STRENGTHENING PROPERTIES STUDY OF M20, M30 GRADE CEMENTS MIXED WITH POLYMER AND STEEL FIBERS WITH COURSE AGGREGATE

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ABSTRACT:

There is a growing awareness of the advantages of fibre reinforcement techniques of construction all over the world. Even though concrete possesses several desirable properties, its relative low tensile strength and deformation properties prompted many researchers to work on to improve these properties. One such development of improving or modifying the brittle characteristics of concrete is by supplementing the concrete matrix with fibre reinforcement. Steel Fibre Reinforced Concrete has become very popular due to its exceptional mechanical performance compared to the conventional concrete. The concrete is considered to be the second in consumption by mankind, first being the water. The manufacture of cement and steel causes several adverse impacts to the environment. It is inevitable to think about sustainable development by reducing the wastes generated or reusing it. This paper aims to have a comparative study between ordinary reinforced concrete and steel fibre reinforced concrete. The fibres which were used in the study were the turn fibres. They were the scraps from the lathe shops. Experimental investigations and analysis of results were conducted to study the compressive & tensile behaviour of composite concrete with varying percentage of such fibres added to it. The concrete mix adopted were M20 and M30 with varying percentage of fibres ranging from 0, 0.25, 0.5, 0.75 & 1%. On the analysis of test results the concrete with turn steel fibres had improved performance as compared to the concrete with conventional steel fibres which were readily available in market. These sustainable improvements or modifications could be easily adopted by the common man in their regular constructions.

***Index Terms**: Steel Fibre, Turn fibres, Compressive strength, Tensile strength, Sustainable.*

1.INTRODUCTION

Concrete is one of the most versatile building materials. It can be cast to fit any structural shape from ordinary rectangular beam or column to a cylindrical water storage tank in a high-rise building. It is readily available in urban areas at relatively low cost. Concrete is strong under compression but weak under tension. As such, a form of reinforcement is needed. The most common type of concrete reinforcement is by steel bars. The advantages in using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life. The disadvantages in using concrete include poor tensile strength, and formwork requirement. Other disadvantages include relatively low strength per unit weight. Tensile strength of concrete is typically 8% to 15% of its compressive strength. This weakness has been dealt with over many decades by using a system of reinforcing bars (rebars) to create reinforced concrete; so that concrete primarily resists compressive stresses and rebars resist tensile and shear stresses. The longitudinal rebar in a beam resists flexure (tensile stress) whereas the stirrups, which are wrapped around the longitudinal bar not only holds the longitudinal bars in position but also resist shear stresses. In a column, vertical bars resist compression and buckling stresses while ties resist shear and provide confinement to vertical bars. Cracks in reinforced concrete members extend freely until encountering a rebar and this is where the need for multidirectional and closely spaced reinforcement for concrete arises.

Reinforced bars (rebars), reinforcement grids, plates or fibres both organic and inorganic as well as composites have been incorporated to strengthen the concrete in tension. Steel fibre reinforced concrete (SFRC) comprises cement, aggregates and steel fibres. Steel fibre reinforcement cannot be regarded as a direct replacement of longitudinal reinforcement in reinforced and prestressed structural members. In tension, SFRC fails only after the steel fibre breaks or is pulled out of the cement matrix. Properties of SFRC in both the freshly mixed and hardened state, including durability, are a consequence of its composite nature. The mechanics of fibre reinforcement which strengthens concrete or mortar is a continuing research topic. One approach to the mechanics of SFRC is to consider it as a composite material whose properties can be related to the fibre properties (volume percentage, strength, elastic modulus, and a fibre bonding parameter of the fibres), the concrete properties (strength and elastic modulus), and the properties of the interface between the fibre and the matrix.

STEEL FIBRE REINFORCED CONCRETE:

the early 1900s, asbestos fibres were used to reinforce Portland cement. Even though reinforcing a brittle matrix with discrete fibres is an age old concept, modern day use of fibres in concrete started in the early 1960s. In the beginning, only straight steel fibres were used. The major improvement occurred in the areas of ductility and fracture toughness, even though flexural strength increases were also reported. The law of mixture was applied to analyze the fibre contributions. It was understood that fibre reinforced concrete can be designed to obtain a specific ductility or energy absorption. Research by Romualdi, Batson, and Mandel in the late 1950's and early 1960's represented the first significant steps towards development of steel fibre reinforced concrete (SFRC).

Fibres are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, and so cannot replace structural steel reinforcement. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. However, fibres which are too long tend to "ball" in the mix and create workability problems.

2.LITERATURE REVIEW

Syed ShamsuddinHussaini (2012) Griffiths conducted study to investigate the mechanical properties of glass fibre reinforced polyester polymer concrete. The author observed that the modulus of rupture of polymer concrete containing 20% polyester resin and about 79% fine silica aggregate is about 20MPa. The addition of about 1.5% chopped glass fibre to the material increase the modulus of rupture by about 20% and the fracture toughness by about 55%. Glass fibre improved the strength 0f the material by increasing the force required for deformation and improve the toughness by increasing the energy required for crack propagation soroushian reported the results of an experimental study on the relative effectiveness of different types of steel fibre in concrete. The author observed that the inclusion of fibres decreases the workability of fresh concrete and this effect is more pronounced for fibres with higher aspect ratios. The effects of fibre type on fresh mix workability, as represented both subjectively and by the inverted slump and cone time, seem to be insignificant crimped fibres result in slightly higher slump values when compared with straight and hooked fibre

RavikumarC.Selin, and Thandavamoorthy T. S. (2013) generally, concrete is strong in compression and weak in tesion. Concrete is brittle and will crack with the application of increasing tensile force. The incorporation of fibers into a brittle concrete can have the effect of controlling the growth and propagation of micro cracks as the tensile strain in the concrete increases. The use of fiber in concrete has increased with the development of fast-track construction. Glass fiber are useful because of their high ratio of surface area to weight

ShrikantHarle, Prof. Ram Meghe (2013) Concrete is the most widely used construction material and has several desirable properties like high compressive strength, stiffness and durability under usual environmental factors. Normally reinforcement consists of continuous deformed steel bars or pre-stressing tendons the strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementations material, aggregate and water by adding som special ingredients. Therefore concrete can be considered as a suitable material for a wide range of application. The experimental work was carried out by hand layup method for that GFRP sheet-were used, like E-class glass continuous filament mat and woven roving mat. From the experimental study on reinforced concrete beam it was found that cost of woven roving warp was more as compared to single mat and double mat warp but load carrying capacity also increased as compared single mat and double mat warp.

AvinashJoshi ,Pradeepreddy (2016) The various aspects covered are the materials, mix proportioning for M20, M25, M30, M40 grades of concrete. As the concrete is weak in tension, a work has been carried out to investigate the improvement in tensile, shear, flexure, and even compressive strength of concrete and also to investigate the cracking strength and reserve strength of concrete & FRC.M20, M25, M30, M40 grades of concrete have been added to investigate the compressive strength, tensile strength & shear strength of concrete. 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. The aspect ratio (50) and variable in this study were percentage of volume fraction (0, 0.5, 1.0 and 1.5) of steel fibers. Compressive strength, splitting tensile strength and flexural strength of the concrete were determined for the hardened properties. Their main purpose is to increase the energy absorption capacity and toughness of the material.

Arooj, M. F., Haydar, S., Ahmad, (2011)to meet the demands of any particular situation. In the true sense, concrete is thus the real building material rather than the ingredients like cement and aggregates, which are only intermediate products. This concept of treating concrete as an entity is symbolized with the progress of ready-mixed concrete industry, where the consumer can specify the concrete of his needs without bothering about the ingredients; and further in pre-cast concrete industry where the consumer obtains the finished structural components satisfying the performance requirements. Therefore, treating concrete in its entity as a building material In this context a concrete mix forms a 'system'. Concrete mixes are also characterised by the fact that, unlike the other common structural materials like steel, these are mostly manufactured at site; the inherent variability of their properties and need for proper quality control, therefore, become important considerations.

3.TEST ON MATERIALS

Mix design is made for M20 and M30 grade concrete accordance with the Indian Standard Recommended Method IS 10262-1982. At the beginning of the mixture design, binder content 385.5kg/m3(M20) and 420 kg/m3 (M30) and water– cement ratio 0.55(M20) and 0.44(M30) were kept constant and then, the volume of aggregate was determined for reference Portland cement concrete by assuming approximately2% air is trapped in fresh concrete. The volume of aggregate was used to determine the aggregate weight. Fresh concretes containing 2.5% to 20% rice husk ash as cement replacement in weigth basis were prepared by modifying the reference Portland cement concrete. Fresh fiber reinforced concretes containing 0.25%, 0.5%, 0.75% and 1.0% steel fiber in volume basis were prepared. Aggregate weight for a cubic meter was adjusted when rice husk ash or fiber introduced into concrete. The procedures for mixing the fiberreinforced concrete involved the following. First, the gravel and sand were placed in a concrete mixer and dry mixed for 1 min. Second, the cement and fiber were spread and dry mixed for1 min. Third, the mixing water (90%) was added and mixed for approximately 2 min.min. Finally, the freshly mixed fiber-reinforced concrete was cast into specimens mold and vibrated simultaneously to remove any air remained entrapped. After casting, each of the specimens was allowed to stand for 24 h in laboratory before demanding.

Specific Gravity:

The main objective of this test is to determine the specific gravity of aggregates such as sand, gravel and recycled aggregate used in this study.Specific gravityis the weight of aggregate relative to the weight of equal volume of water. The specific gravity of an aggregate is generally required for calculations in connection with cement concrete design work for determination of moisture content and for the calculations of volume yield of concrete. The specific gravity also gives information on the quality and properties of aggregate. The specific gravity of an aggregate is considered to be a measure of strength of quality of the material.

Now the percentage of moisture is given by the formula [(W2-W3) / (W3)] ×100

	Fine aggregate	Coarse aggregate	Recycled aggregate
Specific gravity	2.6	2.77	2.45
Bulk density	1.6 gm/cc	1.65 gm/cc	1.8 gm/cc
Fineness modulus	3.07	6.7	-
Moisture content	0%	0%	2.28 %
Absorption rate	0.5%	0.35%	3.5%

WATER

The results of tests on water are given in table 3.3

S.No	Test		Permissible value as per code
1	Alkalinity(12 ml of 0.02N, H_2SO_4 is consumed for 50ml sample)	240 mg/l	265 PPm of carbonates
2	Suspended matter	10mg/l	2000mg/l
3	Acidity	40 mg/l	49 PPm of H_2SO_4
4	Chlorides	60 mg/l	2000 mg/l
5	Sulphates	28 mg/l	400 mg/l
6	Inorganic	295 mg/l	3000 mg/l
7	Organic	35 mg/l	200 mg/l
8	P_h value	7.7	≥ 6

MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states.

If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.
The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.
The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.

REQUIREMENTS OF CONCRETE MIX DESIGN

The requirements which form the basis of selection and proportioning of mix ingredients are:
a) The minimum compressive strength required from structural consideration
b) The adequate workability necessary for full compaction with the compacting equipment
available.
c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions
d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

Table no 4.1 standard deviation

Grade of concrete	Assumed standard deviation n/mm2
M10,M15,M20	3.5
M25,M30,M35	4.00
M40,M45,M50	5.00

table estimation of entrapped airThe air content is estimated from table for the normal maximum size of aggregate used.

Maximum size of aggregate mm	Entrapped air.as% of volume of concrete
10	3.0
20	2.0
40	1.0

Table no 4.2 approximate entrapped air content.

Selection of water content and fine aggregate to total aggregate ratio:

The water content and percentage of sand in total aggregate by absolute volume are determined from table numbers 4.3 and 4.4 for medium (below gradeM35) and high strength (above grade M35) concrete respectively. Both values are based on following conditions:

Crushed (angular) coarse aggregate, conforming to IS:383-70

Fine aggregate consisting of natural sand conforming to grading zoneIIof table of IS383-70

Workability corresponds to compacting factor of 0.80(slump 30mm approximately).

For w/c=0.60, workability=0.80c.f (concrete grade up to m35)

Maximum size of aggregate	Water content including surface water. Per cubic meter of concrete(kg)	Sand as per cent of toatal aggregate by absolute volume
10	200	40
20	186	35
40	165	30

Table no 4.3 approximate sand and water content per cubic meter of concrete.

For w/c =0.35, workability= 0.80c.f (grade above m35)

Maximum size of aggregate	Water content including surface water per cubic meter of concrete(kg)	Sand as per cent of total aggregate by absolute volume
10	200	28
20	180	25

Table no 4.4 approximate sand and water contents per cubic meter of concrete.

Calculation of cement content:

The cement content per unit volume of concrete may be calculated from free water-cement ratio and the quantity of water per unit volume of concrete(cement by mass = water content/ water cement ratio.

Calculation of aggregate content: Aggregate content can be determined from the following equations:

V= [w + c/Se +1/p *fa/Sfa]*1/1000

Ca= (1-p)/p *fa*Sca/Sfa

Where

V= absolute volume of fresh concrete, which is equal to gross volume (m3) minus the volume of entrapped air.

W= mass of water (kg) per m3 of concrete

C= mass of cement (kg) per m3 of concrete

Sc= specific gravity of cement

P= ratio of FA to total aggregate by absolute volume

Fa,ca= total masses of FA and CA (kg)per m3 of concrete respectively

Sfa, Sca= specific gravities of saturated, surface dry fine aggregates and coarse aggregate repectively.

Actual quantities required for mix:

It may be mentioned that above mix proportion has been arrived at on the assumption that aggregate are saturated and surface dry. For any deviation from this condition i.e when aggregates are saturated are moist or air dry or bone dry, correction has to be applied on quantity of mixing water as well to the aggregate.

The calculated mix proportions:

Mix proportions shall be checked by means of trial batches. Quantities of materials for each trial shall be enough for atleast three 150mm size cubes and concrete required to carry out workability test according to IS :1199-59.

Calculation of M20 grade concrete mix:

Design stipulations:

Characteristic compressive strength required. In the field at 28 days-20mpa
Maximum size of aggregate-20mm
Degree of workability- 0.90
Degree of quality control-good
Type of exposure- mild
Test data for materials:-Specific gravity of cement-3.15
Compressive strength of cement at 7 day-satisfies the requirement

Specific gravity of coarse aggregate- 2.60
Specific gravity of fine aggregate- 2.60
Water absorption Coarse aggregate 0.50%
Fine aggregate 1.0%
Free surface moisture
Coarse aggregate Nil
Fine aggregate 2.0%

Sieve analysis is shown below

Coarse aggregate

Sieve size mm	Analysis of coarse aggregate fractions(%passing)		Percentage of different fractions			remarks
	I	II	I 60%	II 40%	Combined 100%	
20	100	100	60	40	10	Conforming
10	0	710 20	0	28.5	28.5	To table 2
4.75		9.40		3.7	3.7	IS:383-
2.36						1970

Fine aggregate

Sieve sizes	Fine aggregate (% passing)	remarks
4.75mm	100	Conforming to
2.36mm	100	Grading
1.18mm	93	ZoneIII
600microns	60	Of table 4
300 microns	12	IS:383-
150microns	2	1970

target mean strength of concrete:

The target mean strength for specified characteristics cube strength is

20+1.65*4 =26.6mpa

selection of water- cement ratio:

The water cement ratio required for the target mean strength of 26.6 mpa is 0.50.this is lower than the maximum values of 0.55 prescribe for mild exposure adopt w/c ratio of 0.50.

selection of water and sand content:

For 20mm maximum size aggregate, sand conforming to grading zoneII,water content per cubic meter of concrete=186kg and sang content as percentage of total aggregate by absolute volume = 35 percent

For change in value in water –cement ratio,compacting factor, for sand belonging to zoneIII, following adjustment is required

Change in condition	Percent adjustment required	
	Water content	sand in total aggregate
For decrease in water cement ratio by (0.60-0.50) that is 0.10	0	-2.0
For increase in compacting factor(0.9-0.8)that is 0.10	+3	0
For sand conforming to zoneIII of table IS383-1970	0	-1.5
Total	+3	-3.5

Therefore, required sand content as percentage of total aggregate by absolute volume= 35-3.5= 31.5%

Required water content =186+5.58= 191.6l/m3 determination of cement content: Water-cement ratio =0.50 Water =191.6litre Cement= 191.6/0.50=383kg/m3

Therefore cement content is adequate for mild exposure condition (G). determination of coarse and fine aggregate contents: The specified maximum size of aggregate of 20mm, the amount of entrapped air in the wet concrete is 2 percent. Taking this into account and applying values in formula

0.98= [191.6+383/3.15+1/0.315*fa/2.60]1/1000
Fa=546 kg/m3.
Ca= (1-0.315)/0.315*546*2.6/2.6=1188kg/m3 fly ash (along with cement) as the cementitious material which was generally adopted by many RMC plants widely.

4.TEST RESULTS AND DISCUSSIONS

CASTING AND TESTING:

Casting and testing of concrete cubes, cylinders, beams were done as per IS code recommendations. The proportioning of concrete mixes consists of determination of the quantities of respective ingredients necessary to produce concrete having adequate, but not excessive, workability and strength for the particular loading and durability for the exposure to which it will be subjected. Emphasis is laid on making the most economical use of available materials so as to produce concrete of the required attributes at the minimum cost. The basic assumption made in mix design is that the compressive strength of workable concrete is governed by the water cement ratio. The concrete mix adopted was M20 and M30 concrete with varying percentage of fibres ranging from 0, 0.25, 0.5, 0.75 & 1%. Even though the mix design need not be done for the basic mixes of M20 it was verified by designing it as per the quality of the material and other conditions. The M30 concrete mix design was carried out by incorporating the

Table 1 Mix proportion of M20:

Free Water	Cement	FA	CA
191.5	383kg	572.1kg	1161.6kg

Table 2 Mix proportion of M30:

Free Water	Cement & FA	FA	CA
163	300kg +100kg	622 kg	1227 kg

Nominal concrete cubes (15 cm x 15 cm x 15 cm), concrete cylinders (15 cm diameter and 30 cm long). A mixture of irregular and crimped shaped fibres (3cm - 4cm length) were mixed with the aggregate while casting the specimens, it was made sure that fibres were uniformly distributed throughout the mix.

Tests results:

Tests were conducted on concrete cubes using varying percentage of fibres to check for variations in compressive strength. Tests were conducted on concrete cylinders using varying percentage of fibres to check for variations in splitting tensile strength. For conducting the tests of compressive strength, two sets of ten cubes each of M20 & M30 mix were cast without fibres. Later, different sets of cubes were cast with fibre content ratio as 0.25%, 0.5% and 0.75%. The cubes were then transferred to curing tank for the required period of cur-ing and tested. The results of compressive strength of M20 & M30 grade concrete cubes on 7th and 28th day are as tabulated in table 3 and table 4 below.

Table:3 Compressive strength of M20 grade concrete cubes

Fibre content (%)	7^{th} day		28^{th} day	
	Mean load (kn)	compressive strength(n/mm2)	Mean load (kn)	Compressive strength (n/mm2)
0%	510.6	22.69	581.48	25.84
0.25%	458.8	20.39	469.14	20.58
0.5%	490.5	21.80	558.98	24.84

0.75 %	482.6	21.45	556.16	24.71

Table 4 Compressive strength of M30 grade concrete cubes

Fibre content (%)	7th day		28th day	
	Mean load (kn)	compressive strength(n/mm2)	Mean load (kn)	Compressive strength (n/mm2)
0%	694.58	30.87	885.68	39.36
0.25%	641.92	28.5	794.2	35.29
0.5%	669.68	29.76	845.3	37.57
0.75%	665	29.12	824.98	36.67

There was no significant improvement in the results of the compressive strength as in the case of other conventional fibres. But as a part of the study, for conducting the tests of splitting tensile strength, the cylinders were cast in the cylindrical mould of size 15 cm diameter and 30cm height. Two sets of ten cylinders of M20 and M30 mix were cast as control specimens. Later, different sets of cylinders were cast, with fibre content ratio as 0.25%, 0.5%, 0.75% & 1%. Fibres were evenly distributed throughout the concrete mass. The cylinders were then, on the second day of casting, transferred to curing tank for a period of 7 days and 28 days and tested. The results of splitting tensile strength of M20 & M30 grade concrete cubes on 7th and 28th day are as tabulated in table 3.5 and table 3.6 below.

Table 5 Splitting Tensile Strength of M20 grade concrete cylinders

Fibre content (%)	7th day		28th day	
	Mean load (kn)	Split tensile strength(n/mm2)	Mean load (kn)	Split tensile strength (n/mm2)
0%	70.3	0.99	167.8	2.373
0.25%	118.8	1.68	175	2.476
0.5%	153.2	2.167	201	2.844
0.75%	110.8	1.528	186.4	2.637
1%	104.6	1.48	171	2.419

These results were very significant as it was at par with the results of the conventional fibres readily available in the market.

Table 6 Splitting Tensile Strength of M30 grade concrete cylinders

Fibre content (%)	7th day		28th day	
	Mean load (kn)	Split tensile strength(n/mm2)	Mean load (kn)	Split tensile strength (n/mm2)
0%	89.2	1.262	183.8	2.6
0.25%	125.2	1.77	203	2.87
0.5%	140	1.98	224.4	3.17
0.75%	107.2	1.52	198.2	2.8
1%	98.8	1.39	189.6	2.68

Based on the experimental results the following observations were made:-

i. Significant increase in compressive strength was not obtained by the addition of turn steel fibres in concrete.
ii. The splitting tensile strength of plain concrete is improved by 20% for M20 concrete and 22% for M30 concrete by the addition of turn steel fibres.
iii. The M30 grade concrete mix design the cement content was partially replaced by Flyash

5.CONCLUSION

The variation of direct compressive strength for concrete cubes was found to be inconsistent with the increase in percentage of fibres. The splitting tensile strength was increased by 20-22% for concrete cylinder samples with 0.5% fibre content in M20 and M30 Grade concrete mixes. Much research on readily available fibres was conducted with an additional input of cost for the purchase of fibres. But these tests were thus a true example of sustainable development as the recycling of scraps from lathe shops is done to improve the behavior of concrete and also the cement content was partially replaced by fly ash in higher grade concrete.

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