STRENGTH CHARACTERISTICS USING CRUMB RUBBER AND STEEL FIBER IN RIGID PAVEMENT

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Abstract - The construction of concrete pavements has seen a growing interest, due to its high strength, durability, better serviceability and overall economy in the long run. Nowadays there is a thrust to produce thinner and green pavement sections of better quality, which can carry the heavy loads. The high strength steel fiber reinforced concrete is a concrete having compressive strength greater than 40MPa. It is made of hydraulic cement and containing fine and coarse aggregates and discontinuous, unconnected, randomly distributed steel fibers.

The Current study aims at developing rigid Pavement Concrete mixtures incorporating crumb rubber as partial replacement of fine aggregates as well as addition of steel fibers. The objective of the study is to design slab thickness of rigid pavement using the achieved flexural strength of the concrete mixtures. In this study, the flexural strength and compressive strength for rigid pavement mixtures for different percentage of steel fibers and replacement of sand with crumb rubber are reported.

The study shows that the crumb rubber can be effectively replace sand up to 10% and steel fiber can be added up to 1% as addition in rigid pavement. The flexural strength increase is significant for mixes containing crumb rubber 0% to 10% and steel fiber with a combination up to 1% to 1.5% in development of rigid pavement. The maximum flexural strength is achieved for the mix containing 0% crumb rubber as partial replacements of sand and 1.5% steel fiber addition.

While for 0% sand replaced crumb rubber and 1% addition of steel fibers to concrete by volume, the Thickness of rigid pavement slab comes out to be 19 cm which is shows 20.83% decrease in thickness of slab when compared to normal mix. Thus there will be considerable decrease in the slab thickness there by cost saving increases. Thus this mix is suggested as the best mix for Rigid Pavement .

Key Words: Crumb Rubber, Steel Fibers, Rigid Pavement, Compressive Strength, Flexural Strength.

1. INTRODUCTION

Tens of millions of tyres are discarded across the world every year. Disposal of waste tyres is a challenging task because tyre have a long life and are non-biodegradable. The traditional method of waste tyres management have been stockpiling or illegally dumping or land filling, all of which are short-term solution. The environmental problem from growing, recycling tyre is an innovative idea or way in this case. Recycling tyre is the processes of recycling vehicle's tyres that is no longer suitable for use on vehicles due to wear or irreparable damage such as punctures. The cracker mill process tears apart or reduces the size of tyre rubber by passing the material between rotating corrugated steel drums. By this process an irregularly shaped torn particles having large surface area are produced and this particles are commonly know as crumb rubber.

Research that rubberized concrete can successfully be used in secondary structural components such as culverts, crash barriers, side walks, running tracks, sound absorbers, etc. However, most of the developing third world countries have yet to raise their awareness regarding recycling of waste materials and have not developed effective legislation with respect to the local reuse of waste materials. The proposed work presents an experimental study of effect of use of solid waste material (crumb rubber) in concrete by volume variation of crumb rubber. One of the objectives of this paper is to make these data regarding the basic properties of modified concrete using crumb rubber in the concrete mix available to aid in the development of preliminary guidelines for the use of crumb rubber in concrete.

Dumping of waste rubber products is becoming an environmental challenge in several developing countries due to their non-biodegradability characteristic. Majority of waste rubber products are generated from damaged or scratched automotive tyres and industrial conveyor belts (Pilusa and Muzenda 2013). Until now the way of degrading or recycling them is a major environmental challenge. Tyres made of complex mixtures of very different materials which include several rubbers, carbon black, steel cord and other organic and inorganic minor components. The increasing amount of tyre rubber dissipate is generating more and more ecological problems worldwide. The current rate of monetary growth is unbelievable without reduction of fossil energy like crude oil, natural gas and coal. Appropriate waste management is an additional important aspect of sustainable growth. Rubber misuse represent a substantial part of municipal waste, furthermore a large amounts of waste arise as a by-product or faulty product in industry and agriculture (Rostek and Biernat 2013). The quick development of the automobile industry and superior standard of living of people in India, the quantity of autos increased rapidly. Now India is facing the ecological problems related to the removal of large-scale waste tyres. Near about 1.5 billion waste tyres are generated by the world annually, in which 40% in rising markets such as China, India, South Africa, South East Asia, South America and Eastern Europe etc. And more than 33 million vehicles added to the Indian Roads in the last three years. Now, in accordance with the statistic data, 80 million scrap tyres were created in 2002, and with 12% of enlargement rate every year, the whole number of abandoned tyres reached 120 million in 2005 and 200 million in 2010 (Malarvizhi et al 2012). However with the deal of vast number of waste tyres has become a vital problem of environment in india.

Due to the health and environmental risks presented from used tyre waste a significant body of recent research has focused on utilizing used tyre rubber in concrete as a partial replacement of its mineral aggregates, resulting in a class of concrete called crumb rubber concrete (CRC). Previous experimental studies on CRC materials have shown that using rubber in concrete enhanced its ductility, toughness, impact resistance, energy dissipation, and damping ratio However, it reduced its compressive strength, tensile strength, and modulus of elasticity compared to conventional concrete .To increase the effectiveness of using rubber in concrete, several approaches have been previously introduced and showed that the CRC properties improved with cement content in- crease up to 400 kg/m3. Beyond 400 kg/m3 cement content, only slight improvements were observed. However, the slump was negatively affected when using 400 kg/m3 and showed that 24 hr is the best treatment period for the rubber as it resulted in the highest compressive strength and flexural strength. However, this pre-treatment had no effect on concrete slump. Other researchers reported less positive or contradictory results from these approaches and used modified rubber by saturating it in NaOH solution for 20 min. Their results showed al- most no difference between the compressive and tensile strengths of pre-treated and non�treated rub- ber mixes. However, 12% increase in the flexural strength was reported for the pre-treated rubber mix. CRC compressive strength using NaOH pre-treated rubber for 24 hours followed by tap water wash for 3 hours compared to non-treated rubber. The contradictions and variations in the previous research findings indicate the need for future research in CRC performance enhancement.

Recycling discarded automobile tyres has become an increasingly important issue, since the disposal of used tyres has been banned from landfills. As a consequence of this ban and the lack of an alternative technology to dispose of large quantities of used tyres, there are millions of used tyres stockpiled, some illegally. The growing stockpiles of discarded tyres represent potential fire and health hazards. Recycling waste tyre rubber conserves valuable natural resources and reduces the amount of waste entering landfills. The main method of recycling these waste materials has consisted of using tyre rubber particles as coarse or fine aggregate in concrete. Results indicate that rubberized concrete mixtures possess lower density, increased toughness and ductility, lower compressive and tensile strengths and more efficient sound insulation (Siddique et al., 2008). Raghavan et al. (1998) reported that mortars incorporating rubber shreds achieved workability comparable to or better than a control mortar without rubber particles. Because of the low specific gravity of rubber particles, the unit weight of the mixture containing rubber decreases with the increase in the rubber content. They also observed that rubber shreds incorporated into mortar help reduce plastic shrinkage cracking in comparison to control mortar. Eldin and Senouci (1993) studied the mechanical behavior of concrete containing rubber tyres.

In this study, crumb rubber is used to replace fine aggregate in the production of concrete pedestrian blocks. Replacing fine aggregate in concrete pedestrian blocks with crumb rubber produced from waste tyres will reduce the consumption of primary aggregates and produce a high value use for the wastes. It will also help minimize the use of high value aggregates in low specification applications.

By the year 2030, this number is expected to reach 1200 million. Disposal of waste tyres has become a global problem. In many countries, burying the waste tyres is a common disposal method, which shortens the service life of the burial ground and causes a very serious threat to ecology. Therefore, effectively reusing waste tyres is an urgent and important issue for saving energy and protecting the environment. Several methods of recycling waste tyres have been proposed, including use as a fuel in cement kilns and to produce carbon black. These are technically feasible, while bringing great economic waste and environmental pollution. Using recycled rubber as additives to or replacements of construction materials is a highly preferable option. The initial trial of crumb rubber was used as a modifier of asphalt. However, the high viscosity and the higher temperature required in production made it unpractical to be widely used. In order to reuse waste tyre rubber effectively, one of the possible solutions is to incorporate it into cement‐based material. Partial replacement of mineral aggregates in concrete with waste tyre rubber could control environmental pollution and save sandstone.

Concerning the reuse of waste rubber in concrete, extensive studies had been conducted. Two major opposite effects existed when the rubber was introduced into the concrete mixture. The mechanical strength was reduced, while the durability, toughness, impact resistance, strain capacity and sound insulation properties were enhanced. Due to the compressive and flexural strengths being two major design criteria in concrete structures, the reduction in the strength of rubberized concrete limited its application. However, the desirable characteristics, including lower density, higher ductility, better sound insulation and resistance against cracking, made it a valid option for non-structural concrete with a low strength requirement. The properties of crumb rubber concrete were significantly affected by rubber content. During investigated the durability properties of self‐compacting concrete containing waste tyre rubber, which indicated that the anti-sulfate corrosion was improved with the increasing of rubber content. Holme conducted acoustic tests for concrete with different levels of fine aggregate replacement by crumb rubber Testing results found that the sound absorbance property of rubberized concrete performed well with higher proportions of rubber. Therefore, the investigation of the advantages and disadvantages of replacing mineral aggregate by crumb rubber is necessary. Additionally, the selected optimal content of crumb rubber in the concrete mixture will bring excellent performance to crumb rubber concrete. In order to minimize the loss in strength caused by introducing crumb rubber into concrete, prior surface treatment of rubber particles by modifiers was utilized.

2. Experimental Materials

The materials utilized during the present research are as follows

2.1. Crumb Rubber

Crumb rubber is being used in concrete as a partial replacement to fine aggregate to produce rubbercrete. In comparison to fine aggregate it has lower specific gravity ranging from 0.51 to 1.2, bulk density ranging from 524 kg/m3 to 1273 kg/m3, lower water adsorption, strength and stiffness. Crumb rubber is hydrophobic and non-polar material which repels water and entraps air into its surface. It also has a different gradation compared to fine aggregate which falls below the lower limit of the curve in particle size analysis. Therefore, when it partially replaced fine aggregate in rubbercrete, it changes the grading to a non-continuous aggregate gradation. Partial replacement of fine aggregate with crumb rubber in rubbercrete is normally done by volume of the materials due to the lower specific gravity of crumb rubber compared to fine aggregate.

Fig. 1: Crumb Rubber

Density (g/cm^3)	1.08
Moisture content %	0.5
Break strength (MPa)	10.0
Elongation at Break %	400.0

Table-1: Physical Properties of Crumb Rubber

Ash content %	3.6
Acetone extract %	11.5
Carbon black content %	28.4
Rubber hydrocarbon content %	56.6

Table-2: Chemical compositions of Crumb rubber

2.2 Steel Fibers

Mild steel fibers were obtained from Ekam steel Ludhiana Punjab, having 1mm thickness and 50mm length i.e aspect ratio (I/d)50. These were crimped fibers obtained through cutting of steel wires. The fibers were cut by fiber cutting machine to an accurate size. Three different proportions of fiber i.e. 0%, 0.5%, 1% and 1.5% have been used. Properties of steel fiber used are tabulated in below table

Fig. 2: Steel

Table -3: Properties of Steel Fibers

Average Thickness	1mm
Length	50mm
Density	7850 kg/m³
Tensile Strength	8500 kg/m³
Shape	Crimped steel fiber

2.2. Cement

The broadly and most generally utilized cement in all types of construction works is Ordinary Portland Cement (OPC). The OPC 53 Grade cement conforming to IS: 12269-1987 was utilized for all concrete mixes. Whereas the water is included in the Portland cement, chemical reactions happen between the cement and water and thus coming about within the energy release and the cement paste event which is mindful for making hardened substance. This process of response happens between cement and water is named as the hydration process and the help of the energy during this process is named as the heat of hydration. For the research work, the Ordinary Portland Cement of 53-grade used. Table 4 shows properties of cement which procured from local market.

Property	Values for Cement	IS: 12269:1987
Initial setting time	39 min	30 minutes min
Final setting time	190 min	600 minutes max
Specific Gravity	3.15	3.10-3.15

Table- 4: Physical properties of cement

2.4. Coarse aggregate 20 mm

As per IS 383:1970 an aggregate which is retain on IS 20mm sieve is called coarse aggregate. Coarse aggregates are responsible for providing 70-75% bulk within the constituents of concrete.it is the prime ingredient within the concrete. When it blended with cement and water it gets to be glued and therefore the entire strong matrix is bound during a strong mass which called concrete. Coarse aggregates are larger size filler materials in construction. As the name indicates, they are classified depending on the sizes of aggregate particles. The surface area of the coarse aggregate is less than fine aggregates. Coarse aggregates are utilized in concrete, rail road track ballast, etc. Coarse aggregate size 20 mm graded as per IS 383:1970 locally available is utilized for CRC. Table 5 shows properties of 20mm graded coarse aggregate which procured from local market, Mandi Punjab

Property	Value
Sources	Punjab
Fineness modulus	6,51
Specific gravity	2.76

Table-5: Physical Properties of Coarse Aggregate

2.5. Fine aggregate

As per IS 383:1970 an aggregate which is retain on IS 4.75mm sieve is called fine aggregate. Sand is shining yellow, off white, and rounded. The cost of Construction Sand is nil due to its normal availability but its transportation cost is more. Processing is easy by normal machines without using and Blast materials or any Crushing machines. Sand is free of any Organic Materials or any radiation or big blocks or concrete stones. Sand is utilized for backfilling, mortar, and concrete, road paving, Plastering, Filling under Foundations, reinforced ready-mix concrete, Building Blocks, and manufacturing masonry blocks. Table 6 shows the properties of fine aggregate which procured from the local market, Mandi Punjab

Property	Value
Sources	Punjab
Fineness modulus	3.19

Table-6: Physical Properties of Fine Aggregate

2.6. Water

Water is a universally adopted key ingredient liquid for all types of work.in this research potable water is utilized for casting and curing purposes respectively. When water is mixed with cement it forms a paste that binds all aggregate together. The role of water within the concrete is most critical because of the water-cement ratio (w/c proportion). In this research w/c ratio is 0.40 taken out.

3. Mix Design for Rigid Pavement

IRC 44: 2008 was followed for the mix design for rigid pavement, and the materials used confirmed to the various clauses of MORTH specifications. The cement concrete pavement were designed on the basis of flexural strength requirement of concrete. However, typical practice is to be design the mix on cube compressive strength and relationship between characteristics compressive strength and flexural strength as per IS:456 were used as follow:

Flexural strength, (N/mm²)= 0.7 times the square root of characteristics compressive cube strength of concrete (N/mm²)

Characteristic flexural strength required at 28 days	4.5 N/ N/mm²
Maximum water cement ratio	0.35
Maximum size of aggregate	20mm
Degree of quality control	Good
Minimum cement content	350 kg/m³
Maximum cement content	425 kg/m³
Cement	43 Grade OPC as per IS: 8112
Coarse aggregate	20mm and 10mm as per 602.2.4 of MORTH
Fine aggregate	Sand as per IS 383 of zone II

Table-7: Design Parameters

Table -8: Proportion for Pavement Concrete Mixture (control mix)

	Water	Cement	F.A (sand)	C. A. (20mm)	C.A (10mm)
Quantity (kg/m³)	140	400	716.83	710	473
Proportion (wt)	0.35	1	1.79	1.775	1.1825

Various concrete mix were prepared with the varying percentage of steel and sand replacement with crumb rubber in the laboratory. Table - 9 shows the quantity of material in kg/m³ for different mixes which were prepared in the laboratory.

Table-9: Quantity of Material (in kg/m³) for different Mixes

Fine aggregates (kg/m³)

Mix	Sand	F	C.R
M1	0	0	0
M2	12.2	0	0
M3	716.83	24.4	0
M4	716.83	36.6	0
M5	645.15	0	30
M6	645.15	12	30
M7	645.15	24	30
M8	645.15	36	30
M9	573.4	0	60
M10	573.4	11.7	60
M11	573.4	23.5	60
M12	573.4	35.2	60
M13	501.7	0	90
M14	501.7	11.6	90
M15	501.7	23.2	90
M16	501.7	34.8	90

	Water	Cement	C.A. (20mm)	C.A. (10mm)
Quantity (kg/m³)	140	400	710	473

4. EXPERIMENTAL PROCEDURE

4.1. Compressive Strength Test

When a specimen of material is stacked in such a way that with in the event that the material compresses and shortens it is said to be in compression. Compressive strength is frequently measured on a universal testing machine. Compressive strengths are usually reported concerning a particular specialized standard. Compressive strength is one of the foremost critical engineering properties of concrete. It is a standard mechanical practice that the concrete is classified based on grades. Fig. 3 shows the universal testing machine which is conducted compressive strength test at department of civil engineering in Desh Bhagat University punjab. For the compression test, a specimen of the size of 150mm X 150mm X 150 mm was cast and tested in a compression testing machine concerning the test procedure given in IS: 516-1959. The equation for finding out compression test is given underneath,

Compressive Strength (N/mm2) = P / Δ .... (1)

Where, P =Failure load of specimen (N)

Δ = Area of specimen (mm2)

Fig. 3: Compressive strength test

Test procedure for compressive strength

Test specimens of size 150×150×150 mm were casted for testing the compressive strength of both controlled as well as sand replaced crumb rubber and steel added concretes. The modified mixture with varying percentage of addition of steels and crumb rubber as a partial replacement of sand were prepared and casted into cubes. Compressive strength test results at curing ages of 28 days and percentage changes for control mix as well as for the modified mixes. For testing in compression, no cushioning material was added between the specimen and the plates of the machine. The load was applied axially without any shock till the specimen was crushed. Above fig-3 shows the test setup for the compressive strength. Total Forty eight cubes were casted and testes. Three specimens for each mix were casted and tested comprising of a total of forty eight cubes. The corresponding values were observed and average values were taken into consideration.

4.2. Flexural Strength Test

As the flexural strength of concrete has a direct relation with the thickness of the slab, its calculation becomes the most fundamental component of pavement design. When concrete is undergoing bending, then tensile, compressive and in various cases direct shear stresses are involved. The deflection and cracking behaviour of concrete structure depends mainly upon the flexural strength of concrete. Various factors which impact the flexural strength of concrete are particularly the level of stress, age, size and confinement to concrete flexure member. In the below fig- 4 shows the universal testing machine which is conducted flexural strength test.

FIG. 4: FLEXURAL STRENGTH TEST

Test procedure for flexural strength

The flexural test beam specimens of size of 150×150×700 mm were casted and cured for 28 days under standard laboratory conditions. For testing the specimens were arranged in the machine in such a way that the load was applied to the uppermost surface of the beam as casted in the mould, along two lines spaced 200 mm apart. The axis of the specimen was precisely aligned with the axis of the loading device. There was no packing material used between the bearing surface of the specimen and the rollers. Loading was applied at a rate of 4kN/min and was continued until the specimen failed. The flexural strength of the specimen is demonstrated as the modulus of rupture f_b. If the fracture developed within the central one- third of the beam, the flexural strength was determined on the basis of ordinary elastic theory using the following equation:

$$= P\ s\ S\ /\ b\ s\ f_b\ d^2$$

Where,

f_b is the flexural strength, (MPa)

P is the ultimate load applied to the specimen, (N)

d is the depth of the specimen at the point of failure, (mm)

b is calculated width of the specimen, (mm)

l is the length of the span on which the specimen was supported. (mm)

Figure 4 and 5 shows the test set up for the flexural strength test and the failure crack appearance in the flexural strength test.

FIG. 5: Failure crack appearance in the flexural strength test

Two specimens for each mix were casted and tested comprising of a total of thirty two beams. The corresponding values were observed and average value was taken for further discussion . The value of flexural strength obtained for various mixex including the control mix.

5. RESULTS AND DISCUSSIONS

5.1. Compressive Strength Test

In below Table 10 Compressive strength test results at curing ages of 28 days and percentage changes for control mix as well as for the modified mixes is shown.

Table-10: Compressive Strength Results

Mix	S.F(%)	C.R(%)	C.S(MPa)
M1	0	0	53.35
M2	0.5	0	55.8
M3	1	0	56.3
M4	1.5	0	50.6
M5	0	10	39.85
M6	0.5	10	41.23
M7	1	10	42.5
M8	1.5	10	40.3
M9	0	20	35.69
M10	0.5	20	37.83
M11	1	20	36.6
M12	1.5	20	35.42
M13	0	30	28.32
M14	0.5	30	28.96
M15	1	30	29.61
M16	1.5	30	29.04

S.F =Steel Fiber, C.R=Crumb Rubber, C.S=Compressive strength

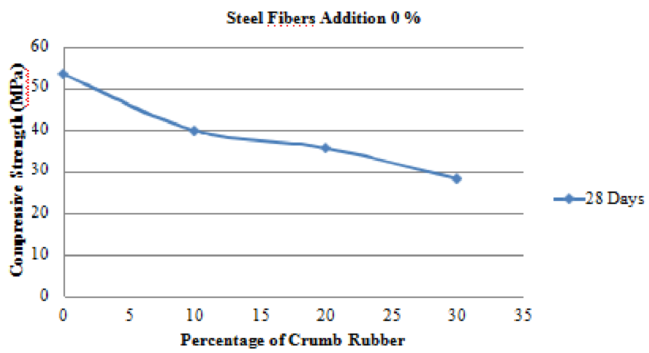

Chart-1:

Variation of compressive strength of concrete for 0% addition of steel with different percentage of crumb rubber

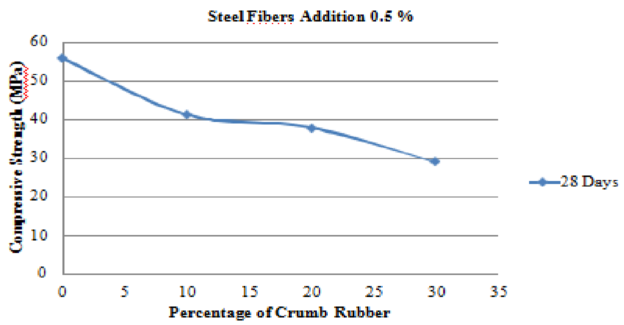

Chart-2:

Variation of compressive strength of concrete for 0.5% addition of steel with different percentage of crumb rubber

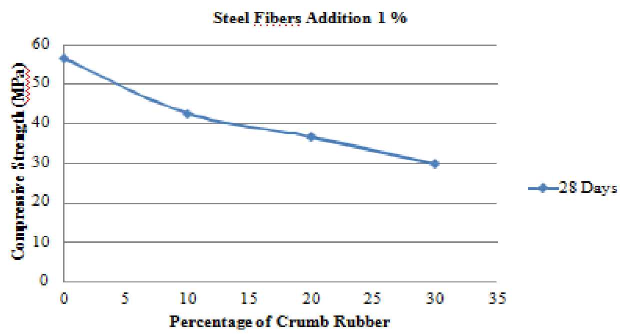

Chart-3:

Variation of compressive strength of concrete for 1% addition of steel with different percentage of crumb rubber

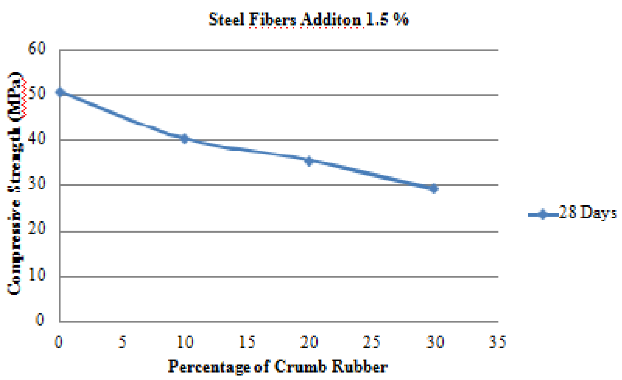

Chart-4:

Variation of compressive strength of concrete for 1.5% addition of steel with different percentage of crumb rubber

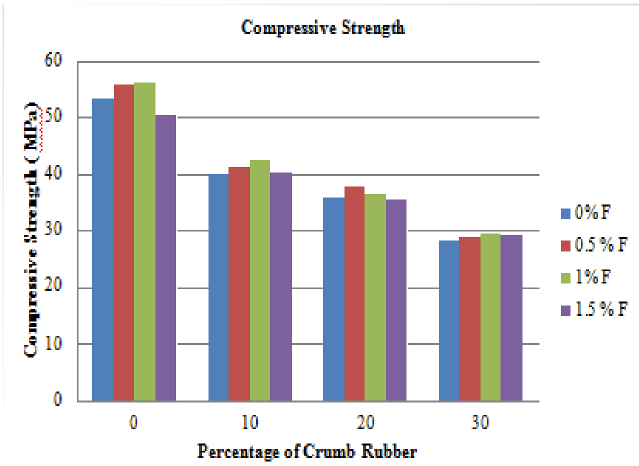

Chart-5:

Variation of compressive strength of concrete for different percentage of crumb rubber and different percentage of steel

From the Table 10 and chat 1 to 5 the results show reduction in concrete compressive strength with the increase of rubber content. The initial 28-day compressive strength of about 53.35 MPa decreased to almost 28.32 MPa when 30% replacement of fine aggregate by crumb rubber was made. This represents about a 46.91% reduction in the 28-day strength. The reasons for strength reduction are first, because the rubber particles are much softer (elastically deformable) than the surrounding cement paste. Therefore, on loading cracks are initiated very quickly around the rubber particles in the mix, which quickens the failure of the rubber-cement matrix. Secondly, due to the lack of bond between rubber particles and the paste, soft rubber particles may be considered as voids in the concrete matrix. The increase in void content would certainly cause a decrement in strength.

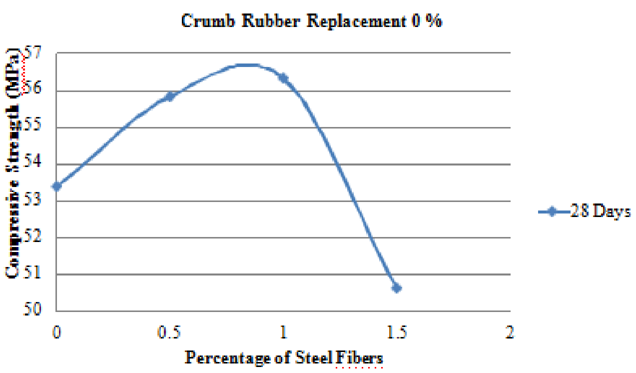

Chart-6:

Variation of compressive strength of concrete for 0% replacement of sand with crumb rubber at different percentage of steels

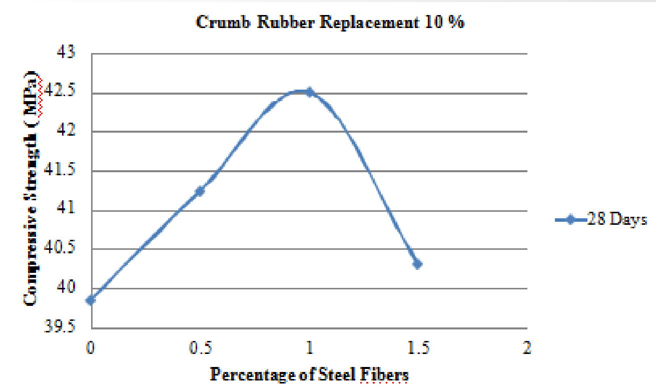

Chart-7:

Variation of compressive strength of concrete for 10% replacement of sand with crumb rubber at different percentage of steels

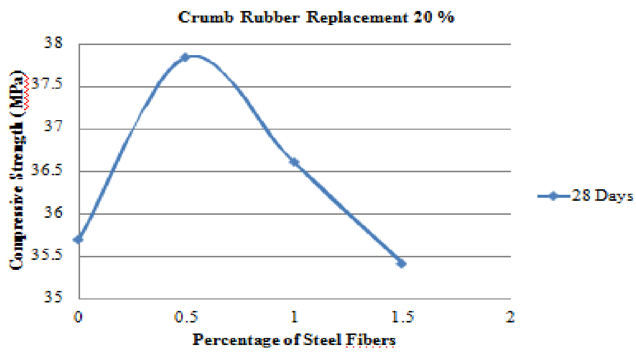

Chart-8:

Variation of compressive strength of concrete for 20% replacement of sand with crumb rubber at different percentage of steels

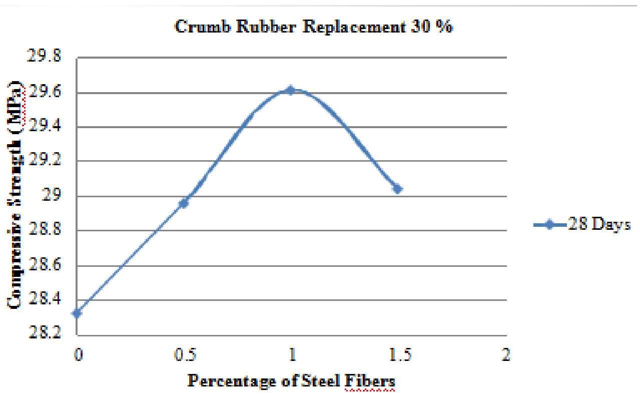

Chart-9:

Variation of compressive strength of concrete for 30% replacement of sand with crumb rubber at different percentage of steels

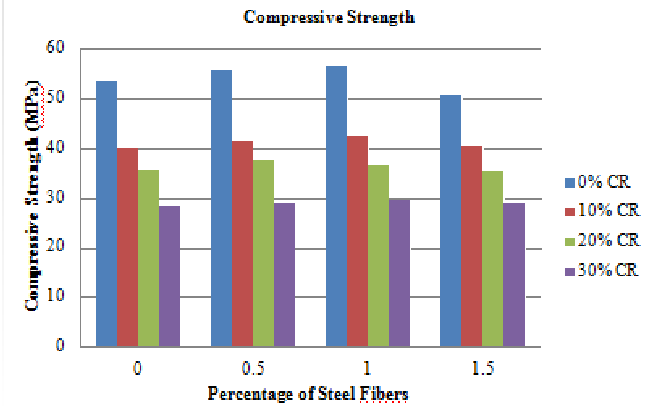

Chart-10:

Variation of compressive strength of concrete for different percentage of steels fibers and different percentage of crumb rubber

From the Table 10 and chart 6 to 10, it can be observed that the compressive strength of concrete for the cubes with steel fibers addition of 0.50% and 1% is more than that of cubes without steel fibers. However, for 1.5% additions of steel fibers the compressive strength reduces. This increase happens because when the steel fiber was added to the concrete, the generation of cracks was restricted due to the bonding of fibers with the concrete (ductile failure). The percentage rise in the compressive strength for the cubes with steel fibers 0.50% and 1% compared to the cubes without steel fibers are 4.59% and 5.52% respectively. Whereas for 1.5% addition of steel fibers the percentage decrease in the compressive strength is 5.15%. It can be seen from the investigation that the maximum percentage rise in compressive strength can be attained for the cubes with steel fibers 1% by volume of concrete (+5.52%). Therefore it is recommended to use steel fibers 1% by volume of concrete to get the most benefit in gaining compressive strength. It can be concluded that the use of steel fibers is an efficient method to improve the compressive strength ofconcrete.

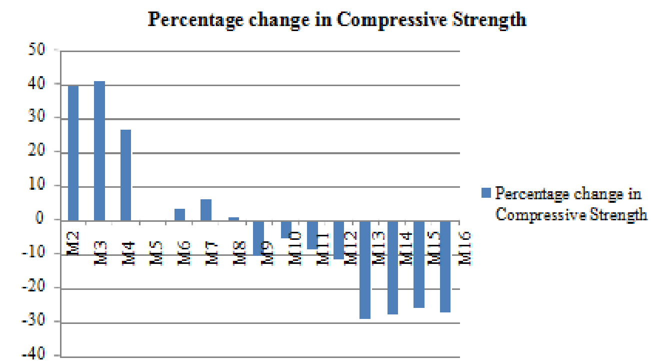

Chart-11:

Percentage variation of compressive strength

Chart: 11 shows the percentage change for all the mixes in compressive strength with respect to M40 grade of concrete and the best mix for maximum compressive strength is M3 comprising 1% steel fibers addition and 0% replacement of sand with crumb rubber.

5.2. Flexural Strength Test

Table-11: Flexural Strength Results

Mix	S.F.%	C.R. %	F.S.(MPa)
M1	0	0	5.08
M2	0.5	0	6.9
M3	1	0	7.2
M4	1.5	0	7.64
M5	0	10	3.59
M6	0.5	10	4.91
M7	1	10	4.96
M8	1.5	10	5.2
M9	0	20	2.65
M10	0.5	20	3.52
M11	1	20	3.73
M12	1.5	20	4.2
M13	0	30	1.59
M14	0.5	30	2.11
M15	1	30	2.4
M16	1.5	30	2.58

S.F =Steel Fiber, C.R=Crumb Rubber, F.S=Flexural strength

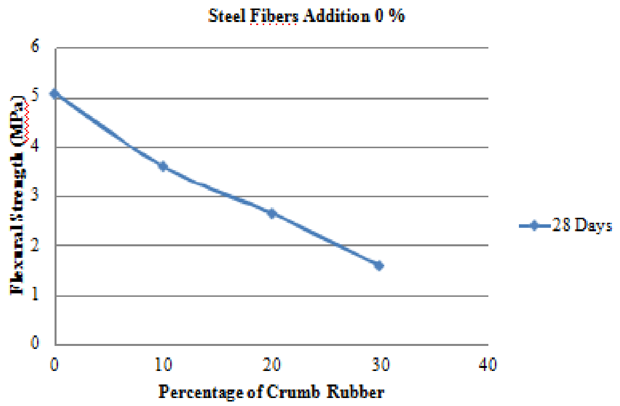

Chart-12:

Variation of Flexural strength of concrete for 0% Steel Fibers with different percentage of Crumb Rubber

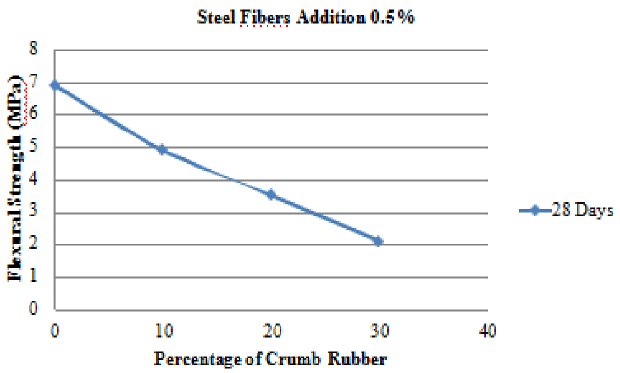

Chart-13:

Variation of Flexural strength of concrete for 0.5% Steel Fibers with different percentage of Crumb Rubber

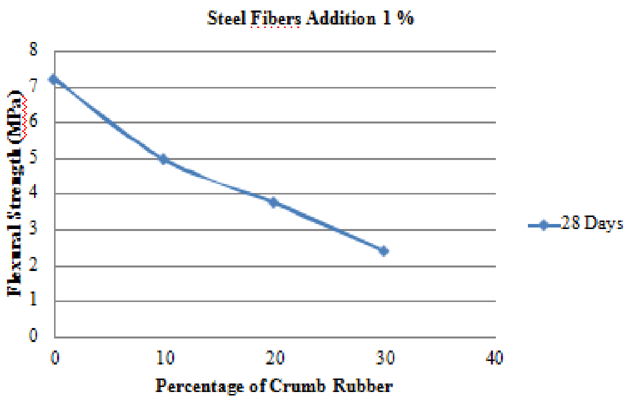

Chart-14:

Variation of Flexural strength of concrete for 1% Steel Fibers with different percentage of Crumb Rubber

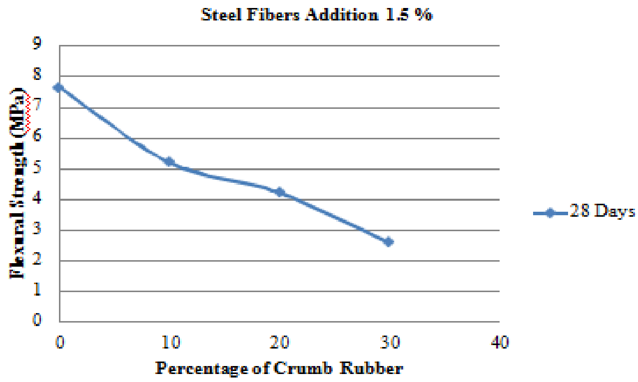

Chart-15:

Variation of Flexural strength of concrete for 1.5% Steel Fibers with different percentage of Crumb Rubber

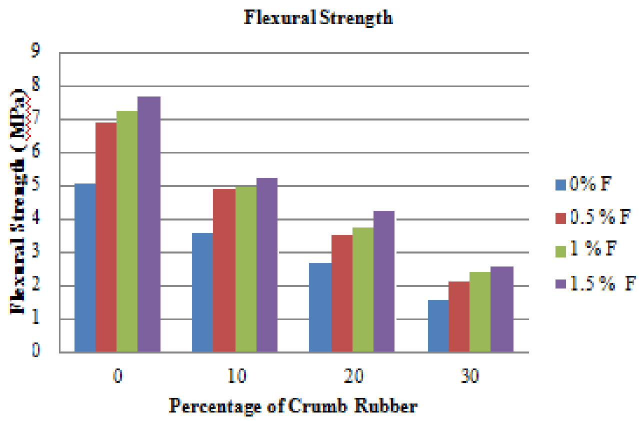

Chart-16:

Variation of Flexural strength of concrete for different percentage of crumb rubber and different percentage of steel fiber.

From the Table 11 and chart 12 to 16, it is observed that with the increase in the crumb rubber, the flexural strength decreases. The percentage decrease in the flexural strength for the beams with crumb rubber 10%, 20% and 30% compared to the beams without crumb rubber are 29.33%, 47.83%, and 68.70% respectively. The rubberized concrete is often softer than normal concrete. Concrete specimens containing crumb rubber will show early failure because of its weakness against tension. Crumb rubber behaves like springs, which delay the stretching of the existing cracks. Continuous application of load further generates more cracks. When the bond between cement paste and rubber is overcome, fracture develops. Secondly, because of the low modulus of elasticity with respect to mineral aggregates, rubber aggregates behaves as large pores and do not enhance the resistance to externally applied load.

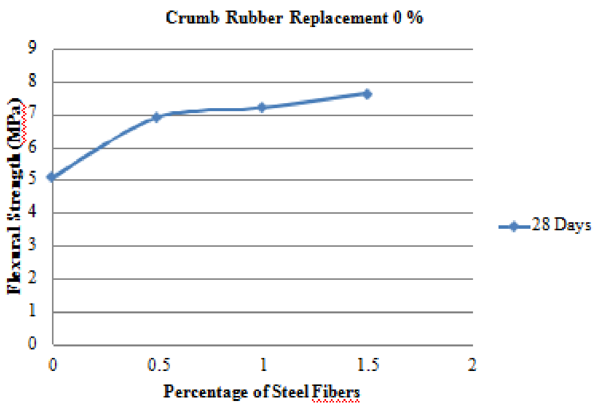

Chart-17:

Variation of Flexural strength of concrete for 0% replacement of sand with crumb rubber at different percentage of steel fibers

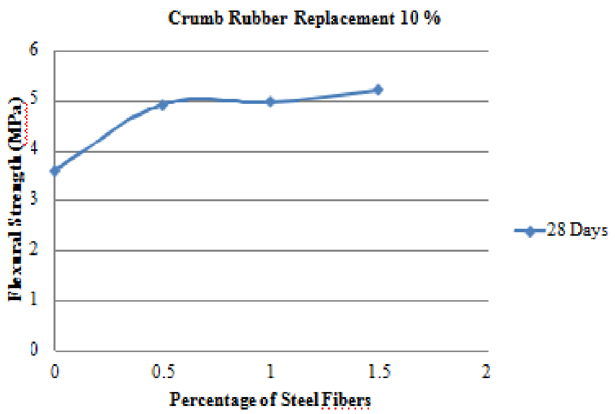

Chart-18:

Variation of Flexural strength of concrete for 10% replacement of sand with crumb rubber at different percentage of steel fibers

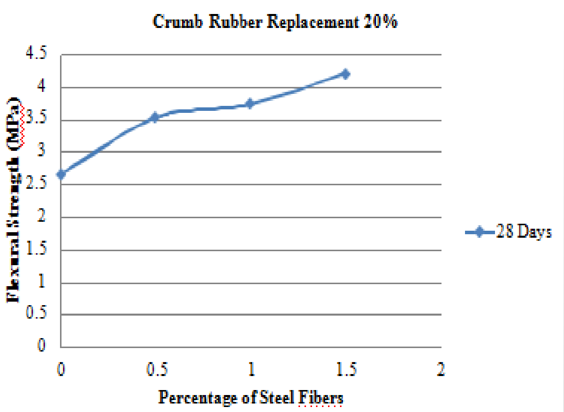

Chart-19:

Variation of Flexural strength of concrete for 20% replacement of sand with crumb rubber at different percentage of steel fibers

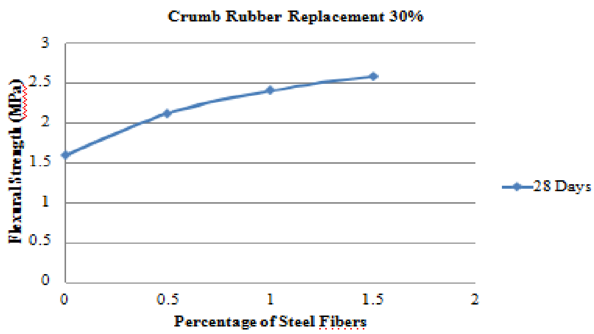

Chart-20:

Variation of Flexural strength of concrete for 30% replacement of sand with crumb rubber at different percentage of steel fibers

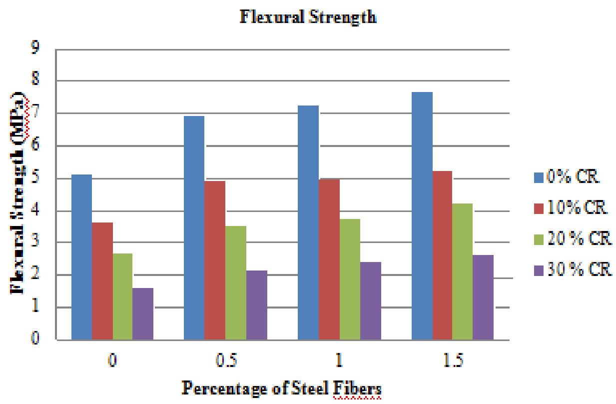

Chart-21:

Variation of Flexural strength of concrete for different percentage of steel fiber and different percentage of crumb rubber.

From the Table 11 and chart 17 to 21, It is observed that the flexural strength of concrete for the beams with steel fibers 0.50%, 1% and 1.5% is more than that of beam without steel fibers This happens because when the steel fibers were added to the concrete, the propagation of cracks was restricted due to the bonding of fibers into the concrete (ductile failure). The percentage increase in the flexural strength for the beams with steel fibers at 0.50%, 1% and 1.5% as compared to the beams without steel fibers are +35.82%, +41.73%, and +50.39% respectively. It can be seen from the observations that the maximum percentage increase in flexural strength was observed for the beams with steel fibers at 1.5% by volume of concrete (+50.39%). Thus for the given study it is recommended to

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use steel fibers at 1.5% by volume of concrete to get the most benefit in improving flexural strength.

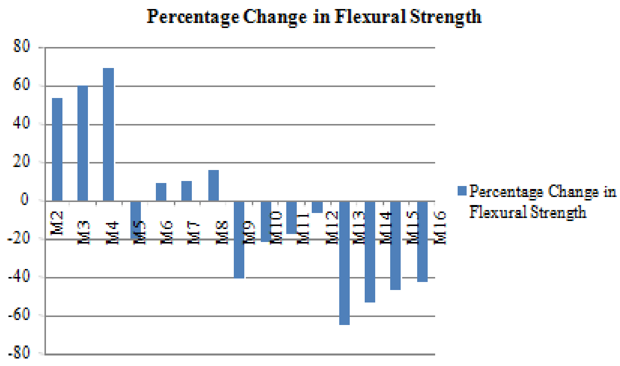

Chart-22:

Percentage variation of Flexural strength

From chart -22 we can see the percentage change in flexural strength with respect to 4.5 MPa and the best mix for maximum flexural strength which is M4 comprising 1.5% steel fibers addition and 0% replacement of sand with crumb rubber

5.3. Design for Rigid Pavement

Flexure Strength =5.08 MPa and Slab thickness = 0.24m

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential

BUC for Rear Single Axles = 0.700

BUC for Rear Tandem Axles = 0

Total Bottom-up Fatigue Damage = 0.700 + 0 = 0.70

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential

TDC for Rear Single Axles = 0.028

TDC for Rear Tandem Axles = 0.145

TDC for Rear Tridem Axles = 0.007

Total Top-Down Fatigue Damage = 0.028 + 0.145 +0.007=0.182

CFD= BUC + TDC

= 0.700 + 0.182

= 0.882 < 1

DESIGN IS SAFE

Thus, seven mixes were qualified for the design of pavement quality concrete which have compressive strength greater than 40 MPa and flexural strength greater than 4.5 MPa which are M1, M2, M3, M4, M6, M7 and M8. Table 12 and chart 23 show the Bottom up Cracking for Rear Single Axles and Rear Tandem Axles and the Top down Cracking for Rear Single Axles, Rear Tandem Axles (Stress computed for 50% of axle load) and Rear Tridem Axles (Stress computed for 33% of axle load) for each of the above mixes respectively. All the mixes are safe for design of rigid pavement

Table-12:

Percentage Change in Thickness of concrete slab

Mix	Slab Thickness (m)	Flexural Strength (MPa)	Percentage changes in Thickness
M1	0.24	5.08	0
M2	0.2	6.9	-16.6
M3	0.19	7.2	-20.8
M4	0.19	7.64	-20.8
M6	0.25	4.91	4.1
M7	0.25	4.96	4.1
M8	0.24	5.2	0

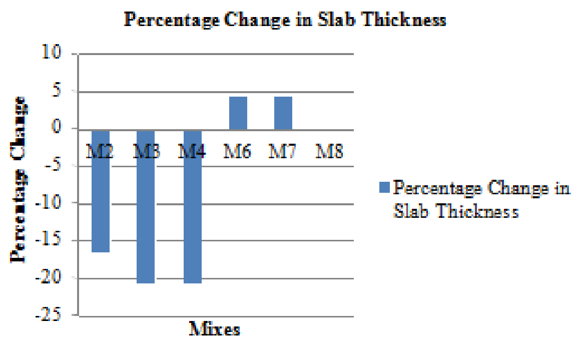

Chart-23:

Percentage Change in Slab Thickness

6. CONCLUSIONS

The present study was undertaken to investigate the flexure strength and compressive strength of concrete with different level of replacement of sand with crumb rubber and addition of steel fiber in concrete mix. Sand was partially replaced by crumb rubber at four different levels of replacement i.e. 0%, 10%, 20% and 30% and steel fiber is added in concrete mix at different percentages i.e. 0%, 0.5%, 1% and 1.5%. Tests were performed after 28 days of curing of concrete. 7 samples of reference mix i.e. with 0% crumb rubber and 0% steel fiber and 73 samples of crumb rubber and steel fiber in concrete with different percentage were prepared for determining flexure strength and compressive strength of concrete with water-cement ratio of 0.35. Super-plasticizer was used in all the mixes at 1% level by weight of cementious material in order to maintain uniform workability across the mixes.

STRENGTH CHARACTERISTICS

Compressive Strength of Concrete Composite:

Concrete mixes produced by partial replacing sand with crumb rubber show decrease in compressive strength as compared to control mix.

On increasing the percentage of crumb rubber, there is a significant reduction in the compressive strength value. This decrease in compressive strength of concrete containing crumb rubber is due to the lack of grip between rubber particles and the paste. Further, soft rubber particles may effectively be considered as voids in the concrete matrix. The increase in void content would certainly cause a decrement of strength.

Concrete mixes when reinforced with steel fiber show an increased compressive strength up to 1% addition of steel fibers as compared to control mix.

When the steel fiber was added to the concrete, the generation of cracks was restricted due to better bonding of fibers in the concrete mix (ductile failure). Also the fibers maximize the energy absorbing capability leading to an increase in the compressive strength of concrete. Beyond 1% addition of fibers there is decrease in compressive strength due to lower workability and more air cavities in the system.

Flexural Strength of Concrete Composite:

Concrete mixes produced by partial replacing sand with crumb rubber show a significant decrease in flexural strength as compared to control mix.

Crumb rubber behaves like springs, which delays the stretching of the existing cracks. Continuous application of load further generates more cracks. When the bond between cement paste and rubber is overcome, fracture develops. Secondly, because of the low modulus of elasticity with respect to mineral aggregates, rubber aggregates behaves as large pores and do not enhance the resistance to externally applied load. Hence there is decrease in flexural strength.

Concrete mixes when reinforced with steel fiber show an increased flexural strength up to 1.5% addition of steel fibers as compared to control mix, because when the steel fiber was added to the concrete, the propagation of cracks was restricted due to the bonding of fibers into the concrete (ductile failure)

The best mix for Pavement Quality Concrete is M3 which has 0% sand replaced crumb rubber and 1% addition of steel fibers to concrete by volume. The Thickness of PQC slab in this case comes out to be 19 cm which shows a 20.83% decrease in thickness of slab when compared to normal mix.

SCOPE FOR FUTURE WORK

In the present study experimental program was devised to study the strength characteristics of mixes containing crumb rubber and steel fiber. The work can be extended to study the durability characteristics aswell.

The performance of the pavement quality concrete slabs containing crumb rubber and steel fiber can be evaluated by constructing some trial stretches. The behaviour of these Pavement Concrete slabs can be analyzed under repetitive loading for estimating the fatigue life.

REFERENCES

1) **Ahsana F.K.M., and Varghese, S., "Behavioural** "Study Of Steel Fiber And Polypropylene Fiber Reinforced Concrete." International Journal of Research in Engineering & Technology, Vol. 2, Issue 10, Oct (2014), 17-24

2) **Aldin, N.N., and Senouci, A.B.**, "Rubber Tire Particles as Concrete Aggregates"(1993)

3) **Jodilson Amorim Carneiro**, **Paulo Roberto Lopes Lima, Monica Batista Leite, Romildo Dias Toledo Filho.** "Compressive stress–strain behavior of steel fiber reinforced-recycled aggregate concrete". Cement and Concrete Composites Vol. 46 (2014): 65-72.

4) **Patel, V.R., Mojidra, B.R., and Pandya, I.I.**, "Ultimate Shear Strength of Fibrous Moderate Deep Beams without Stirrups." International Journal of Engineering 1.1 (2012): 16-21

5) **Semsi Yazici, Gozde Inan, Volkan Tabak.** "Effect of aspect ratio and volume fraction of steel fiber on the

mechanical properties of SFRC". Construction and Building Materials Vol.21 (2007): 1250–1253

6) **Shah, S.F.A., Naseer, A., Shah, A.A., and Ashraf, M.,** "Evaluation of Thermal and Structural Behavior of Concrete Containing Rubber Aggregate", October (2014), Volume 39, Issue 10, pp: 6919-692

7) **More, T.R., Jadhao P.D., and Dumne, S.M.,** "Strength Appraisal of Concrete containing Waste Tire Crumb Rubber", Vol. 4, No. 1, November (2015)

8) **Tayabji, S., Anderson, J.** "Supplemental Report for Proposed Specification for Construction of Concrete Airfield Pavements". Innovative Pavement Research Foundation, Report IPRF-01-6-002-04- 1a (2007).

9) **Soulioti, D.V., et al.** "Effects of Fiber Geometry and Volume Fraction on the Flexural Behaviour of Steel-Fiber Reinforced Concrete." Strain 47.s1 (2011)

10) **Nataraja, M.C., Dhang, N., and Gupta, A.P.,** "Stress–strain curves for steel-fiber reinforced concrete under compression." Cement and Concrete Composites 21.5 (1999): 383-390

11) **Elsaigh, W.A., Kearsley, E.P., and Robberts, J.M.**, "Steel Fiber Reinforced Concrete for Road Pavement Application". Paper Presented to the 24th Annual Southern African Transport Conference (2005)

12) **Haolin, S., Yang, J., Ling, T.C., Ghataora, G.S., and Dirar, S.,** "Properties of concrete prepared from waste tire rubber particles of uniform and varying sizes", Journal of Cleaner Production, Volume 91, 15 March (2015), pp: 288–296.

13) **Kotresh K.M., and Belachew, M.G.**, "Study on Waste Tire Rubber as Concrete Aggregate" International Journal of Scientific Engineering and Technology, Volume No.3 Issue No.4, pp: 433-436.

14) **Kumaran, G.S., Mushule, N., and Lakshmipathy, M.,** "A review on Construction Technologies that enables enviornmental protection: Rubberized Concrete" Advanced Materials Research, Vol. 367 (2012) pp: 49-54.

15) **Khan, S., and Rizvi, Z.,** "Innovation in Steel Fiber Reinforced Concrete-A." IJREAS, Volume 3, Issue 1, January (2013).

16) **Selvakumar, S., and Venkatakrishnaiah, R.,** "Strength Properties of Concrete Using Crumb Rubber with Partial Replacement of Fine Aggregate", IJIRSET Vol. 4, Issue 3, March (2015).

17) **Kamil, E.K., George, B., and Zhu, W.H.**, "Properties of Crumb Rubber Concrete" (2004)

18) **K. Najim, M. Hall**, "Workability and mechanical properties of crumb rubber concrete", Proc. of the ICE – Const. Mats., Vol. 166, No. 1, pp. 7-17, 2013

19) **D. Flores-Medina, N. Flores Medina, F. Hernández-Olivares,** "Static mechanical properties of waste rests of recycled rubber and high quality recycled rubber from crumbed tyres used as aggregate in dry consistency concretes", Materials Struct., Vol. 47, No. 7, pp.1185-1193, 2013.

20) s**T. C. Ling**, "Effects of compaction method and rubber content on the properties of concrete paving blocks", Const. Build. Mats., Vol. 28, No. 1, pp. 164-175, 2012

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