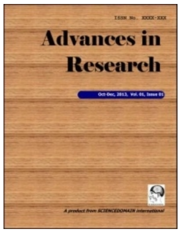

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Characterization of Crushed Brick Lightweight Concrete Reinforced with Palm Fibers

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Author's contribution

This whole work was carried out by author ETD.

Original Research Article

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ABSTRACT

This study was aimed to investigate the effect of palm fibers on the properties of lightweight concrete. Such lightweight concrete was produced from coarse lightweight crushed brick and fine lightweight crushed brick (CLWA and FLWA). Different percentages of palm fiber; 0, 0.25, 0.5 0.75, 1, and 1.25% based on volumetric fractions were included with lightweight concrete mixes. The properties tested include fresh density, compressive strength, splitting tensile strength, static modulus of elasticity, absorption, flexural strength, and toughness indices. The results show that the use of 0.75% of palm fiber would raise the compressive strength, splitting tensile strength and flexural strength of the lightweight concrete by about 11%, 47% and 18%, respectively. The same percentage of palm fibers would significantly enhance the toughness performance of crushed brick lightweight concrete.

Keywords: Crushed brick; palm fibres; lightweight concrete; toughness.

1. INTRODUCTION

Research has been conducted worldwide on a large number of natural or artificial light weight aggregates. The use of a local product for the production of lightweight aggregate depends on its specific properties and the requirements for a particular job. Structural lightweight concrete has its obvious advantages of higher strength/weight ratio, lower co-

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efficient of thermal expansion, and superior heat and sound insulation characteristic due to air voids in the light weight aggregate. Besides, the reduction in dead weight of a construction could result in a decrease in size of structural members and steel reinforcement [1,2].

Structural light weight concrete has an in-place density (unit weight) on the order of 1440 to 1840kg/m^3 compared to the normal weight concrete with a density in the range of 2240 to 2400kg/m^3. For structural applications, the concrete strength should be greater than 17.0MPa for the concrete mix from lightweight coarse aggregate [3]. The mix may be made of a portion or the entire fine aggregate of a lightweight material [4,5].

In most cases, the marginally higher cost of the lightweight concrete is offset by the reduction of the size of structural elements, amount of reinforcing steel, and the volume of concrete used, resulting in lower overall cost [6].

On the other hand, there has been a growing interest in utilizing natural fibers for making low cost construction materials in recent years. Knowledge of natural fibers used in cement composites, mechanisms of mechanical behavior, insulating behavior, etc. has increased substantially. Many Research papers [7,8] has indicated various advantages in the use of natural fibers in cement composites, such as, increased flexural strength, post-crack load bearing capacity, increased impact toughness, and improved bending strength [9]. Natural fibers also enhance mechanical properties and behave like reinforcement for the composites [9,10]. The major advantage of using natural fibers is that, they offer significant cost reduction and benefits associated with processing as compared to synthetic fibers [11].

However, this research was conducted to determine the effect of adding different percentages of palm fibers on the properties of crushed brick lightweight concrete reinforced with such fibers.

2. MATERIALS AND METHOD

2.1 Materials

The cement used in the mixtures was ordinary Portland cement type I, a product of Task corporation berhad. The chemical composition of the cement used is given in Table 1. The super plasticizer (SP) of type Conplast SP1000 was supplied by Fosroc Sdn. Bhd used with a maximum dosage of 1.0-1.2% to produce the desired workability of the mixes. The fine aggregate was natural sand, with fineness modulus of 2.86 and maximum size within 5mm. The light weight crushed brick fine aggregate (FLWA) was also used as partial replacement of sand. The light weight coarse aggregate (CLWA) was also from crushed brick with maximum aggregate size of 20mm, which was used as coarse aggregate. Table 2 shows the properties of the aggregate used in the study. The palm fiber is produced by Fiber-X(M) Sdn. Bhd, and its characteristics are shown in Table 3.

2.2 Mix Proportions

The concrete mixtures were designed according to the absolute volume method given by American Concrete Institute [3]. Concrete of cement content 360kg/m^3 and water-cement ratio of 0.45 were chosen for the mix(CF0). A partial replacement of sand by weight with fine lightweight crushed aggregate (FLWA) was also done. Besides, Coarse lightweight crushed aggregate (CLWA) was used in this mix [12]. The inclusion of the palm fiber with different volume fractions of 0, 0.25, 0.5,0.75, 1.0, and 1.25% were used for the mixes, CF1, CF2, CF3, CF4, and CF5, respectively, as shown in Table 6. However, the super plasticizer was varied from 1-1.2% to obtain the desired workability (Slump=100±10mm).

Table 1. Chemical properties of ordinary portland cement

Constituent	Component of OPC (%)
SiO_2	21.31
Al_2O_3	5.89
Fe_2O_3	2.67
CaO	62.2
MgO	3.62
SO_3	2.6
Loss of ignition	1.59
Insoluble residue	0.24
Free CaO	1.74
L.S.F.	0.88
C_3S	33.37
C_2S	35.92
C_3A	11.09
C_4AF	8.12

Table 2. Physical properties of aggregate

Aggregate Type	Absorption %	Specific gravity
Sand	2.1	2.62
Fine lightweight crushed brick	18.2	2.0
Coarse lightweight crushed brick	15.4	1.8

Table 3. Characteristics of palm fiber

Fiber Properties	Quantity
Average fiber length,(mm)	30
Average fiber width ,(mm)	0.021
Tensile strength(MPa)	21.2
Elongation at break (%)	0.04
Specific gravity	2.14
Water absorption %, 24/48hrs	0.6

2.3 Experimental Tests

Three cubes of size 100mm×100mm×100mm were used for each mix to test the density and the compressive strength of the samples undergoing continuous water curing until the age of test. The density and absorption of hardened concrete were determined in accordance to ASTM C642 [13].

The cube specimens were left in the molds for 24h at room temperature of 20°C. After de molding, the specimens were kept in water curing condition till the age of test was attained. The compressive strength was determined according to BS 1881: Part 116 [14]. Test samples of sizes100 × 100 × 500mm were used for the determination of flexural strength and according to BS 1881: Part 118 [15]. Also, the specimens were used to determine the toughness indices of the lightweight concrete according to ASTM C1018 [16] as shown in Fig. 1. Cylindrical moulds of dimensions "Ø150mm×300mm" were used for determining the static modulus of elasticity according to ASTMC469 [17], whereas, cylindrical moulds dimensions " Ø100mm×200mm" were used for determining the splitting tensile according to ASTM C496 [18].

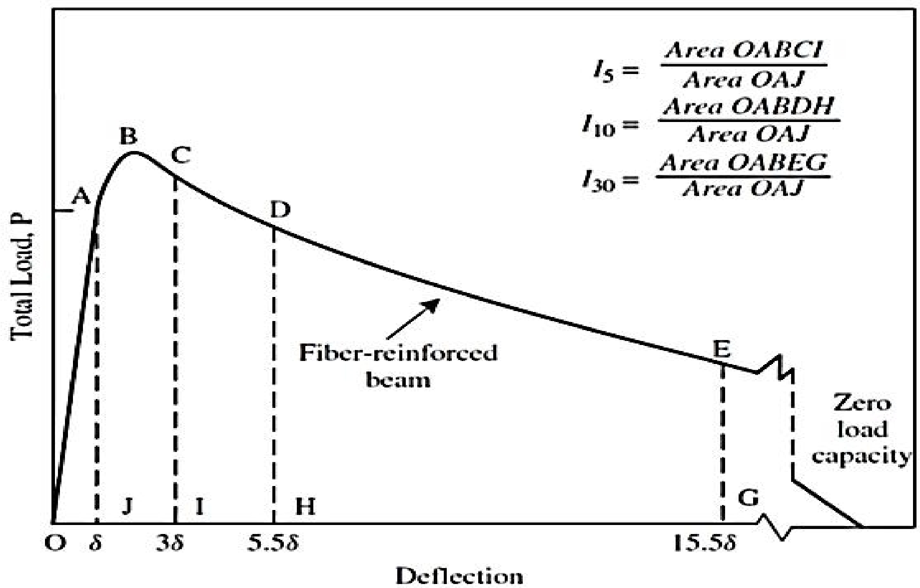

Fig. 1. Toughness indices according to the testing method ASTM C1018

3. RESULTS AND DISCUSSION

3.1 Fresh Status

Table 4 shows the results of the fresh density for all mixes. The results indicate that the inclusion of palm fiber in the crushed brick light weight concrete mixes reduces the fresh density. This can be attributed to the specific gravity of palm fibers (1.24) which affects the overall density of lightweight concrete [5,12].

3.2 Saturated Surface Dry Density

Table 5 shows the results of hardened density for light weight concrete. As mentioned in previous section (3.1 Fresh density), the reduction of density was obtained due to palm fiber inclusion. Thus, the density was decreased from 1980kg/m^3 (Ref. Mix) to 1920kg/m^3 by the use of 1.25% of palm fibers. However, the effect of palm fibers on the density is shown in Fig. 2.

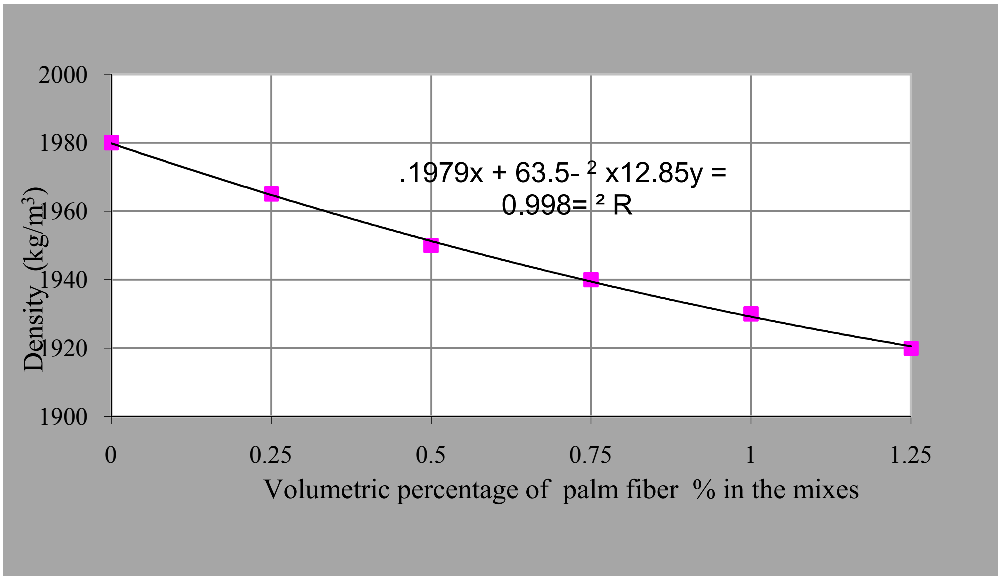

Fig. 2. Relationship between palm fibers and density of crushed lightweight concrete

Table 4. Crushed brick lightweight concrete mixes

Index	Cement (Kg m^{-3})	Water (Kg m^{-3})	SP%	W/C	OPF%	Sand (Kg m^{-3})	FLWA (Kg m^{-3})	CLWA (Kg m^{-3})	Fresh density (Kg m^{-3})
CF0	360	160	1.0	0.45	0.0	540	360	700	1930
CF1	360	160	1.0	0.45	0.25	540	360	700	1925
CF2	360	160	1.1	0.45	0.50	540	360	700	1910
CF3	360	160	1.1	0.45	0.75	540	360	700	1905
CF4	360	160	1.2	0.45	1.0	540	360	700	1900
CF5	360	160	1.2	0.45	1.25	540	360	700	1890

3.3 Compressive Strength

From Table 5, it can be seen that the inclusion of palm fiber up to 0.75% would increase the compressive strength of the lightweight concrete due to the better mechanical bond strength between the fibers and the cement matrix which delays micro-cracks formation [5,12]. However, the inclusion of more than 0.75% of the palm fiber reduces the compressive strength and this is attributed to the voids introduction in the mix due to excessive fiber content that may lead to reduction in bonding and disintegration [19,20].

Fig. 3 shows the relationship between palm fibers and compressive strength of lightweight concrete. It can be observed that the increase of fiber from 0% to 0.75%, increases the compressive strength by about 11%. This increase was accompanied with the reduction in density. Therefore, the use of such fibers with lightweight concrete gives drastic results in term of density and compressive strength.

Table 5. Mechanical properties of lightweight concrete mixes

Index	Density (Kg/m^3) 28 days	Compressive Strength, MPa 28 days	Splitting tensile strength MPa	Static modulus of elasticity, GPa 28 days	Absorption % 28 days	Flexural strength, MPa	Toughness Index I-5	Toughness Index I-10
CF0	1980	25.5	1.7	18.6	13.25	4.40	1	1
CF1	1965	26.3	2.0	19.2	12.8	4.70	1	1
CF2	1950	26.8	2.3	19.8	12.70	4.9	2.36	3.88
CF3	1940	27.5	2.5	20.4	12.10	5.2	2.89	4.54
CF4	1930	27.0	2.4	19.9	12.50	5.0	2.57	4.22
CF5	1920	26.1	1.9	19.1	12.90	4.5	2.12	3.46

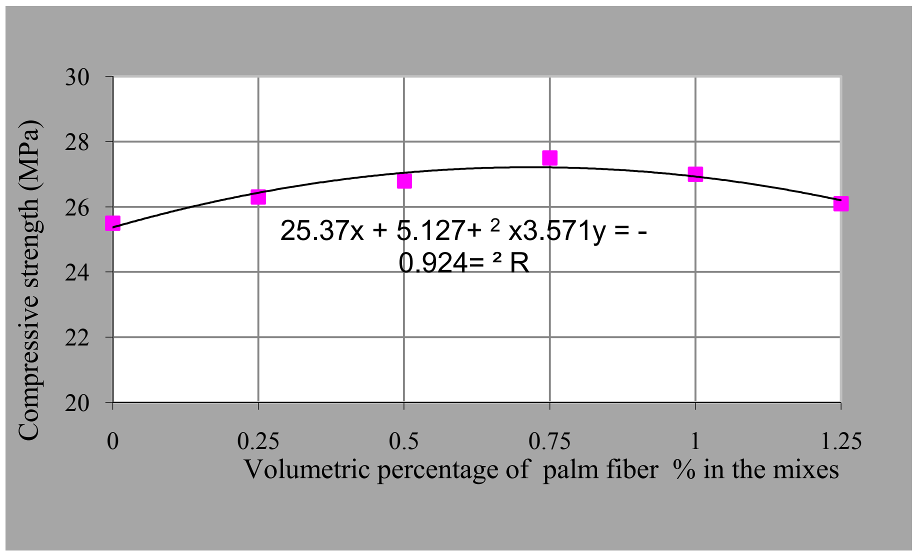

Fig. 3. Relationship between palm fibers and compressive strength of crushed lightweight concrete

3.4 Splitting Tensile Strength

The results of splitting tensile strength for the lightweight concrete mixes are shown in Table 5. It can be noticed that the inclusion of palm fiber up to 0.75% increases the splitting tensile strength of the lightweight concrete due to the same reasons mentioned in compressive strength section. However, the percentage of increase by the use of 0.75% of palm fibers was found to be 47%. The relationship between palm fibers percentage and splitting tensile strength of lightweight concrete is shown in Fig. 4. On the other hand, a significant relationship between the compressive and splitting tensile strengths for crushed brick lightweight concrete reinforced with palm fibers is presented in Fig. 5.

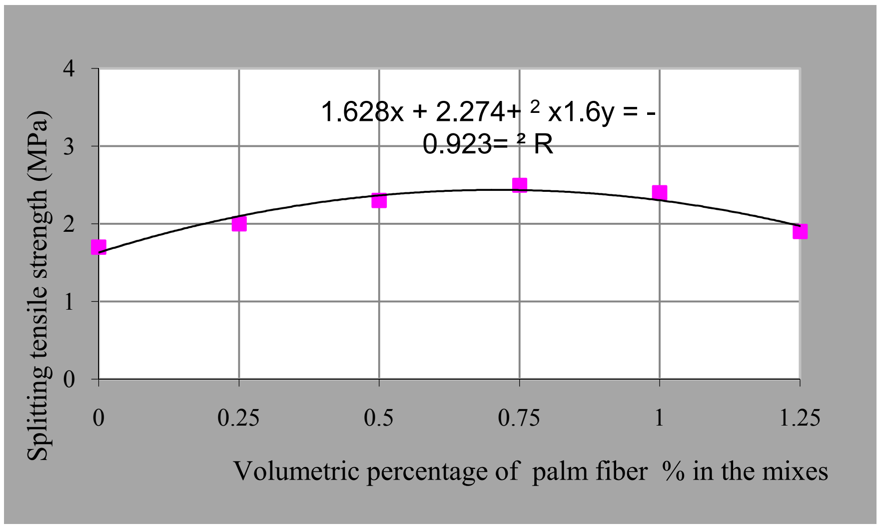

Fig. 4. Relationship between palm fibers and splitting tensile strength of crushed lightweight concrete

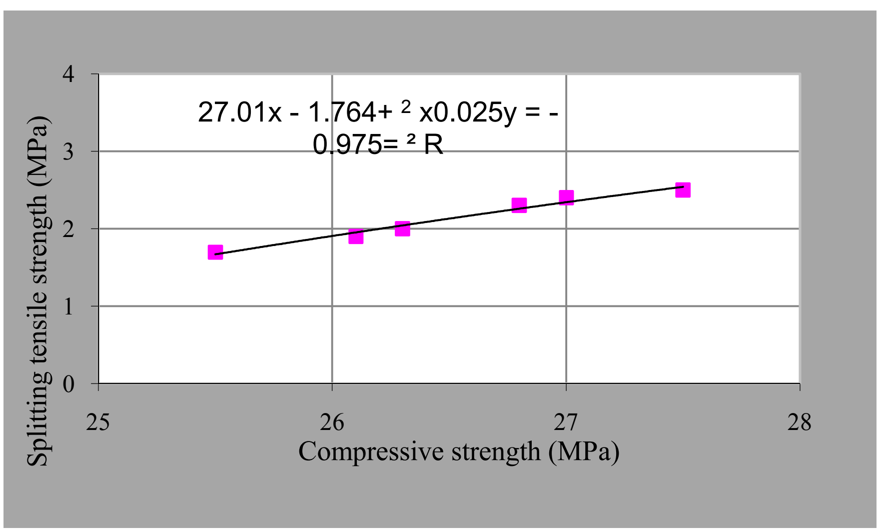

Fig. 5. Relationship between compressive strength and splitting tensile strength of crushed lightweight concrete

3.5 Static Modulus of Elasticity (Ec)

The moduli of elasticity results for all mixes are presented in Table 5. The comparison between (CF0) with (CF3) indicates that the use of 0.75% of palm fiber leads to an increase in static modulus of elasticity. This is probably due to the optimization of this percentage of palm fiber to produce the higher bond strength behavior and thus a higher modulus of elasticity [21]. However, the percentage of the increase for the lightweight concrete by this fiber content (0.75%) was found to be about 10%. Subsequently, the relationship between palm fibers percentages and static modulus of elasticity for crushed brick lightweight concrete are shown in Fig. 6. Besides, a strong relationship was found to exist between compressive strength and static modulus of such concrete as can be seen in Fig. 7.

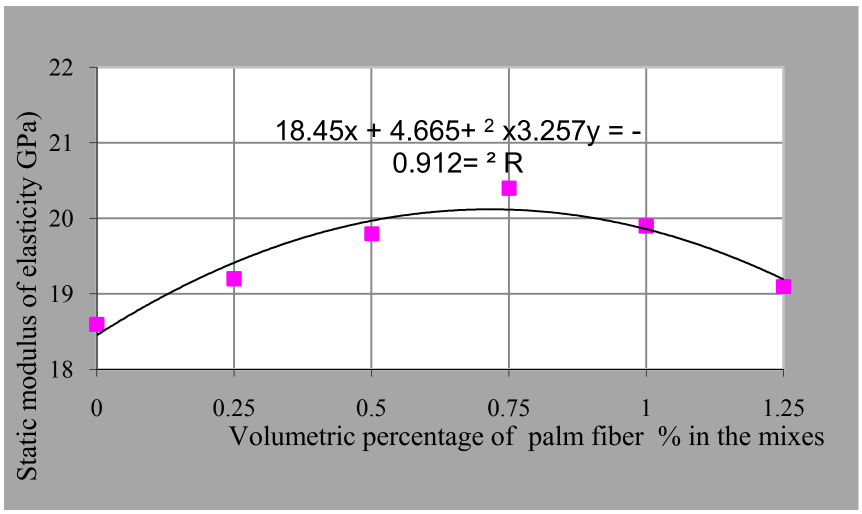

Fig. 6. Relationship between palm fibers and static modulus of elasticity for crushed lightweight concrete

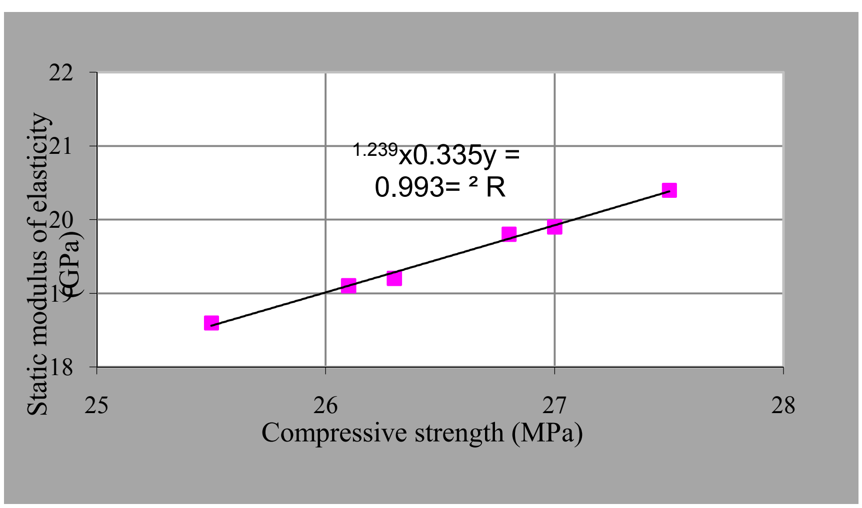

Fig. 7. Relationship between compressive strength and static modulus of elasticity for crushed lightweight concrete

3.6 Absorption

The results of the absorption capacity for all crushed brick lightweight concrete mixes are shown in Table 5. From the results, it can be observed that the least reduction was obtained with crushed brick lightweight concrete reinforced with 0.75% palm fibers. This is also compatible with other results for the properties of crushed brick lightweight concrete which show that the use of such fiber content would significantly enhance the performance of the concrete. The relationship between palm fibers with absorption of crushed lightweight concrete is shown in Fig. 8.

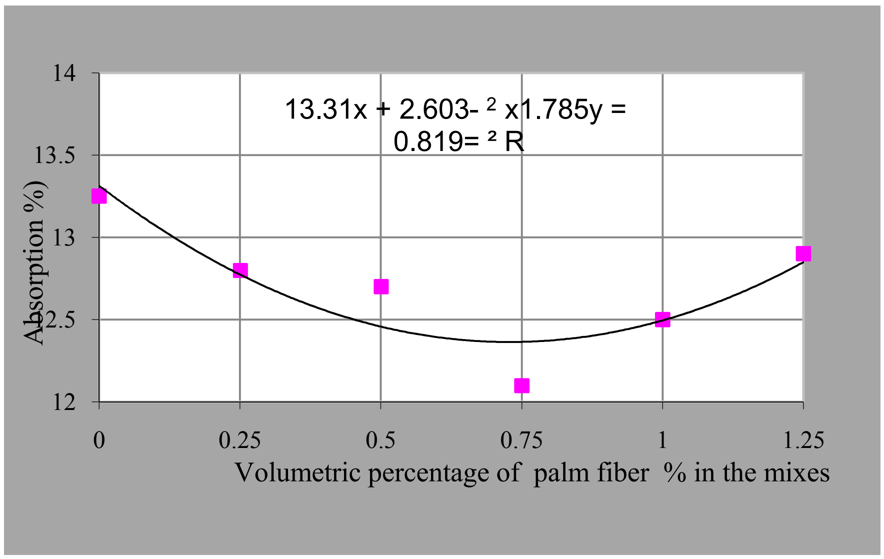

Fig. 8. Relationship between palm fibers and absorption capacity of crushed lightweight concrete

3.7 Flexural Strength

The flexural strength of the lightweight concrete mixes is shown in Table 5. Besides, the relationship between palm fibers and flexural strength of crushed brick light weight concrete is shown in Fig. 9. However, the increase of the flexural strength is comparable with the compressive strength as shown in Fig. 10. The results shows that the increase in the flexural strength is obtained up to 0.75 % of palm fiber used in the mix, and beyond this percentage, the increment in flexural strength would be slightly. The highest percentage of increase using 0.75% of palm fiber was about 18% compared with reference mix. This advantage maybe obtained because of the improvement that the fibers impart to the tensile strength and the ability of palm fibers to bridge the cracks effectively, thus the micro-mechanical features of crack bridging are operative from the stage of damage evolution to beyond ultimate loading [21-23].

3.8 Toughness Indices

The toughness indices results for the crushed brick light weight concrete mixes are shown in Table 5.

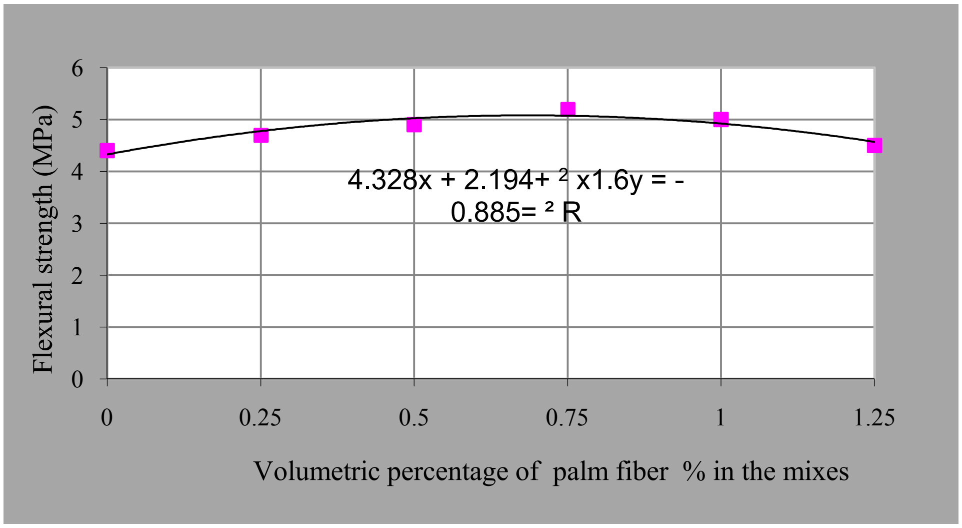

Fig. 9. Relationship between palm fibers and flexural strength of crushed lightweight concrete

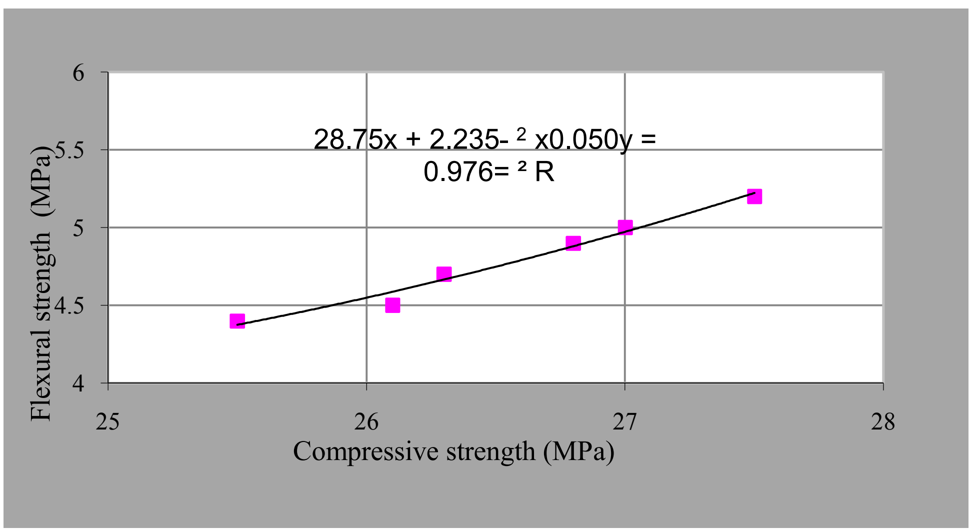

Fig. 10. Relationship between compressive strength and flexural strength of crushed lightweight concrete

The comparison between (CF0) with (CF3) indicates that the use of 0.75%of palm fiber leads to an increase in toughness indices. This is probably due to the optimization of this percentage of palm fiber to arrest cracks at both the micro and macrolevel. At microlevel fibers inhibit the initiation of cracks, while at macrolevel they provide effective bridging and impart sources of toughness and ductility [22-24]. The relationship between palm fiber inclusions and toughness indices for crushed brick lightweight concrete is shown in Fig.11.

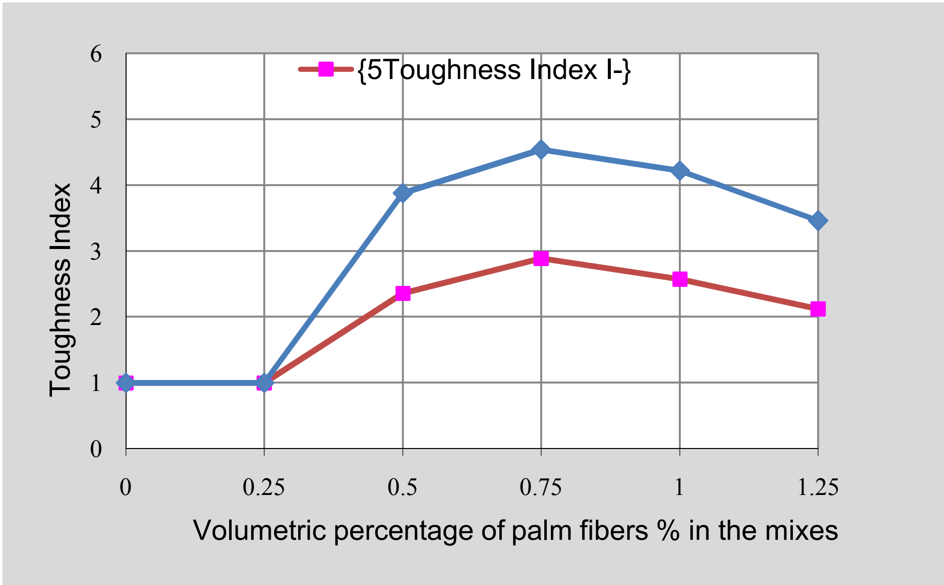

Fig. 11. Relationship between palm fibers and toughness indices of crushed lightweight concrete

4. CONCLUSION

This study was conducted to assess the effect of different percentages of palm fiber on crushed brick lightweight concrete. The following conclusions were made:

1. The incorporation of palm fiber in crushed brick lightweight concrete mix reduces slightly the density of such concrete. This is considered as promising results in the production of lightweight crushed brick concrete.
2. The use of 0.75% of palm fiber increases the compressive strength and splitting tensile strength of crushed lightweight concrete by about 11% and 47%, respectively.
3. The use of 0.75% of palm fiber increases the modulus of elasticity of crushed brick lightweight concrete by about 10%.
4. The use of 0.75% of palm fiber increases the flexural strength of crushed brick lightweight concrete by about 18%.
5. The use of palm fibers enhances significantly the toughness for the crushed brick lightweight concrete. However, the use of 0.25% of palm fibers does not affect the toughness, whereas, the use of 0.75% of palm fibers boosts the best performance in this regards.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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