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COMPRESSIVE CREEP OF KENAF BIO-FIBROUS CONCRETE COMPOSITE UNDER ONE DIMENSIONAL STRESSING

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Abstract: The experiment was designed to investigate the creep of concrete specimens under one dimensional compressive principal stress. The equipment for producing the stress and the gauges for measuring the strains are described. The results of the experimental study illustrated the effects of the inclusion of Kenaf fibre and age at loading on creep signature of the concrete. Creep tests were performed in the drying room with 50±4% relative humidity. Kenaf fibres were used at 50mm fibre length and volume fractions of 0.5% by volume of mix. Results available for specimens subjected to 25 and 35% of the strength in compression were presented. The final discussion compared the effect of Kenaf fibre inclusion and age at loading of specimens subjected to compressive creep at two different stress levels. Low modulus fibrous concrete such as Kenaf bio-fibrous concrete composite demonstrated somewhat greater creep strains than the plain concrete, but the deformation behaviour shows improvement in ductility.

Keywords: *Compressive creep, deformation, Kenaf fibres, loading age, one dimensional stress, stress intensities*

1.0 Introduction

The structural performance of concrete composite can be significantly affected by time dependent deformation of structural elements. For these reason, an adequate consideration must be given to time dependent property of concrete at the design stage of the engineering structures. In most cases, this deformation occurs as a result of sustained load generally referred to creep, or moisture loss due to unrestrained shrinkage. Recently, a huge research effort has been tailored towards the usage of bio fibres in concrete composite reinforcement (Elsaid *et al.*, 2011; Lam *et al.*, 2015; Ogunbode *et al.*, 2016; Hassan *et al.*, 2015). The increasing interest in it usage is due to the several favourable properties it proffers to concrete when compared to conventional plain concrete, steel and synthetic fibrous concrete (Ramaswamy *et al.*, 1983; Elsaid et al., 2011). Though bio fibres are low modulus fibre, with low tensile strength compared to high modulus fibre such as steel fibre. Steel fibres' large tensile strength does not actually account for the improved properties of fibrous concrete composites. Thus, the fibre-matrix bond strength and fibre aspect ratio are responsible for the improved properties exhibited by fibrous concrete composites (Ramaswamy *et al.*, 1983). Therefore, it is obvious that considering bio fibres for concrete composite reinforcement is worthwhile and of immense advantage to the environment, and contributing to a greener planet. The possibility of using low modulus fibres in concrete composite reinforcement is corroborated by the successful use of relatively soft fibre such as sisal, jute, bamboo, coir, and polypropylene in previous researches conducted (Babafemi and Boshoff, 2015; Tara and Jagannatha, 2011, Ramaswamy *et al*., 1983).

Recently, Kenaf fibre is receiving increasing attention both in the research field and industrial application environs (Basri *et al.*, 2014; Aminah *et al.*, 2004). Its application in composite production among other natural fibres is due to the ease in accessibility of Kenaf fibre locally, and its economic benefits with regards to price. Other reasons includes; improvement of life cycle and durability in structure, resistance to corrosion, and other tremendous properties it possess when compared with other bio fibres. Interest is also rising towards the inclusion of Kenaf fibre in concrete, this is meant to obtain a sustainable green material and save our environment from being dominated with concrete products that could pollute and contribute to global warming. Concrete composite made of short discontinuous Kenaf fibres which is simply referred to Kenaf bio fibrous concrete composite (KBFCC), has been under extensive research in the past few years and has many interesting engineering properties when likened with the plain conventional concrete composite (Lam et al., 2015; Ogunbode et al., 2016; Hassan et al., 2015). Application of this green material in civil engineering construction is geared towards concrete beams, bridge deck, concrete pavement and building floor constructions. By virtue of craving to apply Kenaf Fibre in construction, an understanding of the long term performance of KBFCC under sustained uniaxial compression load (creep) is evidently required. This is of utmost importance because; creep has the possibility to prompt excess deflection and or stress relaxation which may invariably lead to the deformation of the concrete and subsequently to collapse in respect to time. Limited study on the influence of bio fibre reinforcement on deformations of cementitious materials at varying load intensity, varying fibre content and different loading age are reported in literature.

Concrete degree of hydration is affected by its compressive strength (Shafiq, 2011). Therefore, parameters such as fibre inclusion, load intensity, curing type, age of loading, age of testing, temperature, and humidity, which influence hydration of cement will also affect the development of strength. The effect of fibres on the material behaviour of concrete depends on the interfacial bond strength between fibres and the matrix; factors which influence strength of concrete, thus, certainly influence bond strength.

The possibility of using bio fibre such as Kenaf fibre, as short discontinuous reinforcement in concrete composite production, coupled with the evaluation of its long-term deformation characteristic was the challenge of the present investigation.

This study will however, provide information required for the understanding of creep behaviour of bio fibrous concrete composites, this time dependent behaviour property can then be included in the bio-fibrous concrete design guidelines. This experimental study is aimed at investigating the effects of Kenaf bio fibre inclusion in concrete as reinforcement. Effect of varying levels of load intensity, and different loading ages on KBFCC and PC was investigated.

2.0 Materials and Methods

2.1 Materials

In this experiment, 50mm long treated Kenaf fibres which were initially collected as curled long untreated fibre from MARDI (Malaysian Agricultural Research and Development Institute) were used. Figure 1 and Table 1 presents the details of the fibers. Type I Portland cement was used as the binder. Crushed granite with a maximum size of 9.5mm, and river sand with maximum size of 5mm was used for concrete production. The river sand had a fineness modulus of 2.46 and a grading satisfying ASTM C33-11 requirement. Rheobuild 1100 water reducing admixture was used to improve the workability of the fibrous concrete.

Figure 1: Treated Kenaf fibre chopped to 50mm length

Table 1: Physical, Mechanical and chemical characteristics of Kenaf fibres

Physical and Mechanical Characteristics			Chemical Composition		
Diameter	(µm)	65.40	Cellulose	(%)	31-57
Density	(g/cm^3)	1.20	Hemicelluloses	(%)	21-23
Elastic modulus	(GPa)	39.77	Lignin	(%)	4.79-19
Elongation at yield	(%)	1.77	Pectin	(%)	2.0
Tensile strength	(MPa)	704.00			

2.2 Mix Proportioning, Test Program and Test Procedure

The mix design of the concrete was done in accordance to the DOI mix design recommendations, and a characteristic mean strength of $30N/mm^2$ at 28days was developed. An optimum fibre content of 0.5% and fibre length of 50mm determined in a previous study (Ogunbode et al., 2016) was used in the concrete mix. Table 2 and 3 presents the details of the tests mix proportion and experimental programme. All the concrete specimens used in the experiment were cast in watertight cast iron 100mmØ x 200mm height cylindrical moulds. The creep specimens are unsealed and were moist cured in a temperature controlled room at 23 ± 2^0C, until the day of testing when the load was applied as described in ASTM C 512-14. The creep test was done under a relative humidity of 50±4.

The major parameters used in the tests were age of loading concrete, fibre inclusion in concrete, and loading intensities. In conducting the compressive creep test, four cylindrical concrete specimens are placed on each other to line up with the circles on the header and the bottom plates of the creep rig. Then the concrete cylinders are centred and ensured to be vertical to form a concrete column as shown in Figure 2.

Table 2: Mix Design of PC and KBFCC

Constituent material	Proportion (kg/m^3)
Ordinary Portland Cement (ASTM Type I)	418
Fine aggregate (River sand)	725
Coarse aggregate (Crushed granite)	1002
Potable Water	230
Kenaf Fibre (0.5% by volume)	6
Super plasticizer (1%)	4.18

Figure 2: Compressive creep rig with specimen under sustained load

A 30 ton hydraulic jack, load cell and a system held in compression by a system of rods and plates between which the specimen was clamped were used to induce the predetermine load intensity on the samples; this is illustrated in Figure 3b. The determined load applied was at 25% and 35% of the companion cylindrical specimen strength of the compressive strength test. The actual applied load was monitored by a personal computer controlled data acquisition system with the signals passing from the load cell installed on top of the upper concrete plug. Once the loading of the specimen is completed, then nuts affixed to the vertical tension rods of the creep rig are subsequently tightened up against the end plates. Hence, the creep strain measurement was taking on the column of four cylindrical specimens with sixteen points using a Demec strain gauge (Figure 3a and 3c) at a predefined time intervals; before loading, immediately after loading is done, between 2, 4 and 6 hour after loading, daily for 1 week, weekly for one 1 month, and monthly until the end of the test. Four accompany control specimen on the same schedule as the loaded specimens that was not loaded serving as a dummy sample was also tested and the strain readings was taken and recorded. The strength of the cylinders used to provide information such as modulus of elasticity and compressive strength was also determined from an average of four cylindrical specimens for the bio-fibrous concrete and fibreless concrete at 7 and 28days age of hydration.

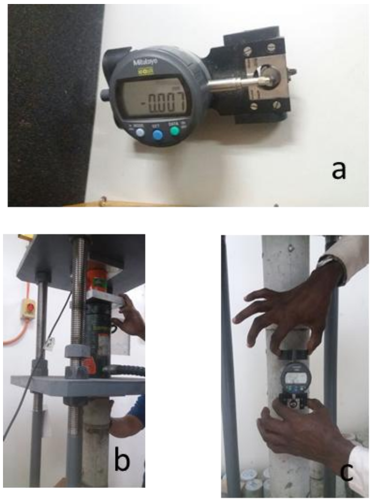

Figure 3: (a) Demec strain gauge (b) Hydraulic jack, load cell positioned to induce predetermine load intensity on concrete sample (c) Creep strain reading using the Demec gauge

3.0 Results and Discussion

3.1 Compressive Strength and Modulus of Elasticity

Compressive strength and modulus of elasticity which are all strength properties of concrete are shown in Table 3 and Figures 4. Inspecting Table 3 and Figure 4, it was observed that compressive strength and elastic modulus of PC yields higher compressive strength and elastic modulus at 7 and 28 hydration ages when compared to KBFCC. However, bio fibrous concrete also showed a significant strength development as the age of concrete increases as shown in Figure 4. The delay in the increase of compressive strength of fibrous concrete may be due to the continuing hydration of cement, and the gradual increase of bond strength between matrix and hydrophilic fibres.

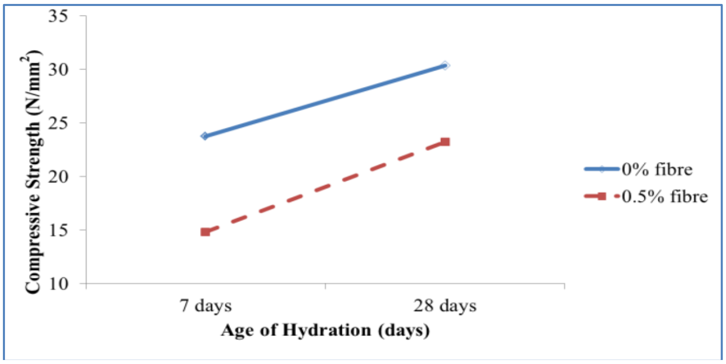

Figure 4: Compressive strength of PC and KBFCC specimens at various ages

Table 3: Experimental series for the uniaxial compressive creep of concrete

Specimen ID	t^1 (days)	V_f (%)	f_c (N/mm^2)	Applied Load (N/mm^2)	Elastic Modulus (N/mm^2)	load ratio (%)
A0X1	7	0	23.753	46.638(5.938)		25%
A0X2	7	0	23.753	65.293(8.313)	23.82	35%
B2X1	7	0.5	14.834	29.126(3.708)		25%
B2X2	7	0.5	14.834	40.776(5.192)	23.65	35%
A0Y1	28	0	30.365	59.622(7.591)		25%
A0Y2	28	0	30.365	83.470(10.628)	27.21	35%
B2Y1	28	0.5	23.243	45.638(5.811)		25%
B2Y1	28	0.5	23.243	63.893(8.135)	26.21	35%

Note: A0= 0% fibre content (Plain concrete); B2= 0.5% fibre content (KBFCC); X1= 7days loading at 25% load ratio; X2= 7days loading at 35% load ratio; Y1= 28days loading at 25% load ratio; Y1= 28days loading at 35% load ratio.
* Stress in parenthesis

3.2 Creep Test

The experimental results based on the average of four creep cylindrical specimens from each rig exposed to the same constant loading of either 25% or 35% of the concrete cylinder compressive strength are given in Figures 5 to 8. An average strain was obtained from four sets of mechanical gauges located on the surface of specimen of each concrete cylinder specimen used in the creep test. The ordinate of Figures 5 to 8, is the creep strain describing the strain deformation of the concrete at time t due to the effect of the sustained load acting since time t'. The age of concrete after casting is related to the age of creep loading of concrete at time t'.

Figure 5 and 6 demonstrate the influence of concrete age at the time of creep loadingof PC and KBFCC. Two loading ages was adopted, they are, 7 days and 28 days. The age of 7 days was chosen to simulate the condition ofconcrete of actual structures at the end of curing and removal of formwork onsite. In addition to that, 7 days is also a minimal curing period advisable for OPC concrete. Testing ofspecimens at the age of 28 days was carried out to determine the materialbehaviour when the plain and fibrous concrete has achieved its desired strength.

From Figure 5 and 6, it can be seen that creep is greater for specimens loaded at earlier age. This phenomenon is valid for the creep subjected to either 25% or 35% sustained stress levels.

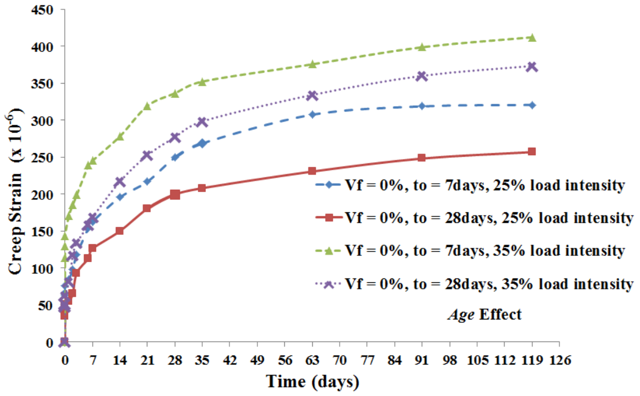

Figure 5: Effect of age on creep of concrete containing 0%fibre volume fractions at varying load intensities

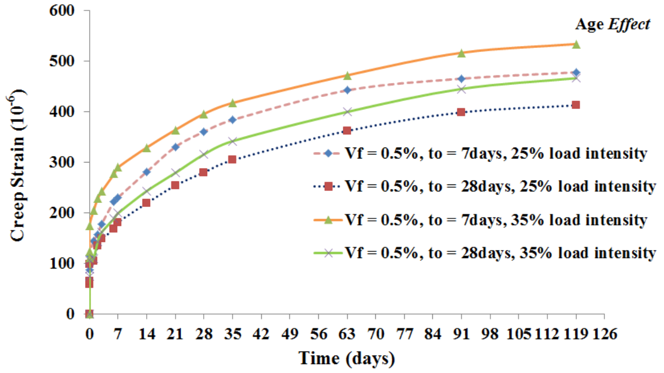

Figure 6: Effect of age on creep of concrete containing 0.5%fibre volume fractionsat varying load intensities

Figures 7 and 8 illustrate the relation between duration and creep strain of concrete with and without Kenaf fibre for concretes loaded at age of 7 and 28 days. In contrary to the common behaviour of high modulus fibres, such as steel fibre; which its inclusion in concrete as reinforcement leads to appreciable reductions in the creep of concrete. This study has shown that low modulus fibrous concrete such as Kenaf fibrous concrete compositedemonstrated somewhat greater creep strains than the plain concrete at 119 days of exposure to sustained load. This is in agreement with an earlier study conducted by Ramaswamy et al., 1983. Higher load intensity at 35% had marginal effect on KBFCC compared to PC at 7 days and 28 days loading age. This deformation behaviour is due to the KBFCC improvement in ductility.

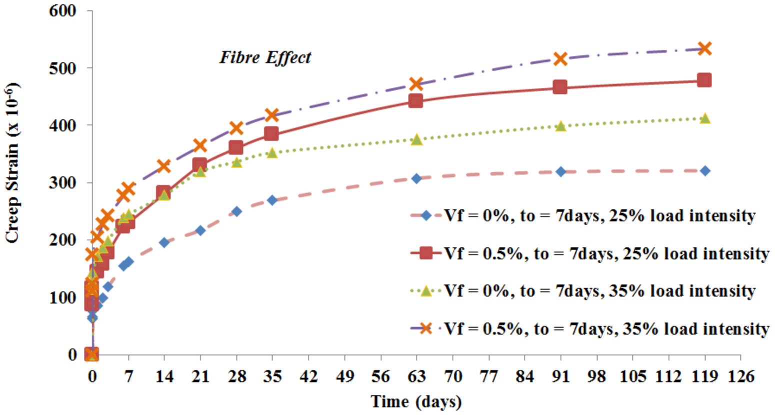

Figure 7: Effect of fibre inclusion on creep of concrete containing at varying load intensities for 7 days loading age

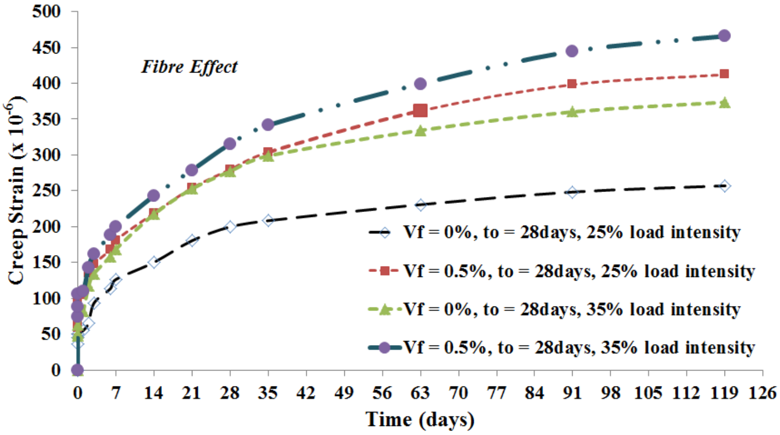

Figure 8: Effect of fibre inclusion on creep of concrete containing at varying load intensities for 28 days loading age

4.0 Conclusions

This paper described the effects of Kenaf fibre on compressive creep under one dimensional stressing with respect to the age of loading and load intensity on bio fibrous concrete composite are reported. Thefollowing conclusions were drawn from the experimental results: The magnitude of drying creep is significantly affected by the loading age of the PC and KBFCC specimen. The older the specimen at the time of loading, then the lesserwill be the drying creep. Deformations are more effectively restrained by Kenaf fibres at later time. The shape of the time set against creep curve is comparable for KBFCC and PC. The magnitude of creep of concrete specimens containing Kenaf bio fibres is higher than that withoutKenaf fibre. Conversely, in this study, after testing the specimens for 119 days, a similar creep rate and trend was observed both for concrete with and without Kenaf fibre.

Higher load intensity was observed to increase the creep rate of plain concrete more for either 7 or 28 days loading age sample. However, this effect is reduced for concrete containing Kenaf fibres. The observed restrained behaviour of KFBCC specimen under load was due to the toughness properties of Kenaf fibre exhibited in the concrete.

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