Here we compare, the compressive strengths of different cubes caste with partially replaced limestone powder in the order of 5%, 10%, 15% and 20 %, with that of the nominal concrete cube. Out of the cubes cast above the maximum strength yielded and its corresponding percentage of limestone replacement is noted. The optimum value of fibre is found. The microstructure study of these samples is done using SEM, EDS and FTIR.

Keywords*: Concrete, durability, limestone, microstructure, polypropylene fibre.

I. INTRODUCTION

Fibres are added into the concrete to increase the mechanical properties like compressive strength, split tensile strength and flexural strength, also to control the microcracks. Polypropylene fibre is added to reduce the plastic shrinkage, impact resistance, abrasion and to increase the mechanical properties [1]. It also helps to reduce the tendency for heat-induced concrete spalling [2]. Adding of supplementary cementitious materials do not decrease the mechanical properties but increases the durability of the concrete with a proper mix design [3]. Limestone acts as a filler and an active reactor [4]. Cement and concrete are the most widely used materials in the construction industry. Due to the manufacturing process of cement matrix, a large amount of CO_2 is released into the atmosphere which causes the greenhouse effect, ozone layer depletion etc. To reduce the CO_2 emission, the cement is replaced with limestone, fly ash, silica fumes etc.[5].

The objective of the project is to study the mechanical properties like compressive strength, split tensile strength, flexural strength and durability tests such as RCPT, acid test. Also, the microstructure study includes SEM, XRF, EDS, FTIR for M40 concrete mix. This study focuses on the effect of partially replacing cement with limestone in various percentages 0%, 5%, 10%, 15%, 20% [6] and the addition of polypropylene fibre into the concrete mix (0%, 0.5%, 1%, 1.5%).

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II. MATERIALS AND METHODOLOGY

OPC of grade 53 affirming to IS:8112-1989 is used in this study. The specific gravity of cement used is 3.09. In this study river sand which free from impurities is used. The size of it is less than 4.75mm. The specific gravity of fine aggregate was found to be 2.27. The coarse aggregate used here is 20 mm in size and free from residue. The specific gravity was found to be 2.79. High-performance superplasticizer is used for obtaining high strength and moderate workability retentions. Properties of admixture are given in Table 1. Limestone powder was used as supplementary cementitious material. It is used in 5%, 10% and 15%. The properties of limestone powder are given in Table 2. Non- metallic polypropylene fibre was used for reinforcing and crack resisting in concrete. The fibre content varied from 0.5% to 1.5%. The properties of fibre are given in Table 3.

Table 1 Properties of Superplasticizer

Appearance	Liquid
Colour	Straw- brown
pH	6
Specific gravity	1.2
Viscosity	300 – 600 cps

Table 2 Properties of Limestone Powder

Chemical properties	
Lime as $Ca(OH)_2$	90%
Active CaO	68%
Acid- insoluble	Max 1%
Magnesia as MgO	Max 0.6%
Iron and Alumina as Fe_2O_3 and Al_2O_3	Traces
Physical properties	
Mesh	

Table 3 Properties of Polypropylene fibre

Length(mm)	6 ± 1
Diameter (µm)	20 ± 5
Aspect ratio (l/d)	300
Colour	Natural white
Materials form	Polyster

A. Concrete mix proportion

Concrete mix design was done as per IS 1026:2009 for M40 mix with a water-cement ratio of 0.4. The concrete mixes were optimized from a set of trial mixes.

B. Concrete mixing, casting and curing

The cement, coarse aggregate, fine aggregate and limestone powder were batched by weight basis and mixed using a mixer. Firstly, the dry ingredients were mixed. Then the superplasticizer (2% weight of cement) was mixed thoroughly with water and added to the mixer. To perform the strength tests cubes, cylinders and beams of steel mould were used. The inside surfaces of the collected moulds are daintily covered with oil to prevent the adhesion of concrete. The mix was put in the mould and compacted with a vibrating table. The specimens were the demoulded after 24hr and placed in a water tank.

III. EXPERIMENTAL WORKS

A. Compressive strength test

Concrete cubes of 150mm x 150mm x 150mm were used. The compressive strength test was carried out on 7day, 14day and 28day. The cubes are tested as per IS 516:1959 in the compressive strength test machine. The loads are applied continuously till the specimen breaks, the maximum load given to the cube were noted.

B. Split tensile strength

Cylinder specimens of 150mm diameter and 300mm length were used. Split tensile strength was tested on 7day, 14day and 28day and tested according to IS 516: 1959. The maximum load (P) at which the specimen breaks is noted.

C. Flexural strength test

Beams of size 1000mm x 500mm x 500mm were used. The test was carried out on 7day, 14day and 28day. The test was done confirming to IS 516: 1959 and the maximum load at which the specimen breaks was noted.

D. Rapid Chloride Penetration Test (RCPT)

The durability of the concrete specimen was found by (RCPT). The test was done as per the procedures are given in ASTM C1202. The cylinders of size 100mm diameter and 200mm length are cut in the size of 50mm length by core cutter. 60V DC is used in this experiment and it is carried out for 6hrs continuously. For every 30 minutes, the readings are taken. One lead is immersed in 0.3M NaOH solution and the other in 3% NaCl solution. The chloride permeability depends upon the charges passed through the specimen. The chloride permeability is high if the charge passed is above 4000. It is moderate if the charge passed is from 2000 to 4000 and the chloride permeability is low if the charge passed lies between 1000 to 2000. Also, the chloride permeability is very low if it is between 100 to 1000 and below 100 is negligible.

E. Microstructure study

For a better understanding of the properties of concrete microstructure study of the samples are required. It can also help to control the properties of concrete. The samples which are needed for the further investigation of microstructure study are crushed into a powdered form of size less than 90 micrometres. Scanning Electron Microscopy (SEM) analysis, Energy Dispersive Spectroscopy (EDS), X-Ray Diffraction (XRD) Analysis, Fourier-transform infrared spectroscopy (FTIR) are the most common techniques used to study the microstructure

IV. RESULTS AND DISCUSSIONS

A. Compressive strength

Figure 1 shows the compressive strength results for the three mixes tested on 7day, 14day and 28day. M1 is the conventional concrete, M2 is the mix with 10%limestone replacement and M3 is the mix with 10% limestone replacement and 1% polypropylene fibre.

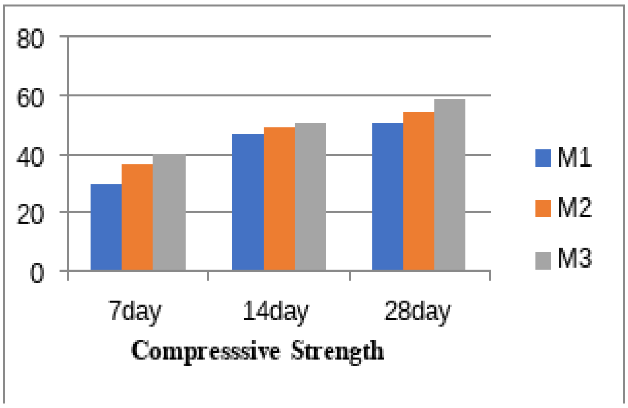

Fig 1 Compressive strength results

B. Split tensile strength

Split tensile strength of concrete for the mixes M1, M2 and M3 tested on 7day, 14day and 28day are shown in figure 2.

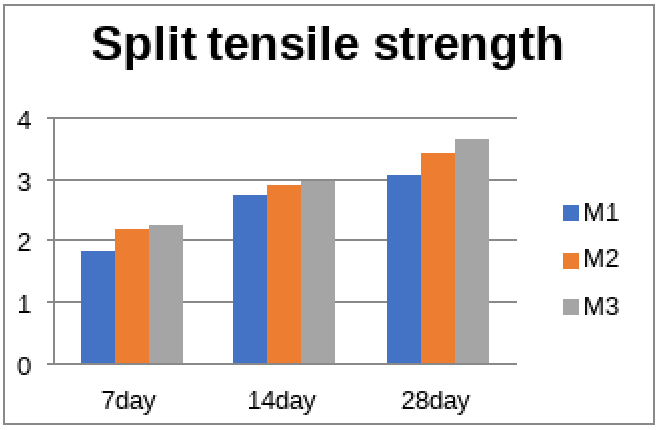

Fig 2 Split tensile strength results

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C. Flexural strength

Flexural strength of concrete for M1, M2 and M3 tested on 7day, 14day and 28day are shown in figure 3.

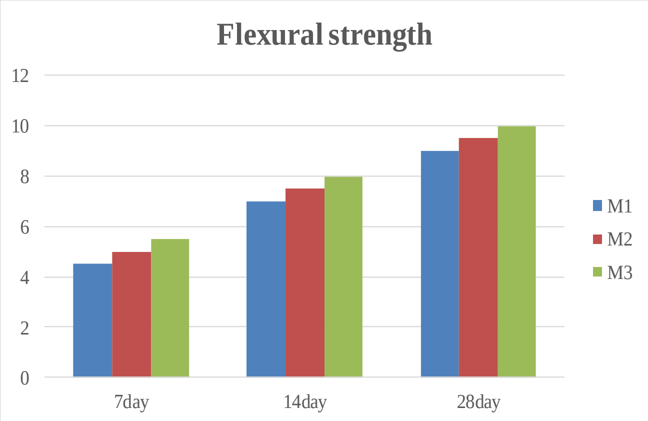

Fig 3 Flexural strength results

D. Regression Analysis

Regression analysis in statistical analysis is used to measure the relationship among variables. It encourages us to know how the estimation of the dependent factors changes when any of the independent factors is shifted, while the other independent factors are held fixed. The figure shows the regression analysis between compressive strength and tensile strength of the concrete. The R^2 value which is obtained from the graph is near to 1 which shows that the results are more accurate.

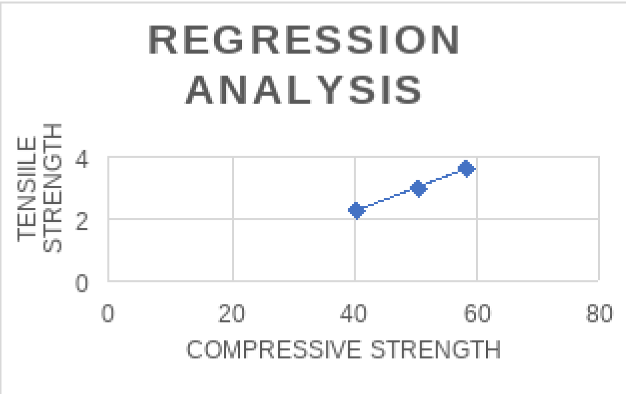

Fig 4: Regression analysis

E. Rapid Chloride Penetration Strength

Fig 4 shows the durability study of the three optimum mixes M1, M2 and M3. From fig 4 it indicates that M3 has more penetration value than M1 and M2. So M3 is less durable than M1 and M2.

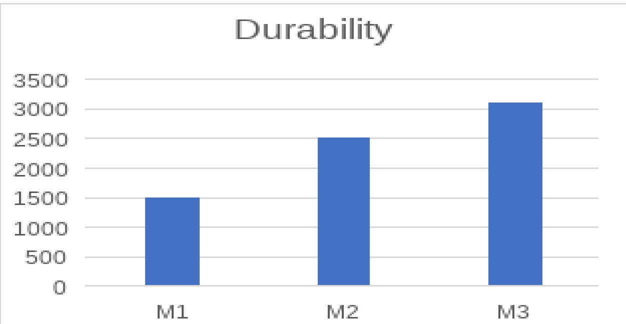

Fig 5 Durability Analysis

F. SEM and EDS Analysis

SEM analysis will help us to get a magnified image of samples topography and this will help to identify the hydrated, non-hydrated parts and also the voids present in the sample. SEM can scan the samples up to 1 nanometer. Figure 2 shows the SEM structure of conventional concrete (M1) which is closely compacted. the needle-like structure present in figure 1 is the ettringite. Figure 3 shows the microstructure of concrete with limestone (M2) where limestone acts as a filler and hence the voids are less. Figure 4 is of concrete with limestone and polypropylene fibre (M3) which has denser surface than with concrete having limestone, so the binding properties have increased.

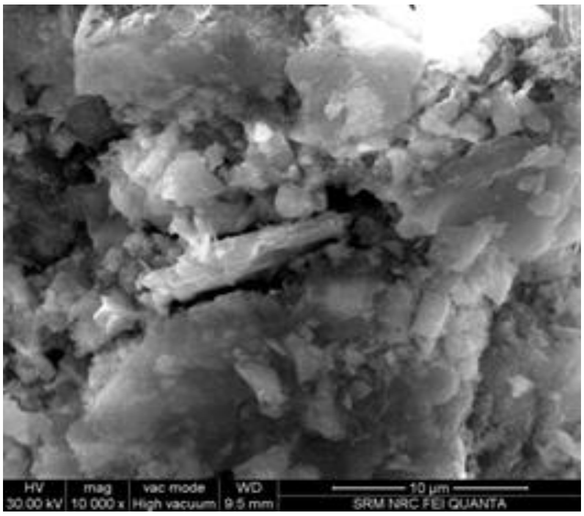

Fig 6 SEM Analysis of conventional concrete

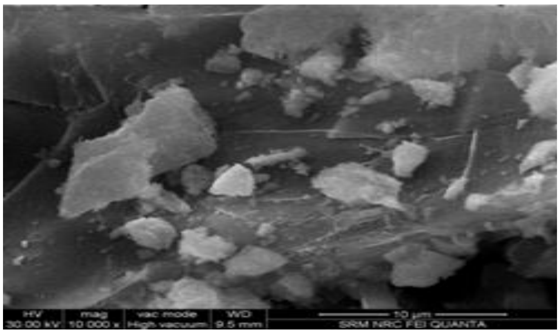

Fig 7 SEM Analysis of conventional concrete with limestone

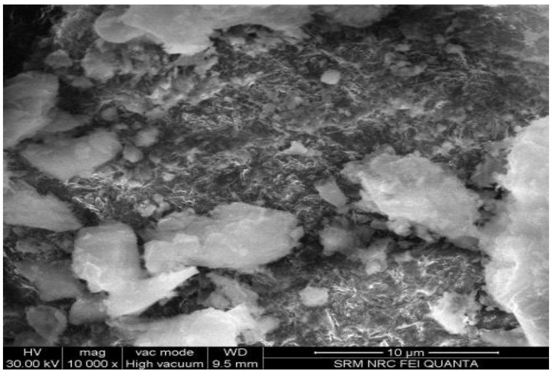

Fig 8 SEM Analysis of conventional concrete with limestone and polypropylene fibre

The chemical composition of the samples was determined using EDS analysis. Fig 9 shows the eds analysis of M1 mix; Fig 10 is of M2 and fig 11 is of M3. From the figures, it can be seen that Ca, Si and C are major constituents of the samples.

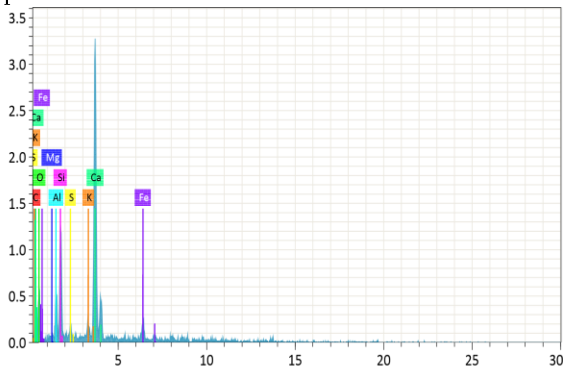

Fig 9 EDS Analysis of conventional concrete

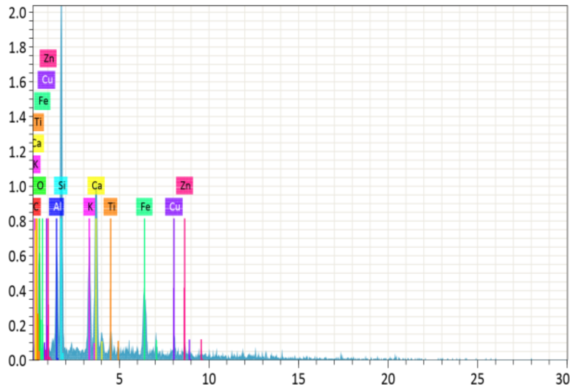

Fig 10 EDS Analysis of conventional concrete with limestone

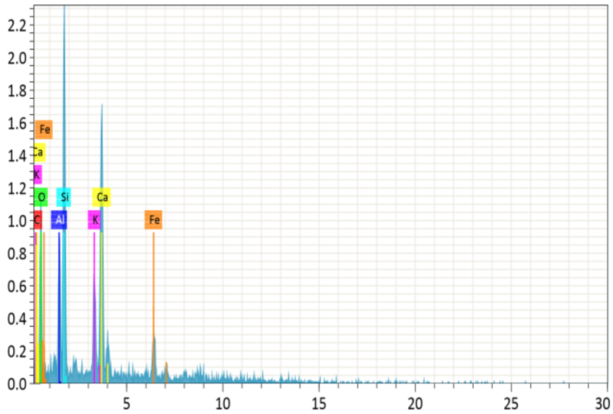

Fig 11 EDS Analysis of conventional concrete with limestone and polypropylene fibre

G. FTIR Analysis

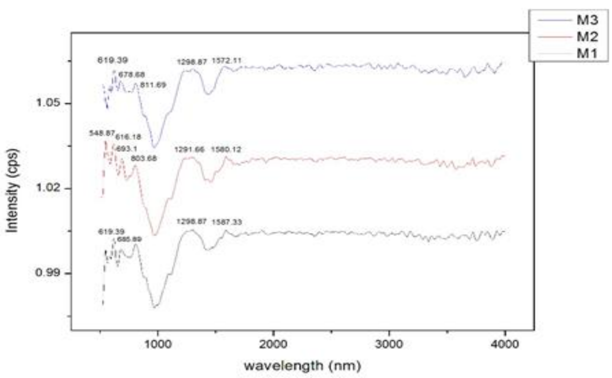

Fig 12 FTIR analysis of the samples

Fig 12 shows the FTIR spectra of the samples cured for 28 days. The C-O bending vibration occurs in the range of 800cm^{-1} whereas C-O stretch occurs between 1200cm^{-1} to 1300cm^{-1} range. CO_3^{2-} occurs at 1550cm^{-1} to 1600cm^{-1}. Peak around 619cm^{-1} shows Al-O. Si – O peak can be observed in the range of 670cm^{-1} to 690cm-^{1}. The intense peak is around 1000cm^{-1} shows Si – O – Si which is thermally stable. Peaks at 1000cm-1 show the Si – O vibrations.

V. CONCLUSION

- Mix M3 with 10% limestone replacement and 1% of polypropylene fibre gives the optimum strength as maximum compared to M2 and M3 in compressive, split tensile and flexural strength test.
- Regression analysis shows that compressive strength is directly proportional to tensile strength.
- From the SEM analysis, it is observed that by adding limestone and polypropylene fibre the surface has become denser and better binding.
- With the help of EDS, Ca, Si and C were identified as the major constituents..

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