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COMPARISON OF PROPERTIES OF DIFFERENT CEMENT CONCRETE MIXES AND THE DESIGN OF RIGID PAVEMENT FOR THESE MIXES

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ABSTRACT

Nowadays, the use of different types of sub-products in cement-based materials has become a common practice in concrete industry. This Thesis report discusses the feasibility of adding metal as a by-product fibres as reinforcement of normal concrete in rigid pavement. The effects of the incorporation of various types of metallic fibres on the mechanical properties of fibre-reinforced concrete were experimentally investigated. A normal concrete (M_{40}) was used as a control mixture. The influence of type, length and quantity of Steel Fibres on the compressive and flexural strengths of Engineered Wire-cut Steel Fibre Reinforced Concrete (SFRC) is evaluated. A slight decrease of the compressive strength was also observed with the composites containing 2% of the Steel Fibres. In the present paper, an attempt has been made to assess the suitability of crusher dust in concrete making. Cubes, prisms were cast and tested for compressive strength, modulus of rupture after a curing period of 28 days. The results indicated effectiveness of stone dust as fine aggregate up to 25 percent, without affecting the design strength.The compressive strengths and flexural strengths and by comparing the compressive strength results with two types of curing methods. They were Traditional curing Method (28 Days Normal Curing Method) and Accelerated curing Method (28 ½ hrs curing by Boiling water Method). From the test Results it is known that there is a less variation between Traditional curing Method and Accelerated Curing Method.

KEYWORDS: SFRC, Crusher dust, Compressive strength, Flexural strength, Rigid pavement, Traditional Curing, Accelerated Curing.

1. INTRODUCTION

Concrete is one of the most versatile building materials. It can be cast to fit any structural shape from a cylindrical water storage tank to a rectangular beam or column in a high-rise building.The advantages of using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life.The major disadvantage is that concrete develops micro cracks during curing. It is the rapid propagation of these micro cracks under applied stress that is responsible for the low tensile strength of the material.Hence fibres are added to concrete to overcome these disadvantagesThe main reasons for adding steel fibres to concrete matrix is to improve the post-cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility, and to provide crack resistance and crack control.In the present study an attempt was made to study the proportion of cement concrete mixes with steel fibres and also to study the variation in strength by partial replacement of sand with crusher dust in the mix of same M_{40} Grade concrete mix but with different types of cements (ACC for Steel fibres used Mix and RAMCO for crusher dust used Mix) with the following two types of test methods and two types of curing methods.

1.2 OBJECTIVE OF THE EXPERIMENT

In the present study an attempt was made to study the proportion of cement concrete mixes with steel fibres and also to study the variation in strength by partial replacement of sand with crusher dust in the mix of same M_{40} Grade concrete mix but with different types of cements (ACC for Steel fibres used Mix and RAMCO for crusher dust used Mix) with the following two types of test methods and two types of curing methods.

1.3 EXPERIMENTAL PROGRAMME:

I Test Methods conducted in the study:

1) Compressive strength 2) Flexural strength

II Two types of curing methods:

1) Traditional curing 2) Accelerated curing

III Two types of Materials used in the concrete mix:

Different percentages of

- steel fibres used in the study (SF):
- Steel fibres of 0 % usage in concrete mix (SF_0)
- Steel fibres of 1 % usage in concrete mix (SF_1)
- Steel fibres of 2% usage in concrete mix (SF_2)

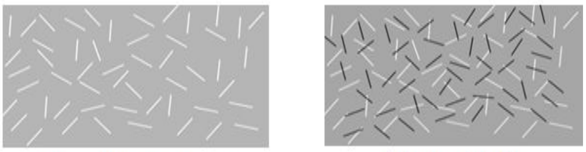
Different percentages of dust used in the study (CD):

- Sand 100% and crusher dust 0% (CD_0)
- Sand 75% and crusher dust 25% (CD_{25})
- Sand 50% and crusher dust 50% (CD_{50})

2. LITERATURE REVIEW

2.1 Fibre Reinforced Concrete (FRC)

Fibre reinforced concrete (FRC) is a concrete composite of cement, fine and coarse aggregate and fibres with different proportions. In plain concrete, micro cracks develop even before loading, particularly due to drying, shrinkage or other causes of volume change. The width of these initial cracks seldom exceeds few microns. When loaded, the micro cracks propagate and open up due to the effect of stress concentration additional cracks form in place of minor defects. The structural cracks proceed slowly in the matrix and the development of such micro cracks is the main cause of inelastic deformation in concrete. Fibres enable concrete to progress from plastic state to hardened state without weakness. This is achieved by the reduction of micro crack formation, reduced segregation and decreasing the scope of capillary formation, thus reducing permeability. Development of micro cracks and arrest of these cracks by fibres are shown in Fig 1.
The mechanical and physical properties of fibre reinforced concrete depend upon the fibre volume, fibre geometry, fibre orientation, fibre distribution, mix proportions, size, shape and volume of coarse aggregate contents and mixing and compaction methods.



Development of micro cracks in the concrete. Crack arrestment by the fibres.

Fig 1cracks by fibres

Gopalakrishnan et al (2003) of Structural Engineering Research Centre (SERC), Chennai have studied the properties of steel fibre reinforced shotcrete namely the toughness, flexural strength, impact resistance, shear strength ductility factor and fatigue endurance limits. It is seen from the study that the thickness of the Steel Fibre Reinforced Shotcrete (SFRS) panels can be considerably reduced when compared with weld mesh concrete.

Taylor et al (1996) reported on strength and toughness measurement on the range of normal and high strength concrete mixes with and without fibre reinforcement. The toughness measurements were carried out through two fracture type test specimens rather than four point loading arrangement. Therheology of these concrete is such that they can be reinforced by sufficient volumes of polypropylene and steel fibres to significantly increase their toughness, while their strengths in compression and tension remain relatively constant.

2.2 Classification of Fibres used in Concrete:

The fibres can be broadly classified into two groups

1. Low modulus, high elongation fibres
2. High Strength, high modulus fibres

1. Low modulus, high elongation fibres:

Nylon, polypropylene, plastic are some of the low modulus high elongation fibres which are capable of large energy absorption characteristics. They do not lead to strength improvement but impart toughness, resistance to impact and explosive loading.

2. High Strength, high modulus fibres:

High Strength, high modulus fibres are Glass, Carbon and Steel. These fibres impart primary characteristics of strength and stiffness to composite and varying degrees of dynamic properties.

3.EXPERIMENTAL STUDIES AND DATA ANALYSIS

The following tabular column shows the physical Tests results of **ACC 53**grade cement which is used in Steel Fibres used cement concrete Mix.

Sl. no	**Physical Tests**	**Obtained results**	**Requirements as per IS CODES**
1	Fineness	0.47%	Not>10% as per IS 4031 part 1
2	Standard Consistency	27.50%	4031 part 4
2	Initial Setting time	31 min	Not less than 30 minds as per IS 4031 part 5
3	Final setting time	498 min	Not more than 600 minds as per IS 4031 part 5
4	Soundness	5mm	Not>10mm as per IS 4031 part 3
5	Specific gravity	3.08	IS 2720 part 3 (3.15 is generally assumed)

The following tabular column shows the physical Tests of Aggregates which were used in Steel Fibres used Concrete Mix.

S. N o	**Physical Tests**	**Obtained results**	**Requirements as per IS 383**
1	Crushing Test	38%	Not more than 45% (other than wearing surfaces)
2	Impact Test	32.95%	Not more than 45% (other than wearing surfaces)
3	Los Angeles Abrasion Test	28.50%	Not more than 50% (other than wearing surfaces)
4	Flakiness Index	20.12%	Not > 35% as per MORTH
5	Specific gravity		
	a) Coarse Aggregates	2.31	
	b)Fine Aggregates	2.42	
6	Water absorption		
	a)Coarse Aggregates	0.20%	
	b)Fine Aggregates	0.50%	

Dimensions of the specimens used for compressive strength and flexural strength:

S.NO	SPECIMENS	DIMENSIONS IN MM
1	CUBE	150 X 150 X 150
2	PRISM	100 X 100 X 500

3.1 TEST FOR COMPRESSIVE STRENGTH OF CONCRETE

Placing the Specimen in the Testing Machine — the bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platens. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.

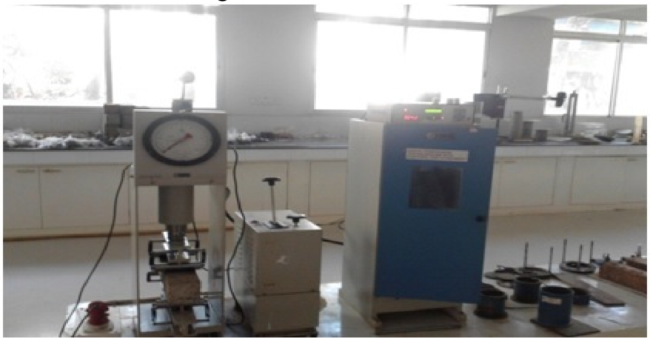


FIG 3.1 Compressive Testing Machine With Flexural Setup

Fig 3.2 Cube Under Compression IN CTM

Fig 3.3 CUBE AFTER CRUSHING

3.2 TEST FOR FLEXURAL STRENGTH OF CONCRETE

Hydraulic testing machines provided on Portland Cement Concrete paving
Projects shall conform to AASHTO T-177. The hydraulic machine consists of a frame to hold the specimen, a hand-operated hydraulic jack, and a pressure gauge to read the load. Practically all of the hydraulic machines have a micro pump in the loading line to facilitate control of the last half of the load within specifications, and without pause in loading. Included with each machine of this type is a calibration sheet, a calliper, plastic ruler.The test specimen shall have approximate dimensions of 100 mm x 100 mm x 500 Test Procedure. Either before or after the beam is placed in the testing machine, draw a reference line on the top and bottom of the beam, as cast, about 10 in. (250 mm) from the end of the specimen. The two reference lines should be exactly opposite each other. A line drawn across the bottom of the beam, as placed in the machine, will meet these two lines, and will be perpendicular to them. The bottom of the beam as placed in the machine will be the side of the beam as cast.Insert the stirrup pins in the slots at the bottom of the stirrups to prevent the stirrups from swinging while the beam is being placed in the machine. This also assures that the support bearings are in the correct position. Place the beam in the testing machine so that the two reference lines on the side of the beam are directly under the centreline of the centre bearing. The maximum fibre stress during application of the load will occur in the outer fibre in the line drawn across the bottom of the beam, this line being directly under the load. Rotate the micro pump handle counter-clockwise to expose the maximum number of threads, and close the loading valve on the pump. Apply a small initial load, and remove the stirrup pins.The load may be applied rapidly up to approximately 50 percent of the estimated breaking load with the pump handle. The final half of the loading is accomplished by turning the crank of the micro pump, at a rate that the extreme fibre stress does not exceed 150 psi (1.0 MPa) per minute. This is approximately 1200 pounds (500 kg) per minute on the test gauge.

Fig 3.4BEAM UNDER FLEXURAL LOADING

Make measurements to the nearest 0.02 in. (0.5 mm) to determine the average width and average depth of the specimen at the section of failure6. Measure the distance from the line drawn at the centre of the span to the location of the break on the bottom side of the beam as tested. If this distance exceeds 1 1/2 in. (40 mm), the test results will not be used in determining when a pavement can be opened to traffic.

Fig 3.5BEAM AFTER FLEXURAL FAILURE

3.5. TESTS ON FIBRES

Locally available Mild Steel binding wire is cut into smaller lengths based on the required Aspect Ratio.Diameter of the binding wire was determined by using Digital Screw Gauge. Its value was found to be 0.944mm

Aspect Ratio = L/d (where, dia of wire = 0.944mm)

For l/d = 40, L = 3.7 cm

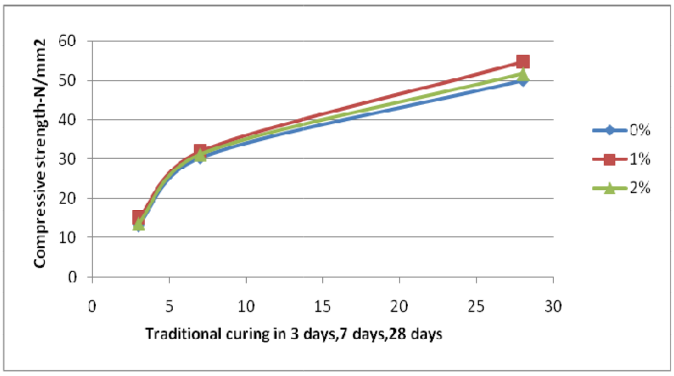
FIG 3.6TENSOMETER

FIG 3.7STEEL FIBRES

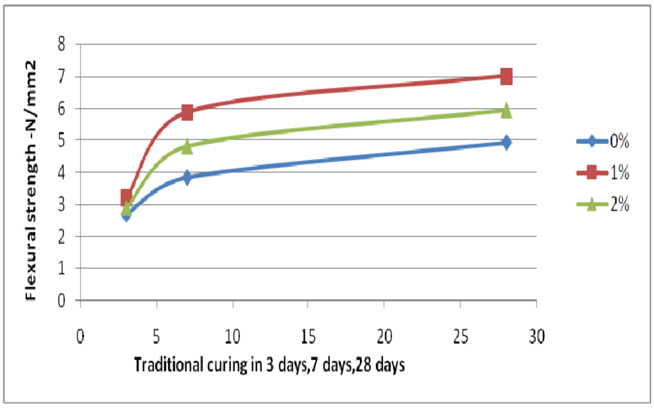
The tensile strength of steel fibre is 364.42 N/mm^2, determined by using Tensometer.

4. RESULTS

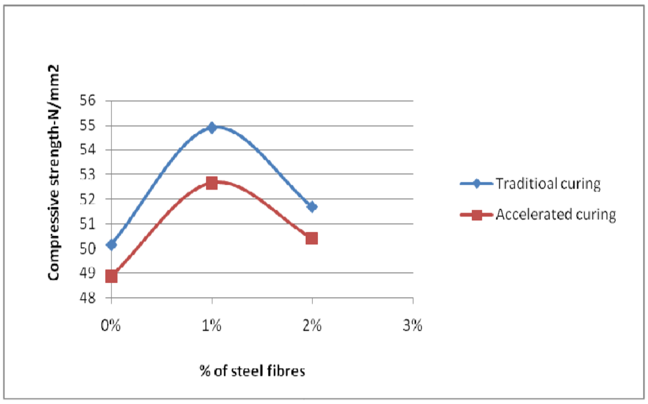
In the present investigation the two different curing methods were done. One is Traditional curing method (i.e., 28 days curing method) and another method is Accelerated curing method (i.e., 28 1/2 Hrs curing method).The compressive strength for different percentages of steel fibres and percentage of increase or decrease with respect to normal M_{40} grade concrete. By taking normal M_{40}grade as referring percentage, the percentage of increase or decrease in compressive strength other percentage is calculated.



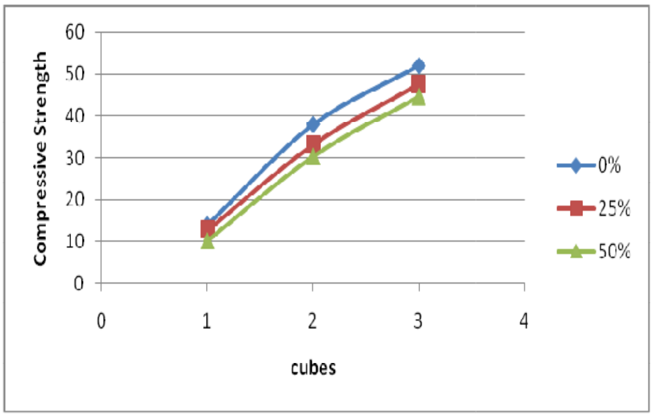
Graph 4.1 Compressive Strength *V/S* Traditional Curing



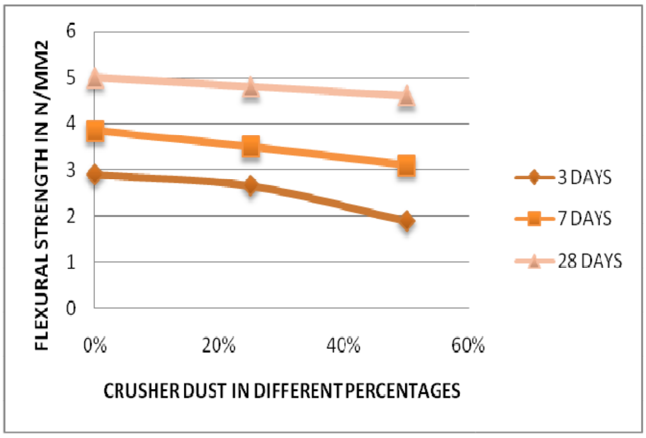
Graph 4.2 Flexural Strength *V/S* Traditional Curing Of Different Days Of Curing



Graph 4.3 Compressive Strength*v/S* Different Percentages Of Steel Fibres



Graph 4.4 Compressive Strength*v/S* Different Percentages Of Crusher Dust



Graph 4.5 Flexural Strength*v/S* Different Percentages Of Crusher Dust

5.DESIGN

5.1RIGID PAVEMENT DESIGN FOR THE FLEXURAL STRENGTH OF 1% USED SFRC:

For the pavement quality concrete of M-40 grade and Temperature differential of 21^0 C and above are considered (Refer Table 1 of IRC 58-2002).The 98^{th} percentile of the Axle load and design wheel load is 12T and 6T.

Rigid Pavement design is revised as follows:

Rigid pavement composition has been designed as per IRC 58-2002.The following inputs have been considered for design.

- Design life = 20 years
- Flexural strength of cement concrete = 52 kg/cm^2
- Poisson ratio value for cement concrete = 0.15
- E for concrete = 3.0 x 10^5 kg/cm^2
- Coefficient of thermal expansion of concrete = $10x10^{-6}$ / ^{0}C
- Tyre pressure = 8 kg/cm^2
- Spacing of contraction joints = 4.0 m
- Width of slab = 3.75 m
- Cumulative repetition in 20 years = 26185,148 commercial vehicles
- Design Traffic = 25 % of traffic in predominant direction (6,546,287 commercial vehicles)
- 98 percentile Axle load = 12 T
- Load safety factor is 1.2
- Design wheel load = 12/2 = 6T
- Modulus of subgrade reaction (K) = 20.8
- IRC 58-2002 (page 10), recommends that if K value of subgrade is less than 6.0 Kg/cm^3 ,CC Pavement should not be laid directly over the subgrade .A dry lean concrete (DLC) sub base is generally recommended for modern concrete pavements.
- Providing 100 mm thick Dry Lean Concrete (DLC) below the concrete slab .The effective K value = 20.8 Kg/cm^3.

  Using these inputs the design thickness for rigid pavement is worked out as follows for arriving thickness 300 mm.

Axle load spectrum

Axle load (AL), Tons	**ALx1.2**	**Stress Kg/cm^2**	**Stress ratio**	**Expected repetition (n)**	**Fatigue life (N)**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**Ratio (5/6)**
Single rear Axle :						
18	21.60	23.0	0.44	87048	0	0
16	19.20	20.0	0.38	43197	infinity	0
14	16.8	18.5	0.35	130246	infinity	0
Tandem Axle:						
28	33.6	14.5	0.27	129591	infinity	0
Cumulative fatigue life consumed 0.00						

DESIGN TRIAL:

Assuming slab thickness h = 260 mm

FATIGUE CHECK:

The stress ratio computed is 0.44, since the stress ratio is less than 0.45; infinite numbers of repetitions are possible. Cumulative fatigue life consumed is 0.00 < 1.Hence the design is safe from fatigue life consideration.

CHECK FOR TEMPERATURE STRESS:

Total of temperature warping stress and the highest axle load stress = 24+15 = 39 Kg/cm^2 which is less than the 52 Kg/cm^2, the flexural strength. So, the pavement thickness of 260 mm is safe under the combined action of wheel load and temperature.

CHECK FOR CORNER STRESS:

Corner stress computed is 15 Kg/cm^2 which are less than flexural strength of concrete, i.e., 52 Kg/cm^2 and the pavement thickness of 26 cm assumed is safe.

CHECK FOR BEARING STRESS IN DOWEL BARS:

Assuming to provide 25 mm diameter dowel bar of length 500 mm at 300 mm spacing the bearing stress in dowel bar is 129 Kg/cm^2 which is less than 321 Kg/cm^2 (allowable bearing stress).Hence the dowel bar spacing and diameter assumed are safe.

TIE BARS:

Provide 12 mm diameter plain bar of length 58 cm at spacing of 49 cm or 12 mm diameter deformed bar of length 84 cm at spacing of 75 cm.

Proposed rigid pavement composition**:**

Pavement layers	GSB	DLC	PQC
Pavement thickness mm	150	100	260

REMARKS:

It is proposed to provide 25 mm diameter dowel bars of length 500mm at 300mm spacing across transverse joints and 12mm diameter tie bars of length 58 cm at 49 cm spacing (or 12 mm diameter tie bars of length 84 cm at 75 cm spacing).

- Length of the slab = 4.0 m
- Width of the slab = 3.75 m
- Sugared CBR value = 8.0%

  Dry lean concrete (DLC) sub-base is recommended as the K value of the subgrade soil is less than 6.0 Kg/cm^3.

  A separation membrane of minimum thickness of 125 microns polythene is recommended to reduce the friction between concrete slabs and dry lean concrete

  Sub-base (DLC).Cross section details are enclosed in annexure.

5.2 RIGID PAVEMENT DESIGN FOR THE FLEXURAL STRENGTH OF 50% USED CRUSHER DUST:

For the pavement quality concrete of M-40 grade and Temperature differential of 21^0 C and above are considered (Refer Table 1 of IRC 58-2002).The 98th percentile of the Axle load and design wheel load is 12T and 6T.

Rigid Pavement design is revised as follows:

Rigid pavement composition has been designed as per IRC 58-2002.The following inputs have been considered for design.

- Design life = 20 years
- Flexural strength of cement concrete = 45 kg/cm^2
- Poisson ratio value for cement concrete = 0.15
- E for concrete = 3.0 x 10^5 kg/cm^2
- Coefficient of thermal expansion of concrete = 10x10^{-6} / ^{0}C
- Tyre pressure = 8 kg/cm^2
- Spacing of contraction joints = 4.0 m
- Width of slab = 3.75 m
- Cumulative repetition in 20 years = 26185,148 commercial vehicles
- Design Traffic = 25 % of traffic in predominant direction (6,546,287 commercial vehicles)
- 98 percentile Axle load = 12 T
- Load safety factor is 1.2
- Design wheel load = 12/2 = 6T
- Modulus of subgrade reaction (K) = 20.8
- IRC 58-2002 (page 10), recommends that if K value of subgrade is less than 6.0 Kg/cm^3 ,CC Pavement should not be laid directly over the subgrade .A dry lean concrete (DLC) sub base is generally recommended for modern concrete pavements.
- Providing 100 mm thick Dry Lean Concrete (DLC) below the concrete slab .The effective K value = 20.8 Kg/cm^3.

  Using these inputs the design thickness for rigid pavement is worked out as follows for arriving thickness 320 mm.

Axle load spectrum

Axle load (AL), Tons	**ALx 1.2**	**Stress Kg/cm^2**	**Stress ratio**	**Expected repetition (n)**	**Fatigue life (N)**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**Ratio (5/6)**
Single rear Axle :						
18	21.60	19.84	0.44	87048	0	0
16	19.20	18.22	0.40	43197	0	0
14	16.8	15.0	0.33	130246	Infinity	0
Tandem Axle:						
28	33.6	12.48	0.27	129591	Infinity	0
Cumulative fatigue life consumed 0.00						

<u>DESIGN TRIAL:</u>

Assuming slab thickness h = 320 mm

<u>FATIGUE CHECK:</u>

The stress ratio computed is 0.44, since the stress ratio is less than 0.45; infinite numbers of repetitions are possible. Cumulative fatigue life consumed is 0.00 < 1.Hence the design is safe from fatigue life consideration.

<u>CHECK FOR TEMPERATURE STRESS:</u>

Total of temperature warping stress and the highest axle load stress = 22.68+19.84 = 42.52 Kg/cm^2 which is less than the 45 Kg/cm^2, the flexural strength. So, the pavement thickness of 320 mm is safe under the combined action of wheel load and temperature.

<u>CHECK FOR CORNER STRESS:</u>

Corner stress computed is 11.29 Kg/cm^2 which are less than flexural strength of concrete, i.e., 45 Kg/cm^2 and the pavement thickness of 32 cm assumed is safe.

<u>CHECK FOR BEARING STRESS IN DOWEL BARS:</u>

Assuming to provide 32mm diameter dowel bar of length 500 mm at 250 mm spacing the bearing stress in dowel bar is 208.9 Kg/cm^2 which is less than 292 Kg/cm^2 (allowable bearing stress).Hence the dowel bar spacing and diameter assumed are safe.

<u>TIE BARS:</u>

Provide 12 mm diameter plain bar of length 58 cm at spacing of 35 cm or 12 mm diameter deformed bar of length 64 cm at spacing of 56 cm.

PROPOSED RIGID PAVEMENT COMPOSITION:

PAVEMENT LAYERS	GSB	DLC	PQC
PAVEMENT THICKNESS MM	150	100	260

REMARKS:
It is proposed to provide 32 mm diameter dowel bars of length 500mm at 300mm spacing across transverse joints and 12mm diameter tie bars of length 58 cm at 35 cm spacing (or 12 mm diameter tie bars of length 64 cm at 56 cm spacing).

- Length of the slab = 4.0 m
- Width of the slab = 3.75 m
- Subgrade CBR value = 8.0%

  Dry lean concrete (DLC) sub-base is recommended as the K value of the subgrade soil is less than 6.0 Kg/cm^3.

  A separation membrane of minimum thickness of 125 microns polythene is recommended to reduce the friction between concrete slabs and dry lean concrete

  Sub-base (DLC).Cross section details are enclosed in annexure.

By calculating the thickness of the Rigid pavement for different types of concrete mixes there is a variation in the thickness by using the steel fibres the thickness can be reduced and by using the crusher dust instead of fine aggregate the thickness has increased .The both thicknesses had compared with the normal concrete used slab thickness. When compared the results with the normal concrete the thickness designed is 300 mm and by using steel fibres the thickness is reduced and it would be 260 mm and by using the crusher dust the thickness is increased and it would be 320 mm.

6. CONCLUSIONS

1. Addition of steel fibres to concrete increases the compressive strength of Concrete marginally.
2. By the addition of steel fibres at 1% were found to be increased the both compressive and flexural Strengths.
3. The addition of steel fibres at 2% reduces both the compressive and flexural strengths.
4. The usage of crusher dust instead of fine aggregate is added in different percentages is done, from this by adding the crusher dust more than 25% reduces the concrete strength.
5. By comparing Traditional curing method and Accelerated curing method for the steel fibres the variation in the results, for 0% it is 2.5% and for 1% and 2% it is 4.0% and 2.6%.
6. In the design of the Rigid pavement the thickness is high where the crusher dust is used Whereas the thickness is reduced by using the steel fibres

7. SUGGESTIONS FOR FUTURE WORK

1. The aspect ratio and types of fibres can be varied and studied.
2. Admixture can be added and the properties can be studied.
3. Reinforced concrete specimens can be tested along with fibres of various proportions.
4. Stress-strain curve can be plotted and their behaviour can be studied.
5. The crack pattern can be studied using fracture mechanics.
6. The usage of different percentages of other materials instead of fine aggregates and check the variations in the strengths.
7. The thickness of the slab is reduced by using the steel fibres in different Aspect Ratios.
8. Some of waste products are fly ash, rice husk, saw dust, and discarded tires, plastic, glass rock, steel slugs, stone dust and ceramic, can be used in different percentages instead of fine aggregate.
9. The thickness of the slab can be reduced by adding the steel fibres of different types and check the compressive strength.
10. The crusher dust had to get from different quarries and add instead of Fine aggregate and check the strengths by adding in different percentages.

8. REFERENCES

1. Shetty, M.S. (2005), “Concrete Technology theory and practice”, (First edition-1982) S.Chand and Company, New Delhi.
2. Swamy, R.N. (October 1996) “Fibre reinforced concrete: Prospect and challenges, Indian Concrete Journal, pp 517-517
3. Johnston, C. (1994) "Fibre Reinforced Concrete." Significance of Tests and Properties of Concrete and Concrete-Making Material, ASTM STP 169C, pp. 547-561.
4. Marc vandevalle, N.V. and Ganesh, P. (March 2003) Fibres in Concrete Indian Concrete Journal, pp 939-940
5. Parameswaran, V.S. (October 1996) “ Research and applications of FRC in Indian Scenario ” Indian concrete journal, pp.553-557
6. Raman, S. N. M., Zain, F. M., Mahmud H. B. & Tan, K. S., 2005. “Influence of quarry dust & fly ash on the concrete compressive strength development”. Proc. AEESEAP Int.Conf. 2005. Kuala Lumpur, Malaysia, 78 Jun 2005
7. Jayawardhane, U. De s and Dissanayake, D. M. S., 2006, “Use of quarry dust instead of river sand for future construction in Sri Lanka”, The Geological Society of London, AEG 200E, paper no38 pp 14
8. Sahu. A. K., Sunil Kumar and Sachin. A. K, 2003, crushed stone waste as fine aggregate for Concrete. The Indian concrete journal.
9. IS 456-2000 Code of practice for plain & reinforced cement concrete.
10. IS 10262-2002 Recommended guide line for concrete mix design
11. IS 9103-1999 Concrete admixture – Specifications
12. IS 9013 - 1978 Accelerating curing
13. IS: 8112-2013 Specification for 43-grade
14. IS 12269-2013 Specification for 53 grade
15. IRC 58-2015 Design of Rigid pavement