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Experimental Investigation On Crimped Steel Fiber In M30 Concrete With Treated Rubber Powder As Partial Replacement Of Fine Aggregate

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ABSTRACT : Concrete is most popularly used construction material having several desirable properties like high compressive strength, stiffness and durability under usual environmental factors. Plain concrete has very low tensile strength, limited ductility and a low strain at fracture. It has been delivered that concrete reinforced with endurable amount of fibre acquires better performance in compression, flexural, toughness and energy absorption. Cubes of size 150mmX150mmX150mm to check the compressive strength and beams of size 500mmX100mmX100mm for checking flexural strength were casted and cylinders of size 100mm Diameter and 200mm depth to check the split tensile strength. All the specimens were cured for the period of 7, 14 and 28 days before crushing. Physical properties of various materials used in this project were carried out and result were tabulated.M30 grade concrete mix design was worked out and proportion were given based on the mix design and control concrete specimens were casted and 7,14 and 28 days strength was tabulated. In future, Steel fibres content were varied by (0.5%, 1.0%, and 1.5%, 2%). All the specimens were cured for the period of 7, 14 and 28 days before crushing and treated rubber various percentage of replacement on fine aggregate (2.5%,5%,7.5% ,10%) and its viability for replacement are discussed in this project.

KEY WORDS: Crimped steel fibre, Treated rubber, Compressive strength, Split Tensile Strength, Flexural strength.

1. Introduction

Concrete is most popularly used construction material having several desirable properties like high compressive strength, stiffness and durability under usual environmental factors. Plain concrete has very low tensile strength, limited ductility and a low strain at fracture. This shortcoming is offset by providing steel bars at appropriate locations at the time of casting the members to bear up the tensile stresses and sometimes the compressive stresses if required[1]. The crimped steel fibres are made of either carbon steel or stainless steel. Crimped steel fibre crimped steel fibre of length 50mm, diameter 1mm. Steel fibers are defined as short, discrete length of steel having an aspect ratio (AR) from 20 to 100 with any cross-section. Aspect ratio means the ratio of length to diameter. The current study adopted an aspect-ratio 50 inside this undertaking. Within this endeavour, we utilize the fiber for increasing the strength of concrete. Crimped steel fibers are have been put into concrete to boost properties such as tensile and flexural strength. The iron content increases the flexural strength up to 25-100% depending upon the ratio of fiber included[2]. Treated rubber is recycled rubber produced from automotive and truck scrap tires. Shredding waste tires and removing steel debris found in steel-belted tires generates Treated rubber. Treated rubber is fine rubber particles ranging in size from 0.075-mm to no more than 4.75-mm[3]. M-sand is artificial sand produced from crushing hard stones into small sand sized angular shaped particles, washed and finely graded to be used as construction aggregate. It is a superior alternative to River Sand for construction purpose[4]. IS 10262 Concrete mix design Concrete mix design is the process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required workability, strength and durability as economically as possible[5]. IS: 2386 gives the methods of test for aggregates for concrete. It has various parts such as: Part I-1963 for Particle size and shape. Part II-1963 for Estimation of deleterious materials and organic impurities[6].

Crumb rubber is recycled rubber produced from automotive and truck scrap tires. During the recycling process, steel and tire cord (fluff) are removed, leaving tire rubber with a granular consistency.[7] Continued processing with a granulator or cracker mill, possibly with the aid of cryogenics or by mechanical means, reduces the size of the particles further. The particles are sized and classified based on various criteria including color (black only or black and white). The granulate is sized by passing through a screen, the size based on a dimension (1/4 inch)[8].

The present work is an attempt to utilize adding of crimped steel fibre and rubber powder particles as a partial replacement of fine aggregates in cement concrete to investigate its mechanical and dynamic characteristics. Experimental data for different mechanical and dynamic properties are obtained by curing test samples in water for a period of 7, 14, 21 and 28 days, respectively. Rubber has a good shock absorbing capacity which can be useful in improving the damping capacity and impact resistance of concrete structures.

2. Experimental investigation

2.1 Materials

2.1.1 Cement

Ordinary Portland cement of 53 grades conforming to IS: 12269-1987 was used for the present experimental investigation. The following experiments were conducted to identify the properties of cement as per IS code. The properties of cement are shown in table 1.

Table 1 Properties of Cement

Properties of cement				
Standard consistency	**Specific gravity of cement**	**Fineness test**	**Initial setting time**	**Final setting time**
32%	3.16	7.11%	60 minutes	400 minutes

2.1.2 Fine Aggregate

Fine aggregate is sand, which is usually obtained from rivers or lakes. In places where sand is not available or a large quantity of sand is required, crushed stone dust is used. The fine aggregate should be free from clay particlesbecause it reduces strength and it takes more amount of water during the period of concrete mixing. Tests Performed on Fine Aggregates as per IS 383-1970.The properties of the fine aggregate are shown in Table 2.

Table 2 Properties of Fine Aggregate

Properties of fine aggregate				
Sieve analysis of river sand	**Sieve analysis of M-sand**	**Specific gravity of river sand**	**Sieve analysis of M-sand**	**Water absorption test**
2.58	2.84	2.63	2.73	0.5%

2.1.3 Coarse Aggregate

Coarse aggregates confirming to IS 2386-1963 was used. Coarse aggregate shall consist of naturally occurring materials such as gravel or resulting from the crushing of parent rock, including natural rock, slags, expanded clays and shelves (lightweight aggregates) and other approved inert materials with similar characteristics, having hard, strong, durable particles, conforming tothe specific requirements of this Section. The aggregate gives volume, stability, resistance to wear or erosion, and other desired physical properties to the finished product. Aggregate of size 12mm and The properties of the fine aggregate are shown in Table 3.

Table 3 Properties of Coarse aggregate

Properties of coarse aggregate				
Sieve analysis of coarse aggregate	**Specific gravity of Coarse aggregate**	**Water absorption test**	**Impact test**	**Abrasion test**
7.33	2.65	0.98	10,28	10.8

2.1.4 Treated Rubber

Treated rubber is recycled rubber produced from automotive and truck scrap tires. Shredding waste tires and removing steel debris found in steel-belted tires generates Treated rubber. Treated rubber is fine rubber particles ranging in size from 0.075-mm to no more than 4.75-mm. The properties of Treated rubber are shown in Table 4.

Table 4 Properties of Treated rubber

Properties of Treated rubber	**Specific gravity**	2.01

2.1.5 Crimped Steel Fibre

The crimped steel fibres are made of either carbon steel or stainless steel. Crimped steel fibre crimped steel fibre of length 50mm, diameter 1mm. Steel fibers are defined as short, discrete length of steel having an aspect ratio (AR) from 20 to 100 with any cross-section. Aspect ratio means the ratio of length to diameter. The current study adopted an aspect-ratio 50 inside this undertaking. Within this endeavour, we utilize the fiber for increasing the strength of concrete. Crimped steel fibers are have been put into concrete to boost properties such as tensile and flexural strength. The iron content increases the flexural strength up to 25-100% depending upon the ratio of fiber included. . The properties of Crimped steel fiber are shown in Table 5.

Table 5 Properties of Crimped steel fibre

Properties of Crimped steel fibre		
Density(kg/m^3)	**Aspect ratio (l/d)**	**Tensile strength (Mpa)**
7850	50	1098

2.2 MIX PROPORTIONING

Concrete mix design in this experiment was designed as per the guidelines in IS 10262-2009. All the samples were prepared using design mix. M30 grade of concrete was used for the present investigation. Mix design was done based on I.S 10262-2009. The table 5 shows mix proportion of concrete (Kg/m^3).

Table 6 Mix proportion of concrete

MIX PROPORTIONING	CEMENT (kg)	FINE AGGREGATE (river sand)(kg)	M-Sand (kg)	COARSE AGGREGATE (kg)	WATER (kg)	STEEL FIBRE (kg)	RUBBER POWDER (kg)
C.C	425.73	647.11	-	1110.21	191.58	-	-
C.CM	425.73	-	639.73	1110.21	191.58	-	-
C.M.SF 0.5%	425.73	-	639.73	1110.21	191.58	0.584	-
C.M.SF 1%	425.73	-	639.73	1110.21	191.58	1.285	-
C.M.SF 1.5%	425.73	-	639.73	1110.21	191.58	2.158	-
C.M.SF 2%	425.73	-	639.73	1110.21	191.58	2.879	-
C.M.RP 2.5%	425.73	-	612.632	1110.21	191.58	-	0.697
C.M.RP 5%	425.73	-	613.25	1110.21	191.58	-	1.394
C.M.RP 7.5%	425.73	--	613.946	1110.21	191.58	-	2.091
C.M.RP 10%	425.73	-	614.64	1110.21	191.58	-	2.788
COMBINED [SF 1% + RP 10%]	425.73	-	614.64	1110.21	191.58	1.285	2.788

C.C = Conventional concrete , C.CM = Conventional concrete with M-sand,
C.M.SF = Concrete with M-sand & Steel fiber , C.M.RP = Concrete with M-sand & Rubber powder ,
COMBINED = Concrete with M-sand & Steel fiber and Rubber powder.

3. FRESH CONCRETE PROPERTIES:

The following tests were conducted to determine the fresh concrete properties.

Test on fresh concrete

1. Slump cone Test
2. Compacting Factor test

3.1 Slump cone Test:

This test is performed to measure the workability of fresh concrete as per IS 1199-1959. Slump cone test is the most commonly used method of measuring consistency of concrete. It is used conveniently as a control test and gives an indication of the uniformity of concrete. Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slump. The apparatus for conducting the slump test essentially consist of a metallic mould in the form of frustum of the cone having the internal dimension of bottom diameter 20cm, top diameter 10cm, and a height of 30cm.

Slump cone = 30 cm height

Slump = 15 cm

Fig 1: Slump cone Test

3.2 Compacting Factor test:

Compaction factor test is the workability test for concrete conducted in laboratory. The compaction factor is the ratio of weights of partially compacted to fully compacted concrete. It was developed by Road Research Laboratory in United Kingdom and is used to determine the workability of concrete as per IS1199:1959 Compaction factor test apparatus consists of two conical hoppers and a bottom cylinder which is arranged as shown in Fig, steel rod of1.6cm Diameter with a length of 61cm is used to tamp the concrete and a weightbalance is used to weight the concrete.

Compaction factor = (W2-W1)/ (W3-W1)

Table 7 Workability of fresh concrete

Workability	
Slump cone Test	**Compacting Factor test**
76	0.83

Fig 2: Compacting Factor test

4. HARDENED CONCRETE PROPERTIES:

The various strength properties of M-sand concrete are discussed below.

Test on Hardened concrete

1. Compressive strength test
2. Split tensile strength test
3. Flexural strength test

4.1 Compressive strength test

150 mm cube specimens were tested under compressive load in the respective to the age of curing. All the specimens were tested in saturated surface dry condition, after wiping out the surface moisture. For each mix combination, three identical specimens were tested at the ages of 7, 14, 28 days using compression testing machine of 2000 KN capacity under a uniform rate ofloading of 140 kg/cm^2/min. and the compressive strength was calculated as per IS: 516 – 1959.

Compressive Strength (f) = (P/A) N/mm^2

Where,

P = Load at which specimen fails in Newton,

A = Area over which the load is applied in mm^2

f = Compressive Stress in N/mm^2

Fig 3: Compressive strength test apparatus

4.2 Split tensile strength test

This is an indirect test to determine the tensile strength of cylindrical specimens. Split tensile strength tests were carried out on 100 mm dia.x200 mm high cylindrical specimen at the ages of 28 days of moist curing, using compression testing machine of 2000 N capacity as per IS 5816-1999.

Split tensile strength (ft) is estimated from the expression

$$T = 2P / \pi DL \ \ N/mm^2$$

Where,

T = Split tensile strength of concrete

P = Ultimate Load (Newton)

D = Diameter of cylinder (mm)

L= Length of cylinder (mm)

Fig 4: Split tensile strength test apparatus

4.3 Flexural strength test

In order to determine the flexural strength of concrete, prismatic specimens of a size 100 mm x 100 mm x 500 mm were cast with various proportions of all the concrete mixtures. After 28 days of moist curing the specimens were tested in flexural testing machine under a uniform rate of loadingof 180 $kg/cm^2/min$. Flexural strength of specimens expressed as the modulus of rupture (fb) is then calculated using the formula and procedure given in IS: 516- 1959.

When the distance between the line of fracture and the nearer support, measured on centre line of the tension side of specimen ('a' in mm) is greater than133 mm for prism of size 100 mm x 100 mm x 500 mm, the modulus of rupture (fb) is then calculated from the Equations.

$$(fb) = Pl/ bd^2$$

For 'a' is less than 133 mm but greater than 110 mm for prismspecimen, then modulus of rupture is calculated from the formula.

$$(fb) = 3Pa / bd$$

where,

b = Width of the specimen (mm)

d = Depth of the specimen (mm)

l = Length of the specimen (mm) on which specimen isSupported (span)

P = Maximum load (Newton) applied on the specimen

a = The distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen.

Fig 5: Beam testing machine

4.4 EXPERIMENTAL PROCEDURE

The specimen of standard cube of (150mmx150mmx150mm) and standard cylinders of (200mmx100mm) and beam of (100mmx100mmx500mm) were used to determine the compressive strength, split tensile strength and flexural strength of concrete. Three specimens were tested for 7,14&28 days before crushing.

The following experiments are conducted on the specimen is the compressive strength test, split tensile strength test and flexural strength test.

5. Results and Discussion:

The normal concrete are tested for their performance by determining their compressive strength, splitting tensile strength and flexure strength development at different ages of 7^{th}, 14^{th} and 28^{th} days. The results obtained are discussed in detail in the following sections.

5.1 Compressive Strength Test

Compressive strength test is done as Per IS 516-1959. The test is conducted on Compression testing machine of capacity 2000 KN. Mechanical behaviour of concrete was studied for M30 grade of cubes were casted and cured for 7,14 and 28days.The compressive strength is computed from following formula.

Compressive Strength (f) = (P/A) N/mm^2

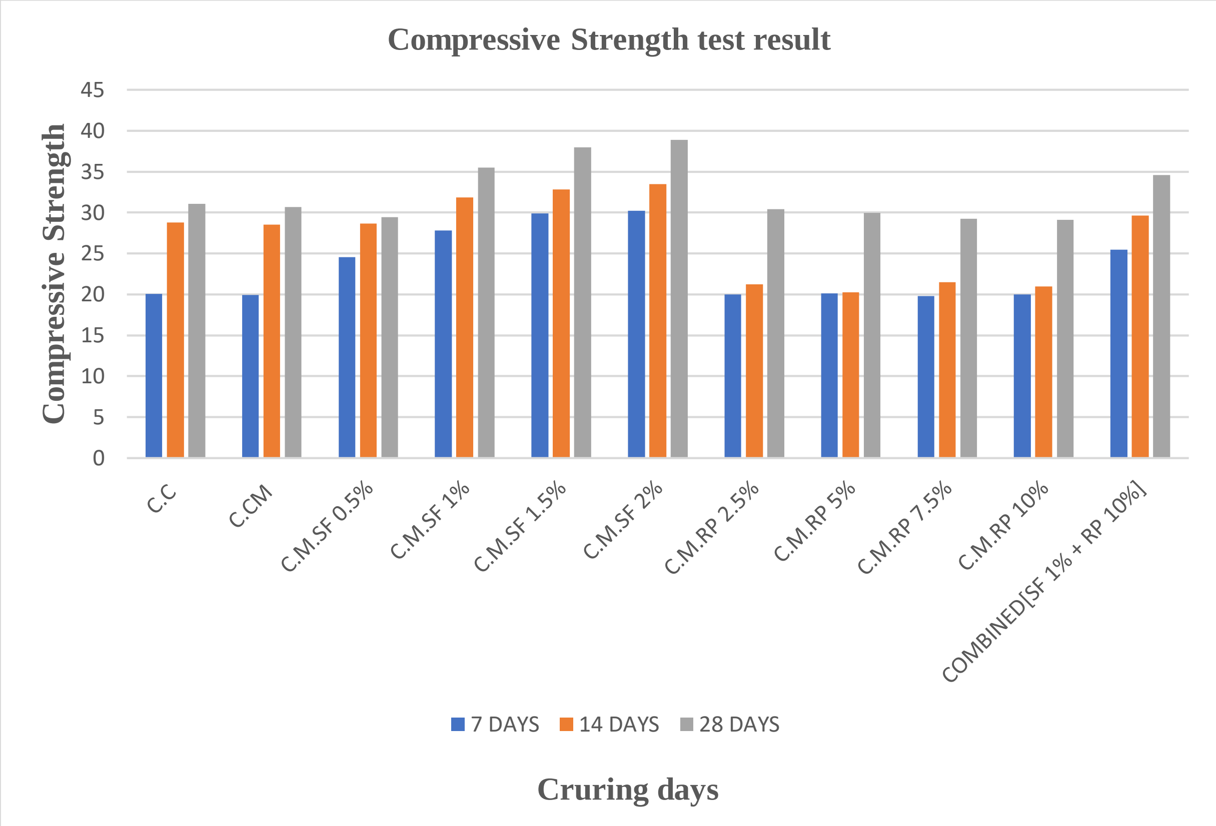

Fig 6 : Compressive strength test result

5.2 Split Tensile Strength test result

Split tensile strength is done as per IS 5816-1999. The test is conducted on Compression testing machine of capacity 2000 KN. The Split tensile strength is computed from the following formula.

T = (2P/π LD) N/mm^2

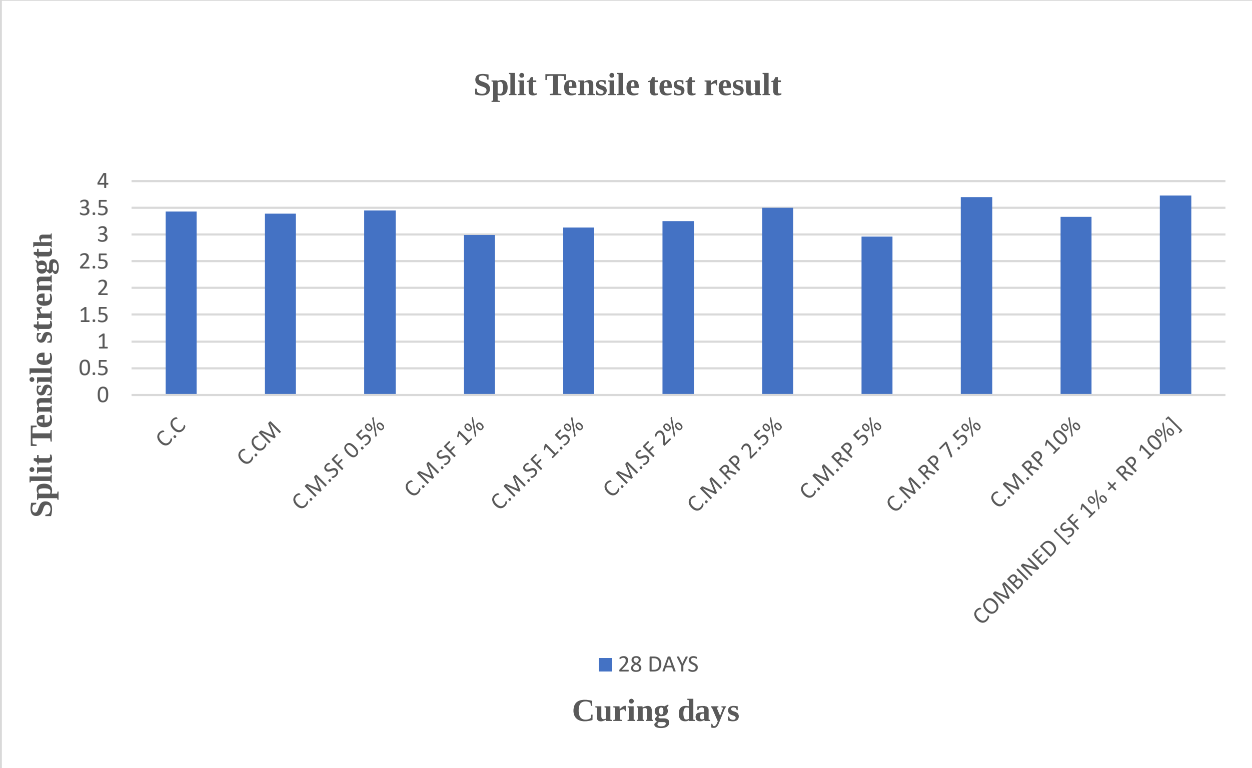

Fig 7 : Split Tensile test result

5.3 Flexural strength test result

In order to determine the flexural strength of concrete, prismatic specimens of a size 100 mm x 100 mm x 500 mm were cast with various proportions of all the concrete mixtures. then calculated using the formula and procedure given in IS: 516- 1959.

$$(fb) = Pl/ bd^2$$

For ‘a’ is less than 133 mm but greater than 110 mm for a100mm specimen, then modulus of rupture is calculated from the formula.

$$(fb) = 3Pa / b$$

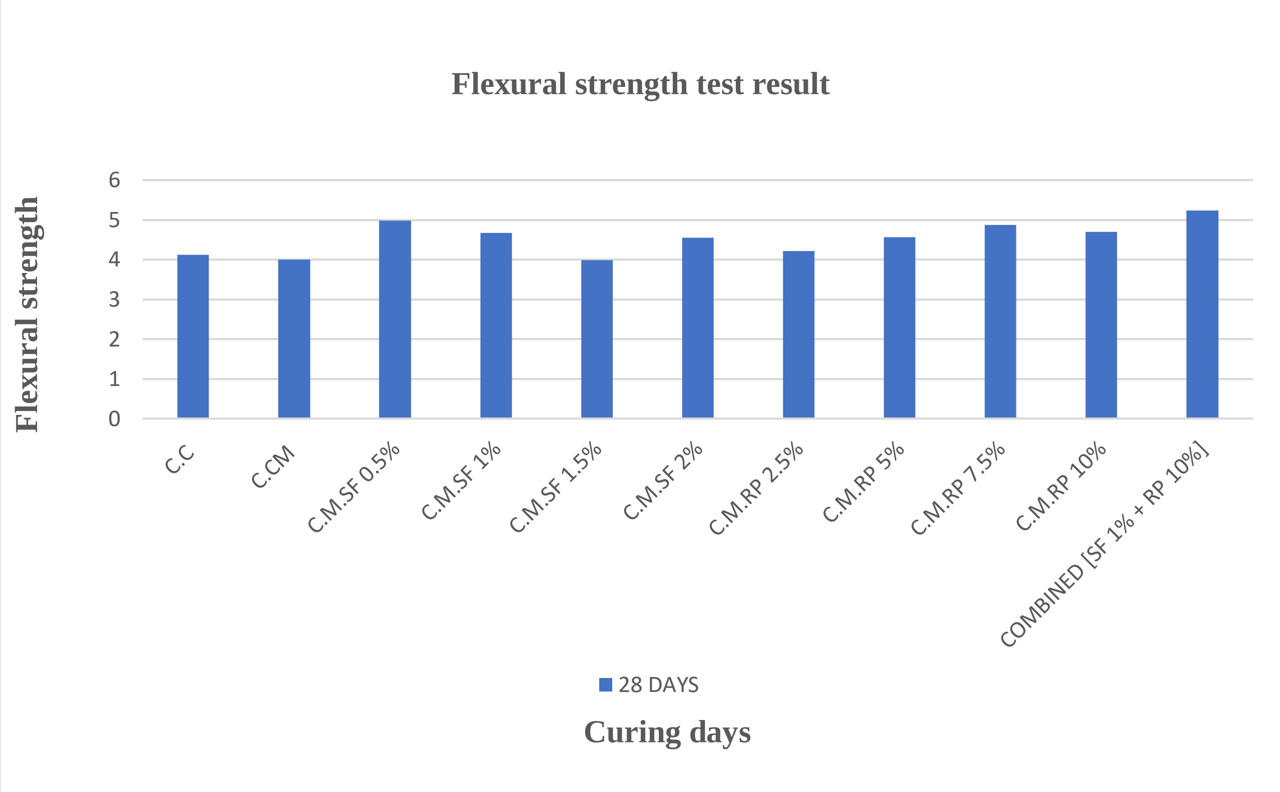

Fig 8: Flexural strength test result

5.4 SEM Analysis [Scanning Electron Microscopy]

The SEM technique can only be used for the evaluation of surface morphology like roughness, homogeneity of dispersion of nanomaterials in the polymer matrix. SEM is a method for high resolution surface imaging. The SEM uses electrons for imaging, much as light microscopy uses visible light. The advantages of SEM over light microscopy include greater magnification (up to 100,000X) and much greater depth of field.

Benefits of SEM testing include:

1. Digital image resolution as low as 15 nanometers
2. Magnification for all imaging is calibrated to a traceable standard. Image analysis for coating thicknesses, grain size determinations and particle sizing can be applied to the saved images.
3. Qualitative elemental analysis, standardless quantitative analysis, x-ray line scans and mapping can be performed on both of the SEM systems.

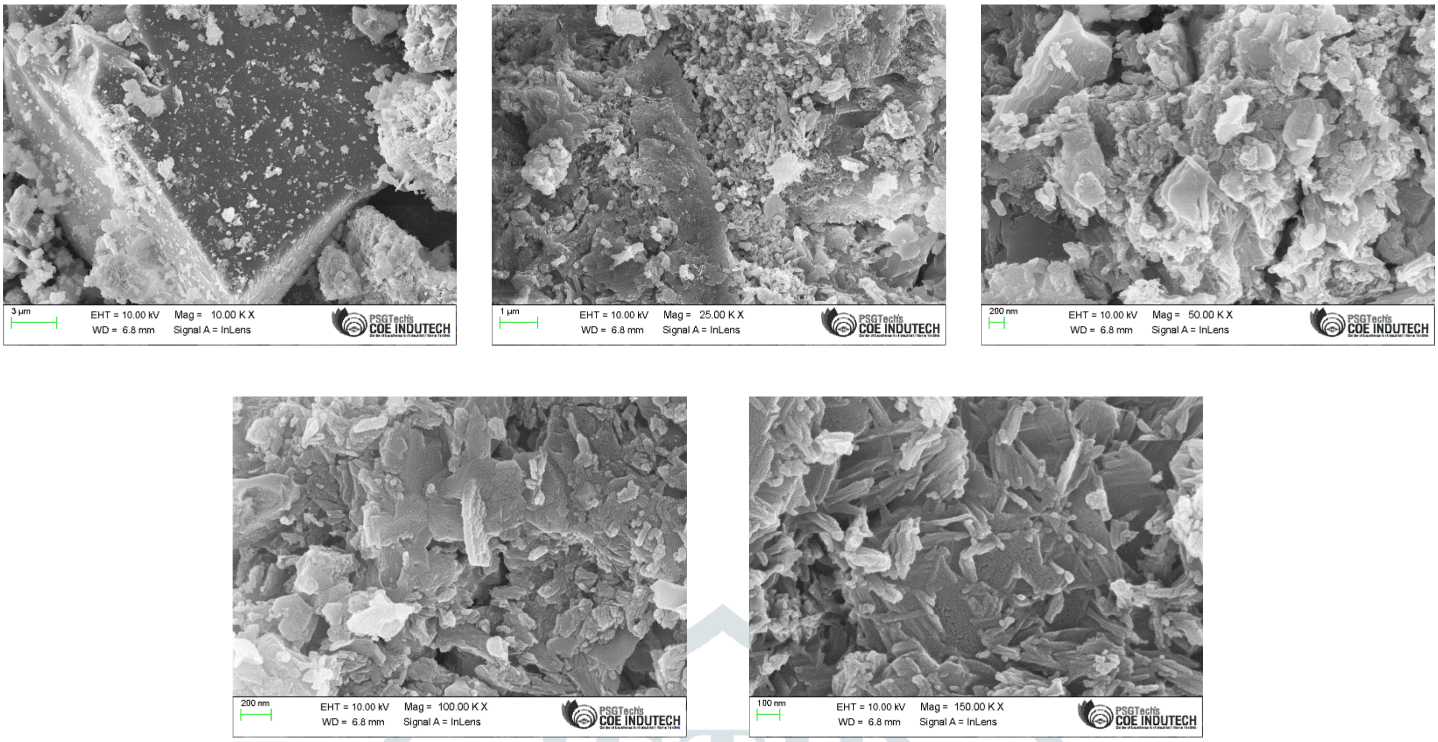

Fig 9: SEM Analysis Conventional concrete

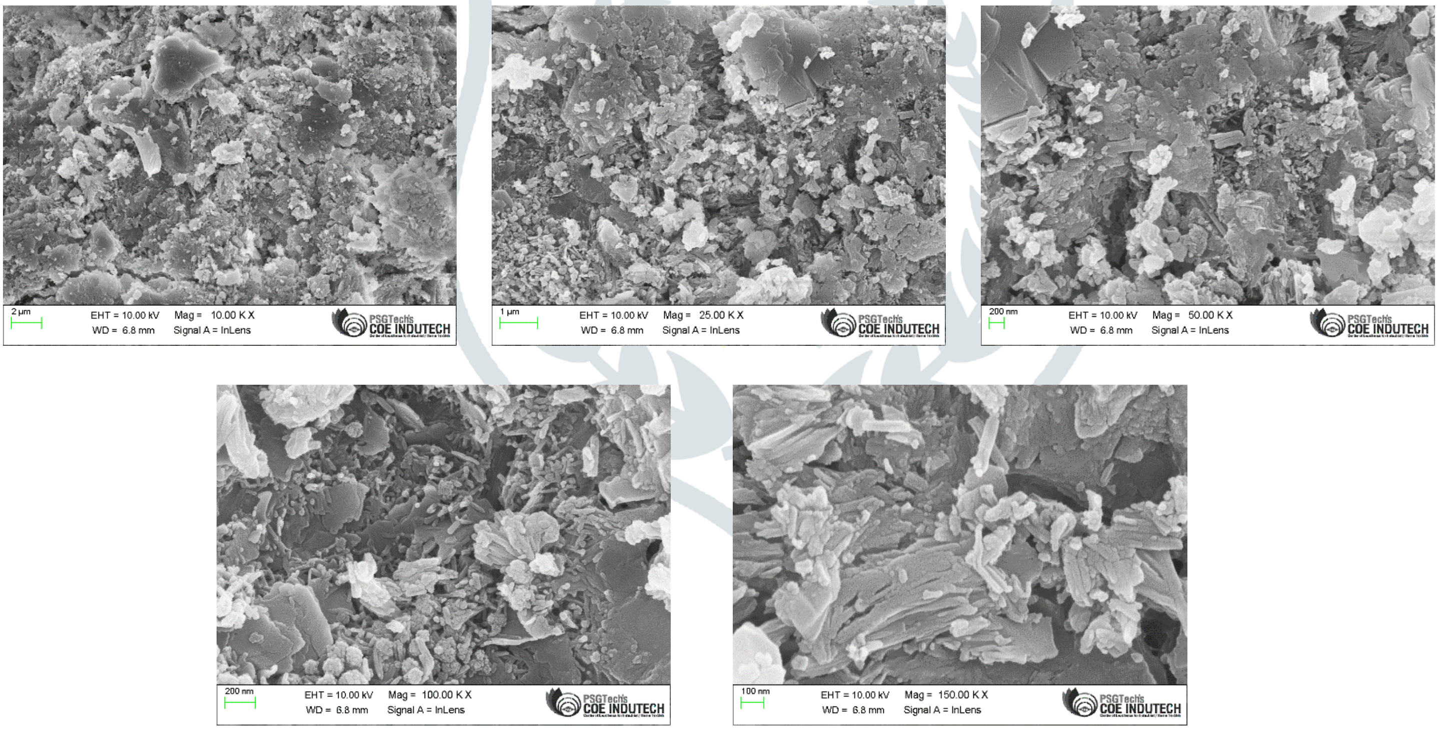

Fig 10: SEM Analysis Rubber powder

6. CONCLUSION

This study's investigation the effect of recycled treated rubber powder with crimped steel fibre at M30 grade concrete the steel fibre was taken at the percentage of 0.5%,1%.1.5%.2% & the rubber powder is taken as 2.5%,5%,7.5%,10%.the result of concrete mix with 1% steel fibre shows 15.78%. increase when compared to Conventional concrete mix with M-sand. The result of concrete mix with 10% of rubber powder shows 5.02% decrease when compared with to Conventional concrete mix with M-sand. The results of combination of concrete mix with rubber powder 10% & steel fibre 1% shows 12.75 %.when compare to Conventional concrete respectively.

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