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Comparison of Tyre Cord Reinforced Concrete to High Tensile Steel Reinforced Concrete Beam Behaviour Under Flexural Loading Condition

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***Abstract*: This research compared the flexural strength and deformation of tyre cord reinforced concrete beam to high tensile steel reinforced concrete beam under flexural loading condition. For investigating the suitability of Tyre cord as reinforcement in concrete beam, it was extracted from waste trye and banded up to 12mm and concealed as reinforcement in a concrete beam of 1:3:6 and 1:1.5:6 mix proportions. The flexural test performed on both type of reinforced concrete showed an appreciable behaviour of strength, displacement and deformation mechanism for both materials, although, the high tensile reinforced concrete beams outshined the beams produced with tyre cord as reinforcement. From laboratory experiment and results obtained, tyre cord can serve as an alternative reinforcement in concrete if used in beams carrying less structural loads.**

***Keywords*: Tyre Cord Reinforcement, High Tensile Steel Reinforcement, Flexural Strength, load-displacement**

1. Introduction

Reinforced concrete (RC) structures has been dependent on the use of carbon steel reinforcement and have become an acknowledged arrangement in the most recent decades, showing numerous favourable circumstances, for example, high solidarity to-weight proportion, corrosion resistance, and relative simplicity of use.

However, the nice majority are tyres from cars. This truth is vital as a result of the kind of fibres is completely different counting on their origin: coming back from automobile tyres or from a truck (Ferrari, De Hanai, & De Souza, 2013).

Accomplishing practical reasonable and ecological well-disposed tyre reusing, it is important to grow new applications and item which will utilize waste tyre remains as concrete materials. Steel ropes recuperated from tires can be utilized as fortifications in solid components. Concrete is commonly viewed as a proper compression resistance. Thusly, steel reinforcement is used to create tensile resistance in concrete (Maalej & Bian, 2001).

First break quality which is equivalent to the disappointment quality of non-fortified concrete bound material relates to the start of splitting in steel fiber strengthened concrete bound material. It likewise diminishes creep and limits the width of split like some other fiber reinforcement. Reinforcing with tyre cord additionally contributes straightforwardly towards the strength of a concrete bound material base by the expansion in shear obstruction of breaks since it is created both by total interlock and tyre steel support. (Li, Wu, Hao, & Su, 2017)

The use of tyre cord reinforcement in concrete has the capability of presenting a conservative and strong capacity in structures. Fibre: Materials, for example, texture, ropes or steels which can be spun, woven or felted into shapes and sizes produced using a mass of common or fake strings or wires.

In respect to the material and geometrical properties of concrete beam such as: diameter, length, aspect ratio, longitudinal profile and cross-sectional shape, the fibers increases the mechanical characteristics of the matrix under tension and flexure (Pająk T & Ponikiewski, 2013). Although, steel fibers do not ensure suitable safety of the concrete structures in contact with flame with higher temperature, which has become one of the major challenges of concrete. The process of destruction of concrete under high temperature can be delayed by addition of the polypropylene fibers (PP), (Alberti et. al. 2014).

2. Materials and Methods

A. Cement

The ordinary Portland cement used in the preparation of concrete specimens in this research is the Dangote 3X Portland limestone c (PLC) of grade 42.5N this cement is locally available in Nigeria produced in bags of weight 50kg. The cement was tested in accordance with the BS EN 196.1 (2016), Methods of Testing Cement, Determination of Strength. British Standard Institute, London, United Kingdom.

B. Fine aggregate

The fine aggregate used in this research were obtained from Choba River in Emouha, Local Government Area, Rivers State Nigeria. The sand was first served through 4.75mm sieve to eliminate any particle greater than 4.75mm. The acceptance of the fine aggregate used in this research is due to its concordance with the BS 882 (1992), Specification for Aggregates from Natural Sources for Concrete. British Standards, Institute, London.

C. Coarse aggregate

The course aggregate applied in this research were crushed grander and rough-textured granite obtained from crushed rock industry Nigeria limited, Akankpa in cross Rivers state Nigeria. Its maximum size was 10mm considering its use for SCC production the selection of coarse aggregate for this research is under EN 12620.

D. Tyre cord reinforcement

In absence of Pyrolysis plant, tyre cords were extracted using a sharp knife. The cord is made up strands bound together as one. It was used in place of high yield steel reinforcement for beams.

Fig. 1. Typical 12mm tyre cord reinforcement

E. High tensile steel reinforcement

The test also requires the use of reinforcement bars of 12mm. All bars used are high yield steel while the Stirrup are 6mm mild steel.

Fig. 2. Typical 12mm high tensile steel reinforcement

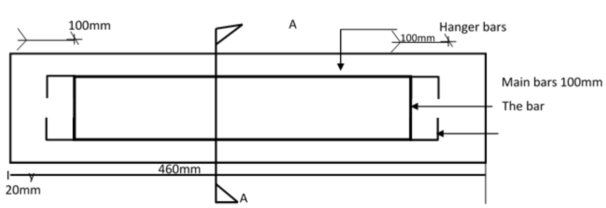

Fig. 3. Longitudinal section of reinforced concrete beam

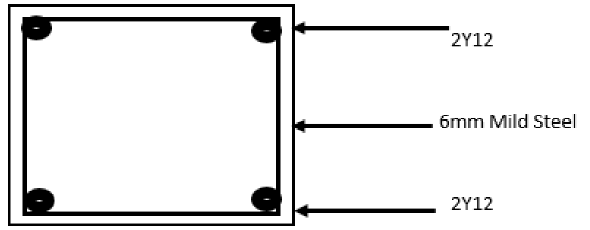

Fig. 4. Section A-A for high tensile steel reinforcement concrete beam

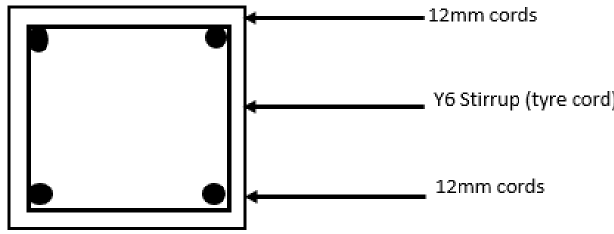

Fig. 5. X-X for tyre cord reinforcement concrete beam

3. Experimental Study

The experimental study consists of casting of 12 sets of reinforced concrete beams of dimension 150 x 150 x 500mm, 6 reinforced steel beams and 6 tyre cord reinforced beams for mix ratio of 1:1.5:3 and 1:3:6 respectively.

Experimental data on initial crack load, failure load, deflection and modulus of rupture of each of the beams were obtained.

A. Casting and Curing

Before concealing of reinforcement and casting, the molds were cleaned and oiled properly. The molds were firmly tight to achieve concrete of regular shape (cubic and cylindrical). Proper care was taken to make sure there were no leakages for possible passage of slurry. After casted specimens have hardened, they were retrieved from the mold and cured in fresh water for the curing process. The concrete specimens were cured for 28 and 56 days and subjected to flexural strength testing.

Fig. 6. Concrete beam specimen marked for testing

B. Experimental setup for flexural strength test

P is the breaking load. This load was applied at two-point C and D on the beam. Load applied at C and D was equal to P/2.

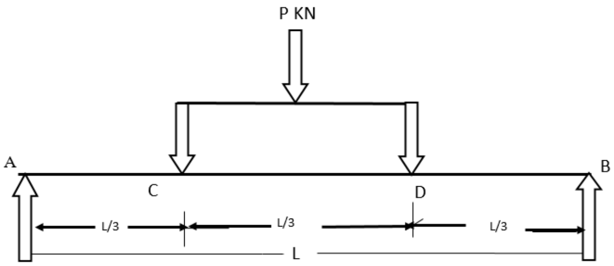

Fig. 7. Experimental setup for flexural strength test

$\sum F_y = 0$

$R_A + R_B = P$ (1)

∴ Taking moment about point D on the beam above, we have;

$\sum M_D = 0$

$$R_A \times L - \left(\frac{P}{2} \times \left(\frac{L}{3} + \frac{L}{3}\right)\right) - \left(\frac{P}{2} \times \frac{L}{3}\right) = 0$$

Hence,

$R_A = R_B = \frac{P}{2}$ (2)

As a simply supported beam arranged symmetrically.
From the beam above, the moments at points C and D becomes,

$$R_A \times \left(\frac{L}{3}\right) - \frac{P}{2} \times \left(\frac{L}{3}\right) = M_D$$

$M_D = M_C = \frac{PL}{6}$ (3)

Recall that,

$f_y = \frac{M}{Z}$ (4)

And section modulus for a rectangular beam

$Z = \frac{bd^2}{6}$ (5)

Putting equations (3) and (5) into (4).
We have,

$$fy = \frac{\frac{PL}{6}}{\frac{bd^2}{6}} = \frac{PL}{6} \; x \; \frac{6}{bd^2}$$

$moment\ of\ rupture\ M_R = f_y = \frac{PL}{bd^2}$ (6)

Fig. 8. Laboratory testing of reinforced concrete beam

C. Mix design analysis

Mold dimension of beam =150mmx150mmx500mm
The volume of beam mold =0.15x0.15x0.50=0.01125m
Density of concrete = 24KN/m^3
Adjusted Volume
The adjusted volume was added as 10% of the volume + the original volume.

$= \left(\frac{10}{100} \times 0.01125\right) + 0.01125 = 0.012375\text{m}^3$

Mass of concrete, M_c = density of concrete X volume of concrete.

= 2400kg/m^3 X 0.012375m^3
= 29.7kg

1) The calculation for concrete beam production (1:1$\frac{1}{2}$:3)

The mix proportion of 1:1$\frac{1}{2}$:3 at water cement ratio of 0.40 for one beam.
Total w/c ratio
= w/c ratio = 0.40
Mix ratio = 1:1$^1/_2$:3
= 0.40 + 1 + 1.5 + 3 = 5.9
Total mass of concrete
= 29.7kg
6 concrete beams will be produced to be tested after 28 and 56 days of fresh water curing.
29.7 x 6 = 178.2
For cement: $\frac{1}{5.9}$ X 178.2kg = 30.20kg
For sand: $\frac{1.5}{5.9}$ X 178.2kg = 45.31kg
For coarse aggregate: $\frac{3}{5.9}$ X 178.2kg = 90.61kg
Water = 30.2kg x 0.40 = 12.08kg

2) Calculation for concrete beam production (1:3:6) proportion

The mix proportion of 1:3:6 at water- cement ratio of 0.60 for one beam.

Table 1
Concrete Mix Proportion

Mix	Mix Proportion	Mass of Cement (Kg)	Mass of Fine Aggregates (Kg)	Mass of Coarse Aggregates (Kg)	Mass of Water (Kg)
Mix 1	Mix 1:1.5:3 conventional steel and Tyre cord	30.20	45.31	90.61	12.08
Mix 2	Mix 1:3:6 conventional steel and tyre cord	16.81	50.43	100.86	10.09

W/C ratio = 0.60, 1:3:6 =1+3+6+0.60=10.6
Total mass of concrete = 29.7kg
6 concrete beams will be produced to be tested after 28 and 56 days of fresh water curing.
29.7 x 6 = 178.2
For cement: $\frac{1}{10.60}$ X 178.2kg = 16.81kg
For sand: $\frac{3}{10.60}$ X 178.2kg = 50.433kg
For coarse aggregate: $\frac{6}{10.60}$ X 178.2kg = 100.86kg
Water = 16.81kg x 0.45 = 10.086kg

4. Results and Discussion

A. *Sieve analysis of aggregates*

The results obtained from the sieve analysis of coarse aggregate and fine aggregates are shown in figure 9 below. Figure 9 shows the grading curves obtained for fine and coarse aggregates respectively. The results of preliminary test on concrete constituent materials showed that the coarse aggregate ranged in particles sizes from 4.75-20mm.

The particle sizes of the fine aggregates were passing the 4.75mm sieve and retained on the 75mm sieve. The fineness modulus obtained for fine aggregate and coarse aggregate are 2.11 and 5.86 respectively.

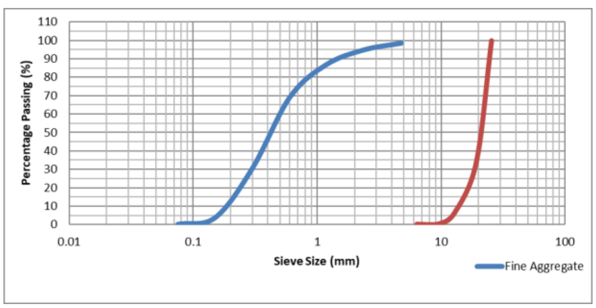

Fig. 9. Particle size distribution curve for both granite and fine aggregates

B. *Workability*

The study showed that the slump value for the mix 1:1.5:3 is less than that of 1:3:6. This is due to the amount of fine aggregate present in the 1:3:6 mix that absorb the water used in preparing the concrete.

Table 2
Summary of slump values for the two mixes.

Mix/ Water-cement ratio	Slump value(mm)	Degree of slump
1:1.5:3 (0.4)	53	Very low
1:3:6 (0.6)	15	Very low

C. *Flexural strength test*

A dial gauge attached to the pure bending region (central) of the beam was used to measure the deflection resulting from incremental load of 10KN. Cracks developed were observed closely upon load increment to ascertain the mode of failure of the beam and note the initial cracking load.

D. *Load deflection history*

The load deflection history of all beams was recorded. The mid-span deflection of each tyre cord reinforced concrete beam was compared with that of their respective control beams (high tensile steel reinforced concrete beam). Also the load deflection behavior was compared for the various types of reinforced beam with respect to curing ages and mix ratios.

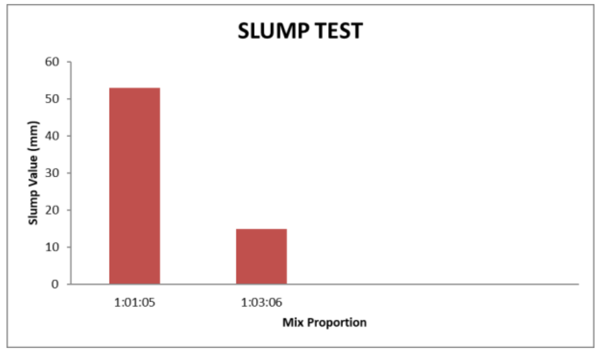

Fig. 10. Variation of slump values for the different mix proportions and water-cement ratio

E. *Load deflection history for reinforced concrete beams*

Two sets of beams were reinforced using 12mm (high tensile steel), with each sets having their various mix ratios (1:1.5:3 and 1:3:6) respectively.

The sets of beams were tested for their flexural strength and load to deflection behavior are presented in figures 10 and 11. The sets of beams reinforced with 12mm high tensile steel and off 1:1.5:3 mix ratios had higher flexural strength and less deflection when loaded. The load carrying capacity of beams produced with mix 1:1.5:3 was higher than that of 1:3:6 mix ratios and the initial crack occurred at the lesser applied load for the 1:3:6 beam when compared to the beams manufactured with 1:1.5:3. This could be as a result of bonding between the constituent materials of the concrete beams. The stresses and failure loads of the high tensile steel reinforced concrete beam increased for the various curing ages at 28, 56 days of pure water curing, the 1:1.5:3 mix beams was tested to have, 21.1 and 26.2N/mm^2 and 112, 118KN failure stress and loads respectively.

While that of 1:3:6 reinforced steel beams were tested to be, 14.4, 16.34N/mm^2 and 89, 94KN failure stress and loads respectively.

The initial crack load of the 1:1.5:3 mix ratio was greater than that of 1:3:6 mix at all curing ages with values of 41, 46KN and 20, 24, 32KN for 28 and 56 days curing respectively, table 3 below gives a summary of the result obtained from laboratory experiment.

The sets of beams reinforced with 12mm tyre cord and produced from 1:1.5:3 and 1:3:6 mix ratios. Were subjected to flexural strength tests and the load- deflection behavior was monitored using a dial gauge placed at the mid span of the beam and read at interval of 10KN incremented loading.

The load carrying capacity of beams produced from mix ratio of 1:1.5:3 had higher flexural strength and fewer less when compared to the beams of 1:3:6 mix ratio.

Table 3
Comparison of the behaviours for 12 mm tyre cord reinforced concrete beam and high tensile steel reinforced concrete beam at varying mix proportion and w/c ratios.

Mix proportion	Parameter	12mm tyre cord reinforced concrete beam		12mm High tensile steel reinforced concrete beam	
		28 days curing age	56 days curing age	28 days curing age	56 days curing age
Mix 1 1:3:6	Initial Crack Load (KN)	24	36	24	32
	Failure Load (KN)	58	85	92	99
	Stress at Failure (N/mm^2)	12.8	14.16	14.4	16.34
Mix 2 1:1.5:3	Initial Crack Load (KN)	33	42	41	46
	Failure Load (KN)	78	92	112	118
	Stress at Failure (N/mm^2)	16.2	17.8	21.1	26.2

The failure stresses (flexural strength) and failure load of the 1:1.5:3 beams were greater.

At 28 and 56 days of curing for 1:1.5:3 mix ratio beams, the stresses and failure loads are, 16.2, 17.8N/mm^2 and, 78 and 92KN respectively, while that of the 1:3:6 mix ratios had stresses and failure load of 12.8, 14.16N/mm^2 and, 58, 85KN respectively.

The experiment conducted on the two types of reinforced concrete beam has revealed that the high tensile steel still remain the best material for reinforcement of concrete member. The stresses obtained from the flexural strength test conducted on the various sets of beams have shown that at 28 and 56 days of curing, the 1:1.5:3 mix ratio beams for high tensile and tyre cord, beams are, 18.6, 24.24N/mm^2 and, 12.9 and 16.43N/mm^2 respectively. And for 1:3:6 mix ratio, the stresses are, 14.6, 16.90N/mm^2 and, 9.16, 12.10N/mm^2 for high tensile steel and tyre cord respectively.

The failure loads of the tyre cord beam are lesser than that of the high tensile steel reinforced concrete for all curing ages and mix ratio. These results are in line with the findings of (Ferrari, De Hanai, & De Souza, 2013) and (Pająk & Ponikiewski, 2013).

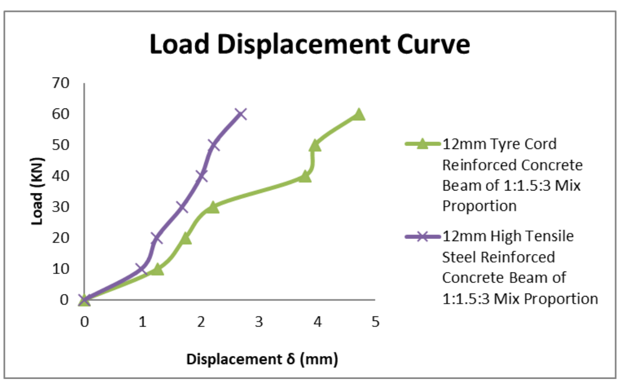

Fig. 11. Load-Displacement curves for 12mm tyre cord and high tensile steel reinforced concrete beams of 1:1.5:3 mix proportion

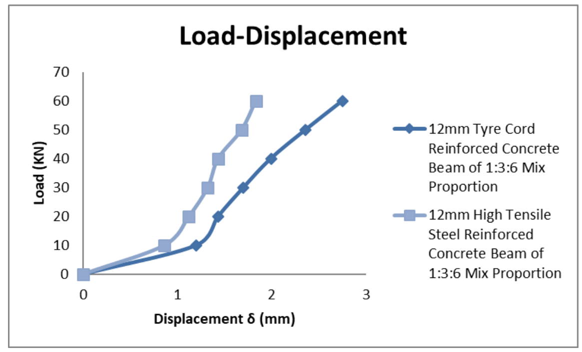

Fig. 12. Load-Displacement curves for 12mm tyre cord and high tensile steel reinforced concrete beams of 1:3:6 mix proportion

5. Findings and Conclusion

- All tyre cord reinforced beam exhibited more ductile behaviour than that of high tensile steel.
- The flexural strength of tyre cord beams are less than that of the high tensile steel reinforced concrete beams.
- Initial crack occurs at lesser loads applied on the tyre cord beams when compared to the control beam at the two mix ratios and various curing ages.
- The deflections in the tyre cord reinforced concrete beams were higher at the various applied load, curing age and mix ratio when compared to the control beams.

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