International Journal of Civil Engineering, Construction and Estate Management
Vol.9, No.2, pp.38-51, 2021
ISSN 2055-6578(Print),
ISSN 2055-6586(online)

ANALYSING THE EFFECTS OF STEEL FIBRES IN CONCRETE PAVING BLOCKS

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ABSTRACT: *Concrete paving blocks are ideal construction materials that are readily seen in our surroundings. They are used in private and public sectors like gardens, walkways, warehouses and even vehicular traffic areas. The production of a unit paving block sample requires about 210kg/m^3 of cement which in a long run affects both health and the environment due to carbon dioxide emitted from cement production. To mitigate this problem, engineers have sought to reduce the amount of cements used in paving blocks and still produce block that will meet up with the required standards through the addition of steel fibres to the blocks. Steel fibres improves the property of concrete blocks, thus, this research work considers improving on the tensile strength of paving block through the addition of steel fibres. The steel fibres used in the research are the CAR19CDM-010 and CAR13CDM-006 fibres. Steel fibres at varying percentage dosage by weight of sample mix were incorporated into the sample and were compared against the control mix not having fibres in them after the curing age of 7 and 28days.It was observed that block samples had noteworthy early strength increment after 7days but not much increase in strength was observed after 28days curing age.*

KEYWORDS: Carbon dioxide, Concrete block paving, fibre reinforced concrete, Steel fibre reinforced concrete

INTRODUCTION

Pre-cast concrete paving blocks are gaining popularity and acceptance as they are becoming more commonly used for different purposes like the street roads, parking lots, outside on land scope and even in areas of heavy wheel loads such as the airports, warehouse pavements and pedestrian walkways just to mention a few. The proliferation of paving block has led to the need to produce improved paving blocks that can put up bearable resistance to harsh conditions posed by the environment and as well as carry heavier loads.

The Netherlands in the early part of the 1950's began the production of hand-size dimensionally consistent concrete blocks which was to serve as replacement for clay brick on streets that were damaged during the Second World War. Due to the country's location below the sea level, the ground often shifts, moves and sinks. Inevitably, concrete pavement was therefore not a suitable solution to the problem. Alternative solution would have been the use of flexible pavement only if not affected by earth movement; no wonder concrete paving block became the better option (Marlon 2015). Although concrete block paving has a long historical existence in Europe, Germany witnessed its first installation of paving block in Stuttgart in the 1960s, afterwards paving blocks became established in Britain, Canada, New Zealand, Australia, Japan and United States of America by 1970's. Subsequently the Middle-East and Asia also embraced the use of paving blocks (Shackle 1980).

Steel fibred high-strength concrete (SFHSC) became in the recent decades a very popular material in structural engineering. Fibre reinforced concrete and high strength concrete are being widely used as important constructional materials due to their excellent properties. Investigation on the Performance of Concrete with adding of Steel Fibres shows that the Compressive strength test, Split Tensile strength test, Flexural strength Test containing 1.0% Steel fibres encountered maximum improvement (Srikar and Kalyan 1984).

According to Song and Hwang (2004), the compressive strength, splitting tensile strength and modulus of rupture of the mechanical properties of high-strength steel fibre-reinforced concrete (HSFRC) all improved with additions of steel fibres at various volume fractions.Steel fibres used in steel fibre reinforced concrete (SFRC) have a needle-like discontinuous look, which has been harnessed for improving concrete element and are manufactured in different types: hooked end, undulated, stranded, crimped, wave, twisted or flat to suit the respective construction project. These fibres are used in construction to increase the tensile strength of concrete materials (Chircu 2009).Behbahani et al. (2011) investigation presented an overview of the mechanical properties of Steel Fiber Reinforced Concrete (SFRC). The result showed that the performance of the Steel Fiber Reinforced Concrete (SFRC) encountered a significant improvement in flexural strength and overall toughness compared against Conventional Reinforced Concrete.

Shah and Ribakov (2011) experimental study on steel high-strength concrete (SFHSC) shows that addition of fibres to high-strength concrete improves its mechanical properties and makes the material very durable as well as the aesthetics for applications in construction. Elavarasi and Saravana (2014) also carried out experimental investigation on the structural behaviour of High strength steel fibre reinforced concrete (HS-SFRC) block pavements and compared it with High strength plain cement concrete blocks (HSC) using 0.5%, 0.75% & 1.0% fibre percentage contents by volume fraction. The results they obtained prove that the addition of the steel fibres has increased the compressive strength, split tensile strength, flexural and tensile strength and static modulus of elasticity of the paving block. Abrasion resistance to wear was improved by the addition of fibre content. It was observed that the mode of failure was changed from brittle into ductile.

Marlon (2015) investigated the use of undulated steel fibre in paving block reinforcement. The findings indicated that not a great deal of research has been directed on the utilization of steel fibres in concrete paving blocks, which is the purpose for the proposition of the analysis. Thus, an extensive knowledge of the properties is necessary in order to make best and economic use of the material in concrete.Dahlke & Charkha (2016) investigated the Effect of steel fibres on the strength of concrete. The addition of steel fibre enhanced the mechanical properties of concrete. All the properties of concrete such as the compressive strength and flexural strength are increased. Furthermore, there is also a reduction in porosity and absorption capacity of the concrete as compared with normal concrete. Gherman et. al. (2016), investigation showed the fact that all engineering properties of concrete improves by addition of fibres to high-strength concrete which provides a better behaviour of the material once the matrix has cracked, by bridging across the cracks and providing post-crack ductility. The compressive strength of fibre reinforced high strength concrete reached the maximum at 0.8% volume fraction, with a 21% improvement over the HSC without fibres. Energy absorption of the fibre-reinforced concrete also achieved an improvement of 97.8% increase in volume.

Zagade et. al. (2018), investigated the effects of Use of Steel Fibres in Concrete. The results showed that the addition of Steel fibres can improve the properties of concrete and it also reduces or even eliminate cracks and the optimum dose of steel fibres in the concrete increases the strength of concrete. Majid and Er (2018) investigation showed that the Compressive strength split tensile strength and Flexural strength increased by the addition of steel fibres. Thus, the use of metal fibre for powerful pavement construction can be cautioned undoubtedly.

MATERIALS AND METHODS

Cement

The Portland cement used throughout this research was manufactured in accordance with BS EN 197-1 (ASTM, 2015), and and supplied by Hanson High Strength cement (Grade 52.5N) obtained from Coventry Building Supplies. The minimum compressive strength of the Portland cement is 32.5 N/mm^2.

The oxides/chemical compositions of the Portland cement are as shown in Table 1.

Table 1: Oxides/Chemical Compositions of the Portland Cement

Oxides	Amount (%)
CaO	60 - 67
SiO_2	17 - 25
Al_2O_3	3 - 8
Fe_2O_3	0.5 - 6
MgO	0.1 - 4
Na_2O	0.5 – 1.3
K_2O	0.5 – 1.3
SO_3	1 - 3

Steel Fibres

The steel fibres CAR19CDM-010 and CAR13CDM-006 manufactured by Fibrecon UK was used for the experimental work. The products are classed as steel fibre having high quality that can be used in a large array of concrete applications ranging from large civil projects to small building centres and plastering (Fibrecon-UK 2015).

Table 2: The description of Steel Fibres

Fibre Type	Deformation	Length (mm)	Diameter (mm)	Aspect Ratio
UF CAR19CDM		18.20	0.50	36.40
UF CAR13CDM		13	0.62	20.97

Aggregates

Aggregates makes up the most parts of a paving block. They influence the ease of block production, performs as inert filler which gives out the required strength and provides durability (Vireen 2013). The quality of the finished product is significantly affected by the aggregate type and sizes. Aggregates used

Vol.9, No.2, pp.38-51, 2021
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in the course of this finding are classified as coarse aggregate with maximum size not exceeding 10mm and sharp sand as fine aggregate with particle sizes ranging from 0-4mm.
Classification from this process defines particles of 0-5mm as fine aggregates and particles exceeding 5mm as coarse aggregates (Claissie et al 2007).

Water
Water serves as stimulant that binds the cement and aggregates together through hydration progression to produce a hardened material. The hydration process changes calcium silicate to Calcium Silicate Hydrate (CHS) gel which forms over a period of time creating a harden paste (Vireen 2013).
The quality of water used in concrete mixes plays an important role in the performance of the concrete both in its fresh and hardened state (Kucche et. al. 2015). Strength, durability and setting time of concrete may be adversely affected if water used contains some impurities.

METHODS

The methods adopted in this research work include;

Paving Block Design Consideration
Four main factors are put into consideration when designing for paving blocks, these factors includes; the traffic load, condition of the subgrade, materials constituent of the pavement and the environmental interaction of the paving block. In designing of paving blocks, it is necessary to determine the underlying soil bearing capacity. California Bearing Ratio test is a simple method used to determine the bearing capacity of the subgrade (Kilsaran 2015).

Paving Block Fabrication Procedure
There are 2 main manufacturing processes used in the fabrication of concrete paving blocks, namely; the wet cast and the hydraulically pressed method.

Wet Cast Process
The wet cast procedure is ideal for blocks not requiring high strength as they are typically used to fabricate fanciful block units. A nearly wet concrete is readied, normally in specifically measured quantity to guarantee consistency. Small mixer machines are utilized to amalgamate the already measured amounts of sand and coarse total with an exact quantity of binder which is usually cement, after which that the part is blended with water and additives to deliver the solid mass of concrete. Additives that may be incorporated includes; plasticisers, colours, rapid hardening agents to speed up the hydration process, blossoming inhibitors, fibres and discharge operators (Paving Expert 2015).

After the materials has been properly mixed, the concrete paste is then poured into moulds placed on a flat surface and vibrated at high frequency to eliminate possible voids. The vibration is achieved by means of a vibrating table mounted over an oscillating motor (Paving Expert 2015).To mitigate or possibly eradicate variation thickness of blocks, moulds are correctly stacked during process of curing. Varying thickness can impose a challenge during installation and may also affect the aesthetics (Paving Expert 2015).

Hydraulically Pressed Method
Unlike the wet-cast fabrication method, the hydraulic press method is used for fabrication of blocks requiring high tensile strength. In the same vain as the wet process, aggregates are prepared in batch but with minimal water content. This enhances best handling characteristics and high tensile strength of concrete is achieved. The already well mixed concrete constituents are poured into steel mould and

compressed using hydraulic vibrating press to eliminate excess water in the mix. Due to effective compaction, samples can be demoulded and the moulds reused immediately without causing any dent to the sample (Paving Expert 2015).

Batching and Mixing
The process of manufacturing paving blocks with a consistent quality as well as the strength requires a suitable mixing method that does not allow fluctuation in the water-cement ratio in the concrete batch.

Curing Of Paving Blocks
Paving blocks loses many qualities if the curing is not rightly done. The curing process of concrete is to achieve sufficient water retention in the concrete and to effectively complete the hydration process of cement. To ensure proper curing, temperature and humidity must be favourable. Usually, relative humidity of about 95% is suggested for concrete pavers. When properly cured, concrete tends to behave like an impermeable material. Suggestions from several theories indicate that net required amount of water for complete cement hydration is about 37% by weight of the cement (Kumar et al 2012).
Basically, there are three main types of curing, one is the conventional or natural air curing, second is the accelerated curing and the third is the membrane curing (Krishna et al 2010).

Conventional or natural air curing
This method requires preventing moisture loss by continuously wetting the exposed surface of concrete, this in turn help in maintaining the required quantity of water in the concrete during the early hardening period.
Accelerated curing
This method involves keeping the surface of the concrete moist and at the same time raise the temperature of the concrete, thereby increasing the rate of strength gain. Typically, this method is used for pre-cast concrete products.

Membrane curing
Excessive loss of moisture is minimized by preventing the loss of water used in the concrete mix. Example is covering the concrete sample with a relatively impermeable membrane usually plastic.

RECOMMENDED TEST PROCEDURES FOR CONCRETE PAVING BLOCKS

Split Tensile Testing

Split tensile strength in generally is usually greater than direct tensile strength and lower than flexural strength (modulus of rupture). Tensile split strength is used in structural design of lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement. Tensile strength is an important property of concrete because it’s vulnerable to tensile cracking due to the effect of applied load and other effects like temperature and moisture (ASTM 2014).
Ganjian, et al. (2013), carried out split tensile strength test on laboratory fabricated blocks in accordance with the British Standard BS EN 1338:2003. The test setup involves placing the paving block sample in a split tensile steel frame, using wood strip of the same material at the top and bottom of the block sample to ensure the sample is adequately packed. Then load was applied at the rate of 0.05 ± 0.01MPa/s along the longest side of the block specimen until failure occurs. At failure point, the test is stopped and the block sample broken into two halves by tensile force. The obtained failure load which is in kN is then used to calculate the tensile strength in MPa in accordance with BS EN 1338:2003.

Slip and Skid Resistance

Ideally, slip resistance deal with traffic for pedestrians while skid resistance is for tyres. Either ways, safety in this regard is very important. Though numerous variables influence slip and skid resistance, interlocking pavements offer surface qualities that give resistance and safety when contrasted with other pavement surfaces (ICPI 2015).

Slip Resistance

Slip in pavements indicates an absence of adequate frictional force existing between the walking pavement and the foot of the pedestrian. Slip resistance test are carried out to determine the extent of susceptibility of an aggregate to polishing under traffic by finding out its polished stone value (PSV) (Omeje 2014).

A surface can be termed as being slip resistant if it provides the friction necessary to keep a shoe heel or crutch tip from slipping under a variety of circumstances. Many human and surface characteristics influence slip resistance. This includes the composition of the surface, footwear, wetness, tainting of the surface, the rate and style of strolling, running, turning pointedly, moving up or down a slope or steps (ICPI 2015).

Slip resistance under dry conditions can be approximately measured using the static coefficient of friction, i.e., the initiating horizontal force sliding at the instant of motion divided by the static weight (gravity force). No conventional way for measuring slip resistance has been established; however, devices used to test for slip resistance are called tribometers.
Mark II and Mark III are Slip-Test devices manufactured in Atlanta USA under the National Institute of Standards and Technology (NIST) by Brungraber for evaluating slip resistance. The figure below depicts a refined version of the NBS/NIST-Brungraber tester.

Skid Resistance

Skid resistance is the force generated when a tire that is supposed to prevent rotation slides along the pavement surface (pavement interactive 2012). Skid resistance is one of numerous variables that influence decisions of agencies on when to re-emerge or recreate a road. Also, the age, movement, an unpleasant ride owing to settlement and rutting, and complains from road users are also contributing factors.Basically, there are two methods used to measure skid resistance; which is the static and dynamic measurements. The static measurement involves using a measuring device while moving across a particular section on the pavement. This method does not require a tire. The dynamic device on the other hand uses a tire to make measurements while traversing at a constant velocity across the pavement surface. The British pendulum tester is a common device used for measurement by the static method. The figure below depicts the pendulum tester device.

MIXED DESIGN FOR PAVING BLOCK SAMPLES

The process used in selecting the right amount of different constituent of concrete to give a desired end product of concrete is referred to as the mix design. Mixes used in fabrication of concrete block paving's are not the same with the conventional concrete mix owing to the fact that they are produced as semi-dry mixes. A mix design that will meet up the minimum requirement was adopted. The mix proportion is given in the table below;

PROCEDURES FOR THE EXPERIMENTATION

All the paving block samples used in the experiment were fabricated in the concrete laboratory of Coventry University, Sir John Laing building. Applied pressure load of 400kN at 00.1kN/s was applied to the already weighed out mix for 120 seconds, afterwards samples were demoulded the next day and cured in a temperature-controlled room for 7 and 28days respectively and finally subjected to tensile strength test. The best mix was further subjected to skid resistance and water absorption tests.

Groundwork for block sample making

The paving blocks were manufactured using a steel mould with dimension of 190mmx100mmx80mm, which is length, breath and thickness respectively. The steel mould is then firmly bolted to ensure the sample shape is not distorted and some part of the mix is not leaked out. To also ensure a hack free sample, the moulds were firstly cleaned, and then oiled before the mix samples are weighed into the mould and compressed.

Mixing

After careful weighing out of the concrete mix constituents for the paving block samples, the items were then poured into the small concrete mixer of 15 litre maximum capacity. The blend is at first dry to ensure proper mixing of the binder and aggregates before the measured amount of water is also added to the mix. Steel fibres were finally added and the mixer is allowed to continue spinning for few more minutes before samples are weighed out into the steel mould.

Hydraulic Pressing

The semi- dry mix of 3.6kg is weighed out and placed into the steel mould ready for compressing. Ideally, factory production of paving blocks requires the mixes to be compressed and vibrated at the same time. In this study however, mixes were only compressed owing to unavailability of the laboratory equipment to execute both tasks simultaneously. The mixes were however compressed using the Avery Denison 500kN machine. A compressive load of 400kN was applied to the mixes at the rate of 0.001kN/s for 120 seconds. The steel mould were braced at both side with a steel metal sheet and clamped to the mould to prevent bolt tear-out due to the high compressive load from the machine.

Curing

The sample after compaction were then placed in a plastic box and covered to prevent rapid and excessive loss of water. The samples were demoulded after 24hrs and placed in a perforated platform that is already placed in the curing box which is partly filled with water. The chambers were all placed in a temperature control room ranging from 19.8^{o}C to 21℃ and relative humidity of the chamber is about 95%.

TEST PROCEDURES

Split Tensile Strength Testing

Following the standards set out in BS EN 1338:2003, the blocks were cured for 7 and 28days respectively with three samples for each age. The blocks samples were then immersed in water tank for about 24hrs prior to the split test. After the hour mark, blocks samples were then removed from the tank, wiped dry and placed in the split tensile steel frame with wood strip packing placed at the center, top and bottom of the block. The steel frame is then placed in the Avery Denison 2000 machine, the machine is at first pre-loaded at 10.24kN before continuous load is applied at a rate of 1.153kN/s along the longest part of the block parallel to the edge of the block. The load at failure for each block sample were recorded in kilo Newton (KN) and were used to determine the tensile split value in Mega Pascal (MPa).

The aim of the split tensile strength test was to investigate effect of the different steel fibres on the strength of paving block samples.

Calculating Split Tensile strength

The following formula provided by BS EN 1338:2003, was used in calculating the split strength of the paving block samples;

T = 0.637 x k x P/S

Where;

T = Split strength of the block measured in MPa

P = Failure load of the block measured in kN

S = Area of the failure plane measured in square millimetre $mm^{2\,=}$ I x t

I = the mean of two failure length, measured in millimetre mm

t = block thickness at failure plane, and

k = correction factor for blocks

k = 1.3 – 30 $(0.18 – t/1000)^2$ if 140mm< t≤ 180mm or k = 1.3 if > 180mm

Skid/ Slip Resistance Test

The pendulum tester is the equipment used to determine the skid/slip resistance of the paving block samples. The equipment has a pendulum with a rubber spring loaded slider that is fixed at one end. At the point when the pendulum is swung, the frictional force generated between the slider and the surface area of the material been tested is measured by the swing length reduction using a calibrated scale.Before beginning of the test, the paving blocks were immersed in portable water of 20±3℃ for at least 30 minutes to enable the slider to swing freely toward traffic flow direction and level the base screws. The equipment swinging arm is raised clear of the test sample and cinched into a flat position and then the arm was released and the pointer value set to zero. The pendulum was permitted and hanging vertically, the spacer was then joined to a chain at the segment base and the head of the tester was brought down so that the slider touched the paving surface and afterward cinched into position and the spacer was then removed.
Subsequent to testing, the pointer was stopped by releasing the pendulum utilizing the stop button and the test was rehashed. The mean of five effective readings were obtained.

RESULTS AND DISCUSSION

The initial phase was to calculate for the split tensile strength values of the block samples. The failure load obtained from the split machine which was in KN but was calculated in MPa. Split test was performed after the curing age of 7 and 28days respectively. The formula used was from BS EN 1338:2003;

T = 0.637 x k x P/S

Where;

T = Split strength of the block measured in MPa

P = Failure load of the block measured in ken

S = Area of the failure plane measured in square millimetre mm^2 = I x t

I = the mean of two failure length, measured in millimetre mm

t = block thickness at failure plane, and

k = correction factor for blocks

k = 1.3 – 30 $(0.18 – t/1000)^2$ if 140mm< t≤180mm or k = 1.3 if > 180mm.

Split Tensile Strength Test

Average tensile strength of block samples with Fibrecon UK (CAR19CDM-010 and CAR13CDM-006) steel fibre samples are illustrated in tables and chart for 7days and 28days respectively.

The optimum fibre dosage for each fibre type that yielded the best tensile strength was obtained from an average of three tested samples.

Figure II shows that the optimum dosage for CAR19CDM-010 has a quick early strength after 7days; the average value again cannot be used because it is also not concurrent. Therefore, the average value of 2.62MPa obtained after 28days is considered as the optimum fibre dosage and is used in the analysis.

CAR13CDM-006 similarly has optimum fibre dosage of 5% with average split strength of 3.40MPa after 7days curing age as illustrated in Figure III.

The control sample had an early strength of 1.91MPa after 7days curing. An increment of 33.51% in the sample tensile strength was observed after 28days. This indicates that the block sample gained more strength with more curing age (Noor 2013).

Percentage decrease in strength was observed from 7days to 28days from most of the fibre types having identical fibre dosage.

CAR19CDM-010 also had 15.81% decreases while CAR13CDM-006 recorded the highest strength decrease of 32.65%.

For CAR19CDM-010 the optimal value was obtained with 3% fibre dosage and tensile strength of 2.72MPa which yielded 42.4% increase in strength when compared with the control mix at the same age.

The overall best strength for the 7days age was observed using the CAR13CDM-006 with 5% fibre dosage producing tensile strength of 3.40MPa which led to 78.01% increase in strength when compare to control mix of same age.

CAR19CDM-010 got its optimal fibre dosage at 5% with tensile strength of 2.62MPa which yielded a minimal tensile strength increase of just 2.75% when compared to the control mix of the same age. CAR13CDM-006 only saw an increment of 0.78% with optimal fibre dosage of 3% and tensile strength of 2.57MPa.

The two samples from the best mix which was CAR13CDM-006 with 5% fibre amount that were oven dried were also subjected to tensile split test. The purpose of the test was to investigate the behaviour of the block samples after they have been placed in the oven for three days. The split test results obtained were 2.95 and 3.06Mpa respectively. On the average, the oven dried sample recorded a 31.44% increase in strength when compared to the same mix with that underwent the membrane curing. This discovery suggests that accelerated or steam curing also increases the tensile strength of paving block.

Table 3: Average tensile strength value for CAR19CDM-010 after 7days

3%	5%
2.72	2.20

Table 4: Average tensile strength value for CAR19CDM-010 after 28days

3%	5%
2.29	2.62

Fig. 1: Average split tensile strength for CAR19CDM-010

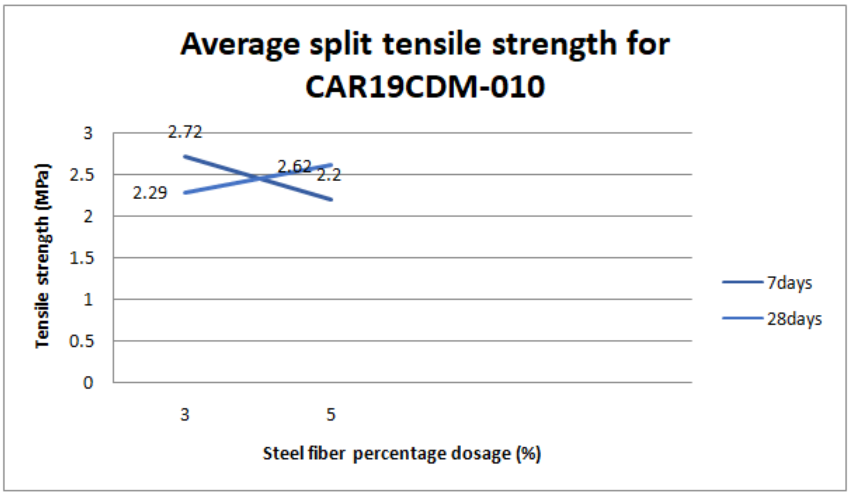


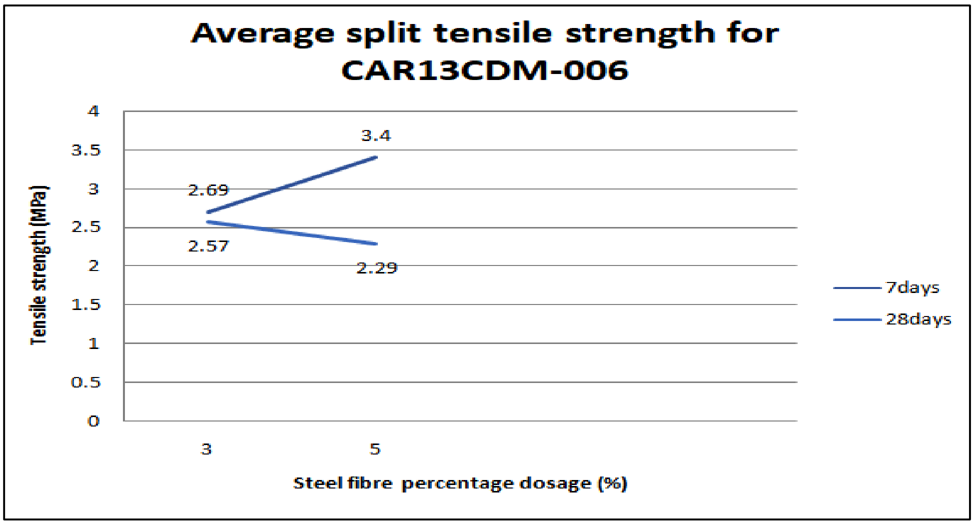
Table 5: Average tensile strength value for CAR13CDM-006 after 7days

3%	5%
2.69	3.40

Table 6: Average tensile strength value for CAR13CDM-006 after 28days

3%	5%
2.57	2.29

Fig. 2: Average split tensile strength for CAR13CDM-006



International Journal of Civil Engineering, Construction and Estate Management
Vol.9, No.2, pp.38-51, 2021
ISSN 2055-6578(Print),
ISSN 2055-6586(online)

Table 7: Split Tensile Strength Results of Paving Block Samples (Control Samples)

Sample Number	Curing Age (days)	Failure load (kN)	Tensile Split Strength (MPa)	Average Split Strength (MPa)	Spread Sheet (%)	Block Dimension (mm)
1	7days	51.40	2.15	1.91	18.60	Length = 190mm Weight = 100mm Thicknes =80mm
2		41.72	1.75			
3		43.83	1.84			
1	28days	60.89	2.55	2.55	8.61	
2		63.69	2.67			
3		58.23	2.44			

Fig. 3: Comparing control mix at 7 and 28days

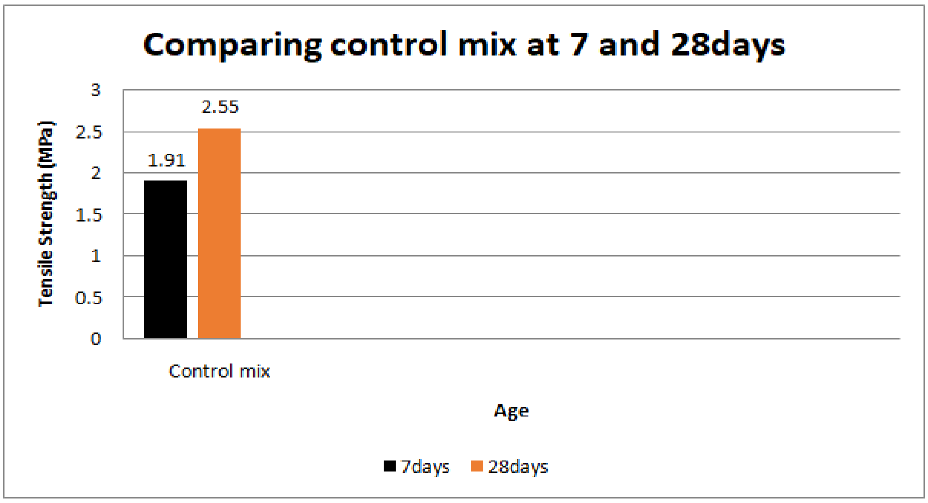


Table 8: Split Tensile Strength Results of Paving Block Samples (CAR19CDM-010)

Sample Number	Steel fire content (%)	Curing Age (days)	Failure load (kN)	Tensile Split Strength (MPa)	Average Split Strength (MPa)	Spread Sheet (%)	Block Dimension (mm)
1	3	7days	61.82	2.59	2.72	0	Length = 190mm Weight = 100mm Thicknes =80mm
2			64.81	2.72			
3			64.90	2.72			
1		28days	50.99	2.14	2.29	13.36	
2			53.79	2.25			
3			59.02	2.47			

Table 8: Split Tensile Strength Results of Paving Block Samples (CAR19CDM-010)

Sample Number	Steel fire content (%)	Curing Age (days)	Failure load (kN)	Tensile Split Strength (MPa)	Average Split Strength (MPa)	Spread Sheet (%)	Block Dimension (mm)
1	5	7days	34.62	1.45	2.20*	46.69*	Length = 190mm Weight =100mm Thicknes =80mm
2			64.80	2.72			
3			58.03	2.43			
1		28days	59.95	2.51	2.62	5.99	
2			64.12	2.67			
3			64.07	2.67			

Table 9: Split Tensile Strength Results of Paving Block Samples (CAR13CDM-006)

Sample Number	Steel fire content (%)	Curing Age (days)	Failure load (kN)	Tensile Split Strength (MPa)	Average Split Strength (MPa)	Spread Sheet (%)	Block Dimension (mm)
1	3	7days	70.91	2.97	2.69*	18.18*	Length = 190mm Weight =100mm Thicknes =80mm
2			63.82	2.67			
3			58.03	2.43			
1		28days	66.80	2.78	2.57	13.31*	
2			60.55	2.53			
3			57.57	2.41			

Table 10: Split Tensile Strength Results of Paving Block Samples (CAR13CDM-006)

Sample Number	Steel fire content (%)	Curing Age (days)	Failure load (kN)	Tensile Split Strength (MPa)	Average Split Strength (MPa)	Spread Sheet (%)	Block Dimension (mm)
1	5	7days	81.12	3.40	3.40	10.05	Length =190mm Weight=100mm Thicknes=80mm
2			85.35	3.58			
3			76.89	3.22			
1		28days	54.72	2.29	2.29	0	
2			54.58	2.29			
3			65.87	2.76			

Figure 4: Comparing percentage difference from 7 to 28days for best of each fibre type

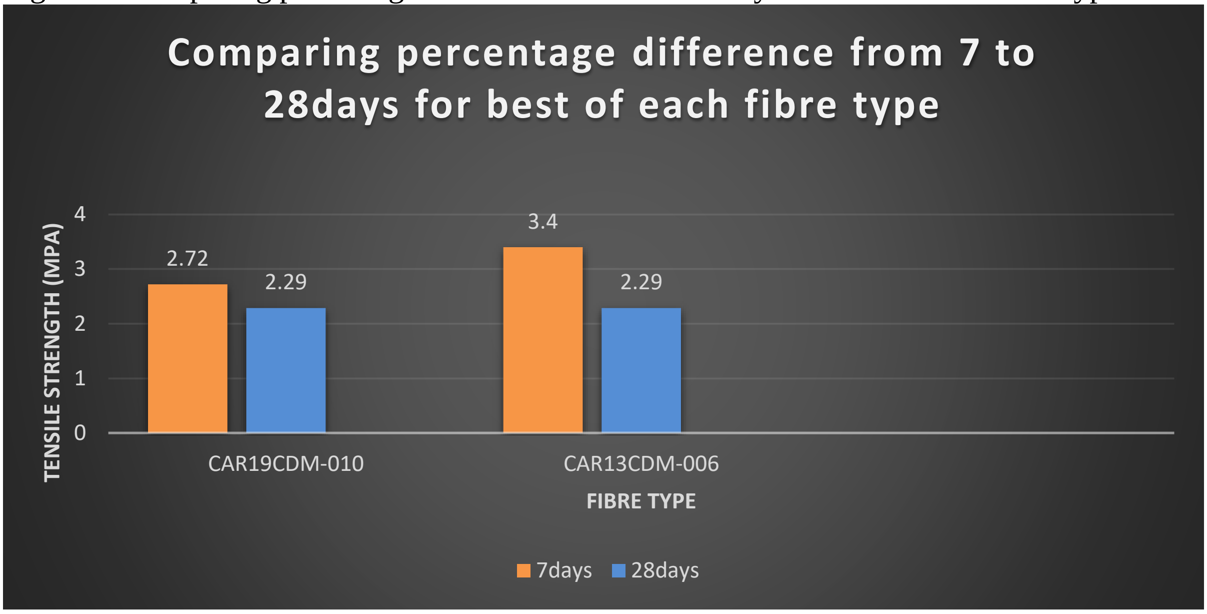
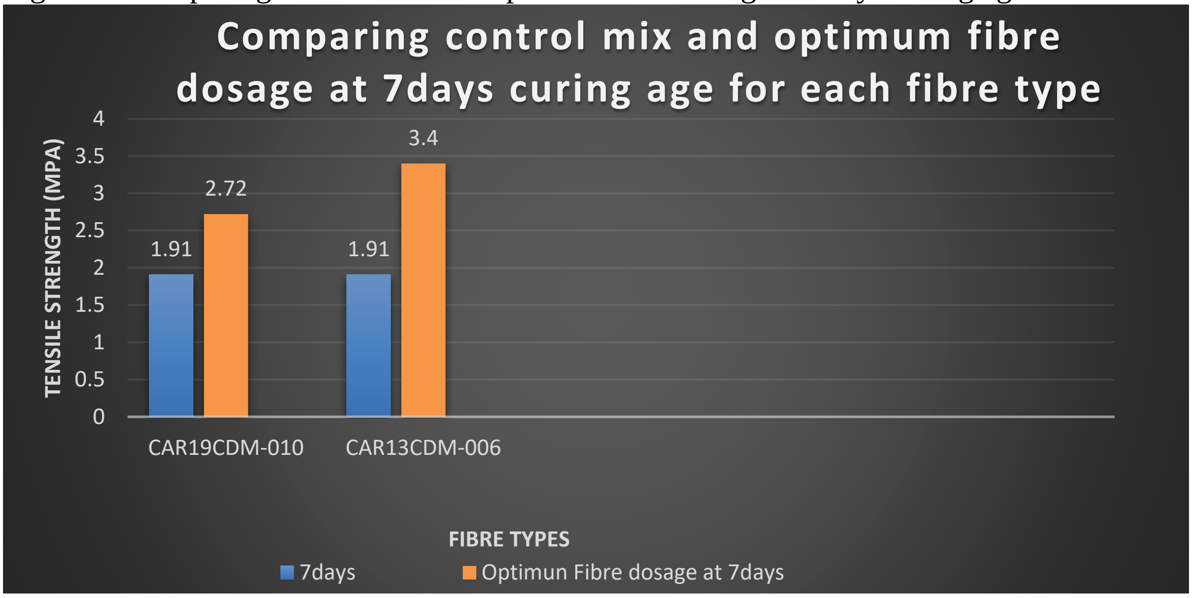


Figure 5: Comparing control mix and optimum fibre dosage at 7days curing age for each fibre type



CONCLUSION

From the experiments conducted, the test results did not meet up the required structural performance of 3.6MPa as recommended by the British Standard Institute, the samples however met with the primary aim of the research which is to improve the tensile strength of CPB by incorporating steel fibres in the mix.

For samples that were consistent, increase in tensile strength were observed. The sample with the best mix was CAR13CDM-006 with 5% steel fibre dosage and 7days curing age. It recorded a split tensile value of 3.40MPa and a percentage difference of 78.01% when compared with the control mix at same age.

After performing the split tensile, skid resistance and water absorption tests, the following conclusions were made;

1. In general, reduced amount of cement in the fabrication of CPB is achievable thru the incorporation of steel fibres.
2. The rate of tensile strength increase is dependent on fibre type and volume content.
3. The mechanical property of the paving block samples is not affected by the incorporation of steel fibres. The best mix and control mix gave acceptable skid resistance.
4. High yield strength cements give higher early strength to paving block samples compared to its 28days age.
5. Block strength increases with increase in the curing age.

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CONFLICT OF INTEREST

The authors have not declared any conflict of interest