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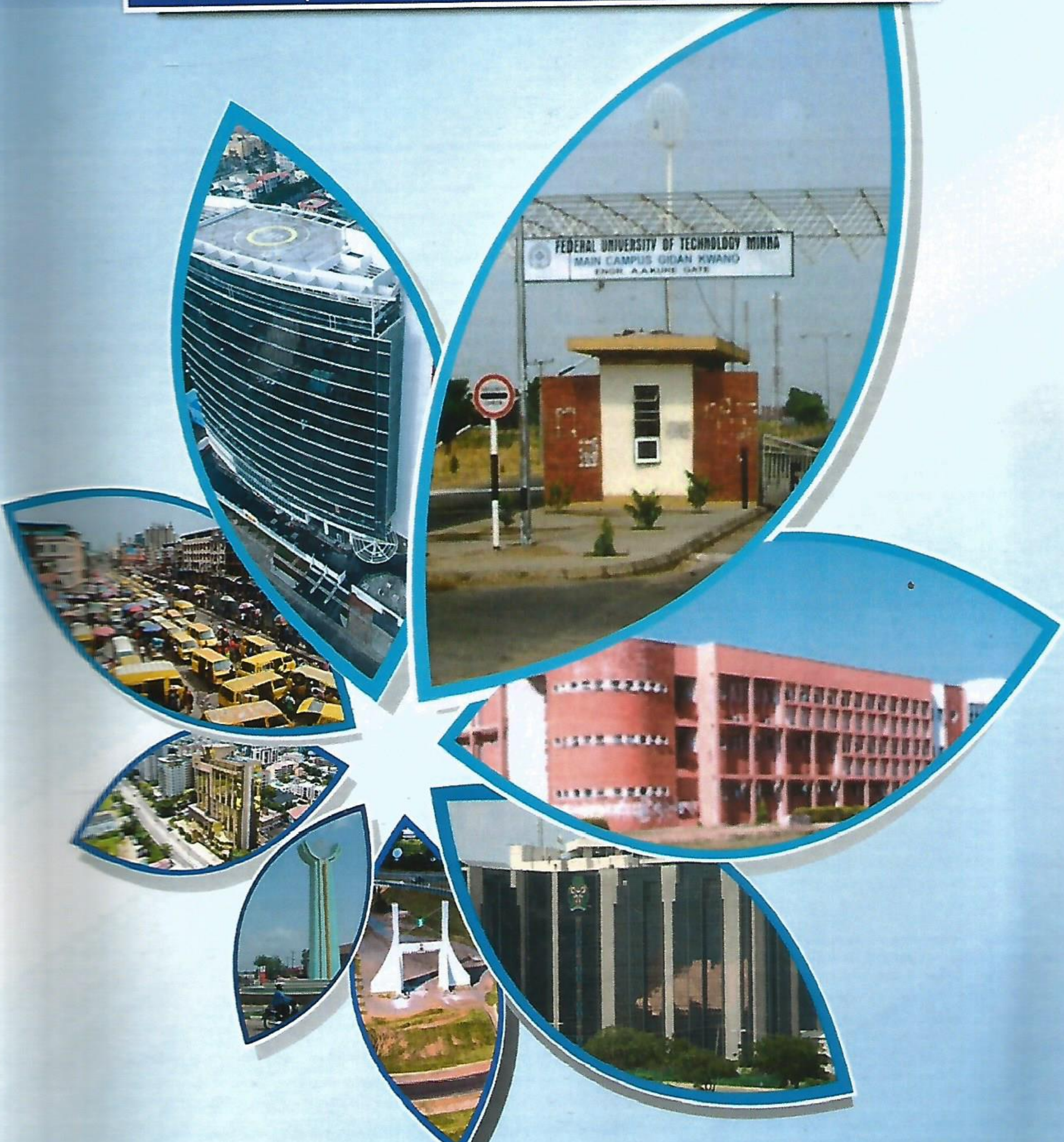

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Influence of Plain and Fibrous Concrete Composite on Creep Development: A Review

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Largely, structures are subjected to static dead loads in building and civil engineering construction. The exposure of concrete structure to sustained load leads to a progressive decrease in its structural strength with time, which may perhaps result to creep deformation. Despite the vast usage of concrete, there still exists a gap in the understanding of the mechanism of creep deformation in cementitious composites due to its complex nature compared to ferrous and synthetic rope materials. This inadequate understanding is more evident in composite materials such as fibrous concrete (FC), especially the bio fibrous concrete. However, it is difficult to determine the quantitative nature of the positive contribution of fibre inclusion in concrete to creep behaviour. The outcome of the review done in this paper submit that the majority of study done and available in literature are on steel fibre, and there is no consensus on volume of fibre content put forward as the optimum. The study assessed the influence of plain and fibrous concrete composite on creep development. This was done through examining available literature recounting the previous and current development of creep deformation and situating it in the context of plain and fibrous concrete in order to be able to bring to the fore appropriate issues on recent advancement in compressive, tensile and flexural creep of concrete. It was discovered that though creep has been an age long phenomenon in concrete technology. The extent of the understanding of creep of FC by concrete scientist and researchers was limited resulting in the lacuna of available literature of creep of FC experienced now. It becomes imperative for all concrete scientist and researchers to give greater attention to understanding the influence of fibre on creep of concrete so that the mechanism of creep deformation in cementitious composites could be well understood.

Keywords: Bio fibrous, Composite, Creep behaviour, Fibrous concrete, Plain concrete.

Introduction

The study of the long-term structural properties of Fibrous Concrete (FC) has recently turned out to be a research focal point (Vrijdaghs et al., 2010). This is due to the effect of time dependent properties of concrete composites on structural elements behaviour, in serviceability limit state and the ultimate limit state as acknowledged by Model Code (2010). Kurtz and Balaguru (2000) and MacKay and Trottier (2004) reported that creep may cause undesirable and unacceptable deflections of FC beams. One of the time-dependent phenomena is creep (Vrijdaghs *et al.*, 2010). Nowadays, creep studies of concrete have taken a broader dimension due to fibre inclusion in concrete. Though, it has been noted that even when studying creep with fibre parameters only (fibre length, fibre volume fraction, fibre aspect ratio), FC creep behaviour is affected by several other factors. These various factors such as age of loading, test configuration, temperature and humidity condition at time of testing, matrix constituents, duration of load, load intensity, change the FC performance due to continuous load imposition (Arango *et al.*, 2012; Babafemi & Boshoff, 2015; Mangat & Azari, 1986).

To a limited extent, researchers have succinctly put it that fibre inclusion in concrete provides a positive contribution to creep performance of concrete (Vrijdaghs *et al.,* 2010; Kurtz & Balaguru, 2000; Arango *et al.*, 2012; Mangat & Azari, 1986; Fládr & Broukalová, 2015). However, it is difficult to determine the quantitative nature of the positive contribution of fibre inclusion in concrete to creep behaviour. The outcome of review done in this paper submit that the majority of study done and available in literature are on steel fibre, and there is no consensus on volume of fibre content put forward as the optimum. Rather, researchers explain that the presence of fibre in concrete has a significant effect in reducing creep of concrete either in compression, tension or flexure. This is hinged on the works of Arango *et al.* (2012); Babafemi and Boshoff (2015); Fládr and Broukalová (2015); García-Taengua *et al.* (2014); Ana (2011); Ramaswamy *et al.* (1983); Mouton and Boshoff (2012), Chern and Young (1989). It is worthy of note that research work on the determination of the influence of natural fibre on the creep of concrete either in flexure, tension or compression is very limited in the literature (Ramaswamy *et al.*, 1983; Ogunbode *et al.*, 2016a).

A well-established test procedure for executing and evaluating creep assessments for FC or bio-fibrous concrete under flexural load in particular is lacking. Additionally, fibres slenderness has an important synergy effect with load ratio concerning the considered creep parameters: using fibres with high slenderness lessens the effect that load ratio has on creep strains. Consequently, adding fibres is a good strategy in order to control creep strains, though fibres are not required in high amounts, the best choice is to use fibres with high slenderness (García-Taengua *et al.,* 2014). In this paper, concerns on the effect of fibre reinforcement on the creep performance of conservative and fibrous concrete were reviewed and recent developments were highlighted.

General Background on Creep of Concrete

Generally, structures are subjected to static dead loads in building and civil engineering construction. Such dead loads comprise of the structure mass, roof, permanent attached items such as walls, plaster board or carpet which are immovable fixtures and machines. The exposure of concrete structure to sustained load leads to a progressive decrease in its structural strength with time, which could perhaps result to creep deformation. Despite the vast usage of concrete in building and civil engineering works, there still exists a gap in the understanding of the mechanism of creep deformation in cementitious composites due to its complex nature compared to ferrous and synthetic rope materials. This inadequate understanding is more evident in composite materials such as fibrous concrete (FC), especially the bio fibrous concrete.

The creep of concrete which initiates out of calcium silicate hydrates (C-S-H) in the hardened Portland cement paste is profoundly dissimilar from the creep of metals or polymers (Acker & Ulm, 2001; Mehta & Monteiro, 2006). Creep of metals differs from the creep of concrete, as it happens at all stress intensities and, inside the service stress ambit. However, if the pore water content is invariant, creep of concrete is linearly reliant on the stress. Also, this creep of concrete of behaviour is different from that of creep of polymers and metals which displays multi-months aging triggered by chemical hardening due to hydration which stiffens the microstructure (autogenous shrinkage) (Mehta & Monteiro, 2006; Neville, 2011). Creep of polymers and metals also display multi-year aging induced by long term relaxation of self-equilibrated micro-stresses in the nanoporous microstructure of the C-S-H (Acker & Ulm, 2001; Mehta & Monteiro, 2006). However, if concrete is fully dried, it does not creep. But drying concrete fully without severe cracking is agreeably impossible to attain (Ana, 2011; Neville *et al.,* 1983).

The Phenomenon of Creep on Concrete

Creep is described as the time-established deformation of concrete composite under a sustained load. When hardened concrete is exposed to sustained loads, it continues to deform further with time. This phenomenon was discovered in 1907 at Purdue University, United States by renowned researcher William K. Hatt (Lopez, 2005). This phenomenon is referred to as creep (Bažant, 1995). Creep could also be referred as the tendency of a material to develop increasing strains over time when they are exposed to a sustained load (García-Taengua *et al.,* 2014; Truong et al., 2013; Fanourakis & Ballim, 2003). As a result, deflection or elongation tend to increase through time in relation to the initial strain, that is, right after the load is applied (Vrijdaghs *et al.,* 2010; Fládr *et al* (2012). In concrete structures, long-term performance is basically affected by the behaviour of cracked concrete (Barpi & Valente, 2002). The total strain of concrete at any time may be understood as the result of the elastic strain; shrinkage and creep (Figure 1a). The initial strain at the application of the load is primarily elastic, even though it may include a non-elastic component as shown in Figure 1b (Neville *et al.,* 1983). It was formerly presented that there are several types of shrinkage. However, only carbonation shrinkage develops in the same time scale as drying shrinkage (Bazant & Hermite, 1988; Ferretti & Bažant, 2006).

Basic creep is the deformation under constant load when no moisture exchange occurs with the ambient (hygral conditions or equilibrium). This is the case for concrete element functioning as underground foundation, or inside water. Drying creep is the additional deformation that occurs when the concrete is also drying (Fanourakis & Ballim, 2003; Miji & Bharati, 2014). Other types of creep are transitional thermal creep and wetting creep (Bazant, 1993). Ordinarily, the sum of basic creep strain and drying creep strain is the creep strain that is considered in structural design (Ogunbode *et al.,* 2017a). Due to the perspiration in differentiating the delayed elastic strain from creep strain and the convenience to build a numerical model to simulate time-creep strain curve with the delayed elastic deformation covered, the total creep strain would usually include both the delayed elastic deformation and permanent creep deformation. Also, the above stated method is usually taken since the delayed elastic strain is usually very small when likened with the total creep strain (Ogunbode, 2017).

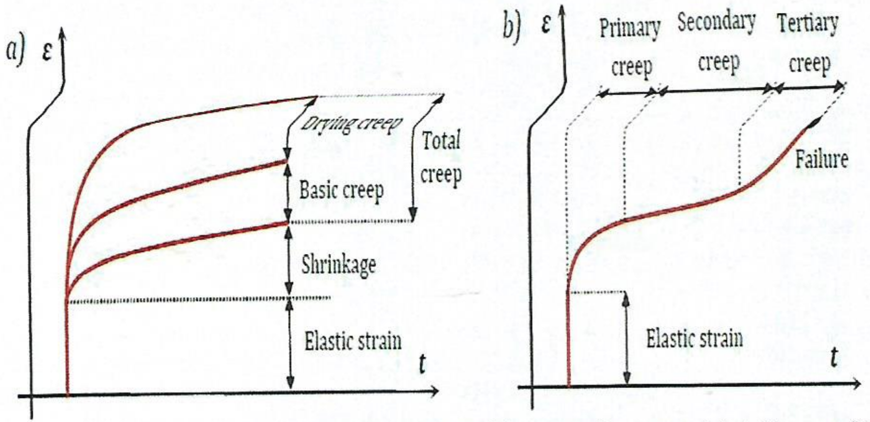

Figure 1: (a) Total strain of concrete with time (b) general form of the curve of concrete subjected to creep (Neville *et al.,* 1983).

After the initial elastic strain, three stages may be identified: the primary creep, the secondary creep and the tertiary creep. Through the primary creep, the creep rate decreases with time, whereas the secondary creep corresponds to a steady state creep rate (Neville *et al.,* 1983, Usibe *et al.*, 2012). At normal levels of stress (up to 40% of the compressive strength), the primary creep may not be distinguished from the secondary creep. Tertiary creep occurs when concrete is subjected to high levels of stress (over 40% of the compressive strength). The results of creep may be expressed by the creep coefficient, which is the ratio between creep strain and elastic strain. When the stress is removed from the concrete, the material exhibits an instantaneous recovery followed by a time-dependent recovery (creep recovery). Thus, concrete subjected to sustained stress presents an irrecoverable or residual strain after the unloading (Neville *et al.,* 1983). The creep behaviour of concrete materials plays a great role in the stability of concrete structures. Also, the creep behaviour of concrete is subjected to the severe instability caused by the variation of raw materials for concrete mixtures and their proportions (Ogunbode, 2017).

The Effects of Creep on Concrete

Creep of concrete is both a desirable and an undesirable occurrence. It is desirable if before fracture of the concrete, a required ductility is infused into the concrete (Fanourakis & Ballim, 2003; Usibe *et al.,* 2012). On the other hand, creep is often responsible for excessive deflections at service loads, which can result in the instability of arch, shell structures cracking, creep buckling of long columns and loss of pre-stress (Usibe *et al.,* 2012). Normally, the detrimental results of creep are more damaging to non-load-bearing components associated with the structure, such as window frames, cladding panels and partitions, than they are in the structure itself. Broken structures or systems are either shut down or go through enormous maintenance, far earlier before the end of the projected lifecycle, resulting in worthy magnitude pecuniary upshots. Creep load is typically associated with its destructive consequences (Usibe *et al.*, 2012).

Creep Testing of Plain and Fibrous Concrete

In creep testing, different loading arrangements have been used, such as compression, tension and bending (flexural) (Mangat & Azari, 1986; Chern & Young, 1989; Ranaivomanana *et al.,* 2013; Babafemi & Boshoff, 2013; Mias *et al.*, 2013; Ogunbode, 2017). The most method widely used so far in determining creep test of plain concrete is the compression creep method in accordance to ASTM C 512 (2010). Compression creep tests have been explored extensively compared to the flexural and tensile creep, and vice-versa when considering FC which study on compression mode of loading is limited compared to flexural and tensile creep. The attention of researchers in previous years have been drawn towards investigating the creep characteristic of both PC and FC in tension and flexure (Babafemi & Boshoff, 2015; Truong *et al.*, 2013; Ranaivomanana *et al*, 2013; Arango *et al.*, 2012). This is due to the developing interest in the introduction of fibre (natural, synthetic, steel etc.) in concrete which some researchers refer to as engineered cementitious composite or fibrous concrete.

There are a number of methodologies and test setups in literature proposed to carry out flexural creep of plain and FC (Kurtz & Balaguru, 2000; Fládr *et al* 2012; Bernard, 2004; Barragán *et al.*, 2008; Buratti *et al,* 2010). The proposed test can be performed in standard equipped laboratories, the test procedure is easier to conduct, equipment used are cheap compared to the conventional equipment for conducting flexural creep test.

Creep of Plain Concrete

Plain concrete has at least two fundamental differences in comparison with many other common structural materials. Firstly, unlike the metals, concrete with its cement gel, crystalline products of hydration, water, unhydrated cement and aggregate is heterogeneous and when reinforcement is present, anisotropic as well. The second difference arises from the fact that the properties of concrete change with time and are greatly affected by temperature and relative humidity, and therefore by the environment (Mangat & Azari, 1986; Chern & Young, 1989; Truong *et al.,* 2013). The shrinkage and creep in concrete is commonly defined by the free shrinkage strain and creep coefficient and they are very much dependent on the above-mentioned variables. Ever since time dependent phenomena in concrete have become recognized, there have been an overwhelming number of publications on the subject (Bazant, 1993; Brooks, 2005; Vandewalle, 2000; Persson, 1996; Smith &Hammons, 1993; Coutinho, 1977; Illston, 1965). Various aspects of creep and shrinkage, such as hypotheses on the mechanism of the phenomena involved along with observed properties of the material and problems related to structural behaviour have been studied (Bažant, 1975). In structural design, the importance and significance of those physical properties of concrete are diagnosed as being a likely reason for cracking. In addition, they affect the deformations and are responsible for the conveyance of load from concrete to metal in compression members, even as the structure is in service (Mangat & Azari, 1985; Mangat & Azari, 1986; Truong *et al.,* 2013; Ogunbode, 2017).

In general, creep tends to eliminate the stress in concrete (Razak, 1986), predominantly when reinforced. Hence, once a constant load is applied to a reinforced concrete member such as a column or beam, a gradual reduction in the load on the concrete and an equivalent increase in the load on the steel are caused by concrete creep. In various structural elements such as continuous beams and slabs, creep discharges some of the pressure within the maximum loads and increases the strain in equal proportion in the concrete, so that finally the stresses are more uniform throughout the member. Hence, the propensity of concrete to cracking is reduced via releasing of the high stresses. Nonetheless, creep possibly will cause excessive deflections and curvatures, and from an aesthetic point of view, it would be undesirable (Usibe *et al.*, 2012)].

Creep of Fibrous Concrete

The use of FC in engineering applications has furthered the need for the study of creep behaviour under sustained loading. Common applications of FC include runway, aircraft parking, tunnel lining, slope stabilization, risers, burial vaults, septic tanks, curbs, covers, sleepers, blast resistant structures, thin shell, walls, pipes, manholes, dams, hydraulic structure, pavements (highways, bridge decks and industrial floors), machine tool frames, lighting poles, water and oil tanks and concrete repairs (Krstulovic-Opara *et al.*, 1995; Ogunbode, 2017; Wenjia, 2019). All this engineering structures and applications are exposed to significant static sustained loading during their service lifetime. Conversely, there appears to be a bay in the understanding of the creep behaviour of FC in terms of variables such as type of curing method, load intensity, fibre content, fibre length, and the influence of loading ages on creep and fibre parameters (Mangat & Azari, 1986; Arango *et al.*, 2012; Babafemi & Boshoff, 2015; Ogunbode *et al.*, 2016b).

Nevertheless, a study by Mangat and Azari (1986) substantiated that creep deformation of concrete in compression is reduced by fibres. Also, Swamy and Theodorakopoulos (1979) explained that creep deformation owing to bending stresses in uncracked specimens experience reduction when fibre is included in the concrete. It should be noted that there exists a substantial quantity of contradictory information in the literature on the action and influence of fibre regarding the creep behaviour of cementitious materials (Truong *et al.*, 2013). Velasco *et al.* (2008) opined that the addition of fibres in concrete results in higher creep. This negates the general consensus and outcome of most researchers such as Zhang (2003) and Chern *et al.* (1989) who put the result of their research succinctly that the addition of fibres can

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reduce creep in concrete. Compressive creep on PC are common in literature, meanwhile, experimental data on concrete creep under tension both in PC and FC are very scarce. This is due to the following factors; difficulty in specimen fabrication, lack of standardized equipment for testing tensile creep, lack of code for tensile creep of PC and FC, limited study on the tensile creep of concrete. When a concrete element is restrained, the appearance of tensile creep strain can counteract the shrinkage strain. Therefore, considering tensile creep precisely will improve the cracking potential of concrete for the long term (Truong *et al.,* 2013).

Recently, the use of bio fibre to replace steel, polypropylene and other common fibres in concrete is being advocated as it is economical, environmentally friendly, non-corroding, easily recycled and demonstrates low density (Ogunbode *et al.*, 2020, Ogunbode *et al.*, 2017b). Though there are limited publications on creep of bio fibrous concrete like kenaf, coir, sisal, bamboo, hemp, etc. (Ramaswamy *et al* 1983; Ogunbode *et al.*, 2015; Ogunbode *et al.*, 2016b). Studies on creep of PC, especially compressive creep are quite available in the literature, though literature has also shown that creep study on FC are more dominant on steel and synthetic fibre. The construction world and our environment are more interested in sustainable and green concrete recently. This make the yearning for replacement of glass, steel and synthetic FC to be paramount in the mind of construction and concrete scientist and engineers. Research conducted empirically on the creep behaviour of FC or SFC is experiencing rapid development. Mangat and Azari (1985) presented a theoretical model to predict creep of steel fibrous cement matrices under compression. Chanvillard and Roque (1999) and Cochrane (2003) recommended an expression obtained from regression of the experimental data. Bernard (2010) indicated in his study that the behaviour of the concrete cannot be dissociated from that of the fibres due to the interactions between both materials. The author also suggested an expression based on rheological models to replicate post-cracking creep behaviour of Fibre Reinforced Shotcrete (FRS). Nevertheless, some of the parameters of the expression remain to be determined.

Thus, making it a much more attractive material than plain concrete, since the inclusion of fibre could significantly reduce creep in concrete, improve appreciable compressive strength, tensile strength, flexural strength, toughness and cracking control (Chern & Young, 1989; Velasco *et al.,* 2008; Mouton, 2012b).

Appraisal of Creep of Plain and Fibrous Concrete from Existing Works

Flexural, uni-axial tensile and compressive creep tests on plain concrete and FC have been carried out by researchers (Chern & Young, 1989; Velasco *et al.*, 2008; Zhang, 2003). Though, there is yet to be a harmony on the action of fibre reinforcement in creep of concrete (Truong *et al.*, 2003). literature explains that bio fibres thus increase the compressive creep of concrete, while steel fibres contributes to the reduction of compressive creep of concrete due to its appreciable high modulus compared to low modulus fibre like bio fibres and synthetic fibres Mangat and Azari (1986); Ogunbode *et al.* (2016b). The studies of Zhang (2003) and Chern and Young (1989) revealed that fibre inclusion in concrete thus reduce compressive creep, while Ogunbode *et al.* (2016b), Ramaswamy *et al.* (1983) and Velasco *et al.* (2008) explained that fibre reinforcement of concrete leads to higher creep. Recent studies have shown that fibres have being seen to contribute more positively to tensile and flexural creep of concrete, in reducing the cracking and tensile deformation of concrete (Arango *et al.*, 2012; Chern & Young, 1989; Babafemi, & Boshoff, 2015b).

Review on work carried out using steel and synthetic (polypropylene) fibres with varying fibre concentrations (by volume) are presented. Chern and Young (1989) in their study using steel fibre as reinforcement in concrete, exemplify the relationship between period of the test in days and basic creep parameter of concrete at diverse volume fractions of steel fibres for concretes loaded at age 4 days, 7 days, and 28 days. The outcomes pointed out that reinforcing concrete with steel fibre leads to a significant reduction in the creep of concrete; also, they observed that the creep of the reinforced concrete declines progressively as the volume of reinforcing fibres added in the concrete increased as illustrated in Figure 2a and Figure 2b.

It was also observed from Figures 2a and 2b that the creep reduction is higher as fibre volume increased from 0% to 1% than from 1% to 2%. The results also show that the fibres become additionally operative in confining creep of the cement matrices as the time under load rises. The research carried out previously by Mangat and Azari (1986) was in agreement with the findings of Chern and Young (1989) presented in Figure 2. They explained that the inclusion of steel fibre in concrete provided restraint to the flow characteristics of cement matrices, thus reducing the creep of the concrete. They also added that reduction in creep was more significant at later age (Figures 2a and b).

The results obtained from creep tests performed in fog room and 35°C high humidity room shown in Figure 3 indicated that the temperature activation on the creep of steel fibre reinforced concrete is less strong as compared to plain concrete. Higher temperature accelerates the gain of bond strength between fibres and matrix, which in turn leads to the reduction of creep deformation. This phenomenon implies that steel fibres can be used at higher temperature conditions to prevent excess creep deformation.

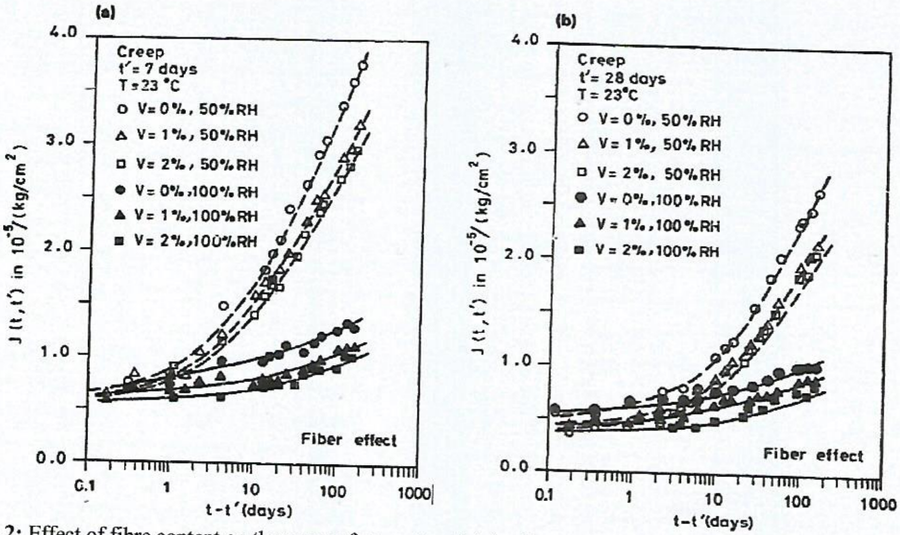

Figure 2: Effect of fibre content on the creep of concrete at (a) loading age t' = 7 days (b) loading age t' = 28days in drying or moist condition (Chern & Young, 1989).

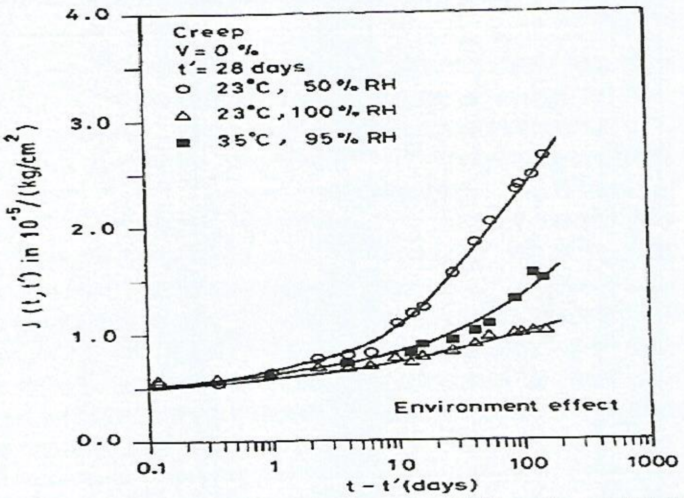

Figure 3: Effect of testing surroundings on deformation of concrete at different fibre content Acker & Ulm (2001)

In a study conducted by Truong *et al.*, (2013), the tensile and compressive creep behaviour of amorphous steel FC showed that fibre inclusion in concrete could meaningfully change the creep behaviour of concrete. The study was on two types of creep; tensile creep and compressive creep. From the test results, tensile creep was lower than compressive creep for all cases of concrete. They further explained that the presence of a fibre volume fraction of 0.2% in concrete evidently reduces compressive creep. By the restraints of fibres, the matrix creep deformation was considerably compensated (Babafemi & Boshoff, 2015). Therefore, the addition of fibres could reduce the compressive creep. However, referring to Figure 4, the case of C-ASF03, depicts that the effect of fibres was not evident. Thus, more studies are needed to completely understand this behaviour. In tensile creep, the effect of fibres was not evident in comparison with plain concrete. While samples with 0.2% content of fibre showed a decline in creep strain. On the contrary, samples with 0.4% fibre volume fraction showed an upsurge. Figure 4 presents the compressive creep strain for plain and fibre-reinforced concrete obtained from the experimental report by Truong *et al.* (2013). From the test results obtained, it can be seen that the presence of Amorphous steel fibres used could significantly change the compressive creep behaviour of concrete. In the case of the specimen with a fibre content of 0.2% (C-ASF02), the decrease was considerably lower than that of the plain specimen (C-Plain), while the specimen with a fibre volume fraction of 0.3% (C-ASF03) was greater than that of C-Plain. However, from the 35-day of testing, the compressive creep strain of C-ASF03 has a tendency to decrease and results in the lowest strain. On the 64-day of testing, the strain of the plain, C-ASF02, and C-ASF03 was 842με, 640με, and 564με, respectively. Obviously, for a fibre content of 0.2%, the decrease was approximately 24%, while the addition of a fibre volume fraction of 0.3% gave a reduction of 33%.

It could be inferred from Figure 5 showing the tensile creep strain for the plain and FC that the creep of FC as mentioned in the section above, could significantly change the tensile creep behaviour of concrete. Nonetheless, the effect of fibres was not as obvious as expected. The addition of a fibre volume fraction of 0.2% (T-ASF02) showed much lower strain than that of plain concrete (T-Plain), whereas T-ASF04 showed greater strain than that of T-Plain. The lowering of tensile creep strain when adding the fibre volume fraction of 0.2% in concrete can be explained in the following manner. In case of tensile creep, the autogenous shrinkage strains would be the opposite course than the basic tensile creep strains, thus those would affect the curves obtained from the experimental curves.

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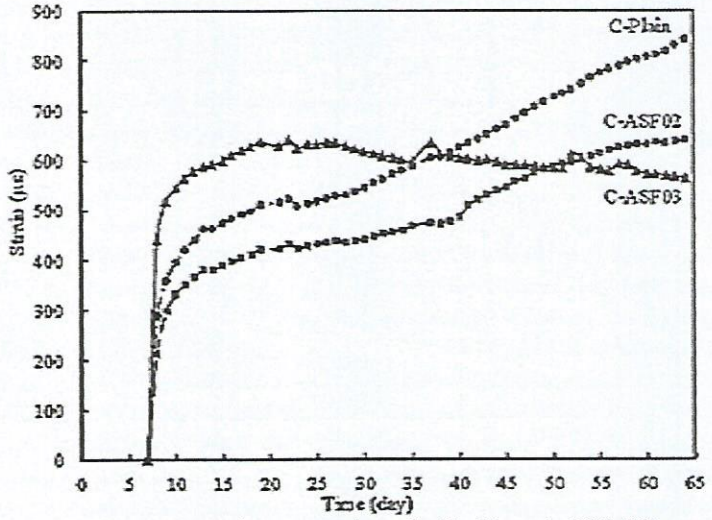

Figure 4: Compressive creep strain profile (Neville et al., 1983) [20]

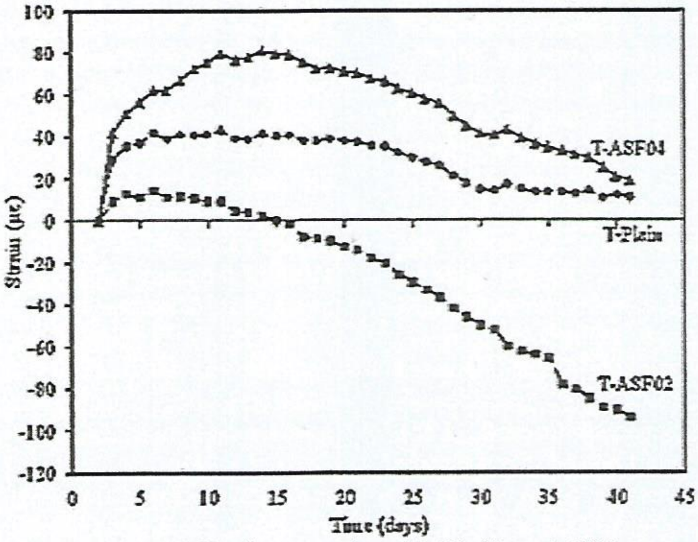

Figure 5: Tensile creep strain profile (Neville *et al.,* 1983).

Based on that superposition of strains, once the autogenous shrinkage strain overcomes the tensile basic creep strain, the total tensile creep strain of concrete will tend to be minus. Obviously, for sealed specimens, the tensile creep is associated with deformation of hydration products such as basic creep and autogenous shrinkage. In case of T-ASF04, the addition of a fibre volume fraction of 0.4% in concrete resulted in increasing the tensile creep strain. This tendency was verified in the experiment by Bissonnette *et al.* (1995), Altoubat *et al.* (2001) and Mouton and Boshoff (2012), where the use of fibres showed an increase in tensile creep strain. Actually, the initial rate of basic creep tends to be reduced by fibres, but increase the creep at later stages. That means that relaxation by mechanisms of creep in fibrous concrete continues for a longer time than in plain concrete.

This is mainly due to the fibres that have ability to detain micro-cracks and to engage a larger volume of the matrix in stress transfer. This leads to a lower and more uniform internal stress intensity affecting the creep rate and thus increase the total tensile basic creep. In addition, Saje *et al.* (2012) reported that fibres could significantly reduce the autogenous shrinkage by fibre volume fraction. Therefore, total tensile creep of FC in association with basic creep and autogenous shrinkage will increase greater than that of plain concrete. However, the difference in performances of T-ASF02 and T-ASF04 compared with plain specimen (T-Plain) showed that further research is necessary to more fully understand this behaviour.

García-Taengua *et al.* (2014) in their study on Flexural creep of steel fibre reinforced concrete in the cracked state did explained the statistical significance of a number of variables (fibre length, fibre volume fraction, load stress) on flexural creep of steel FC. They stated that length of fibre has no statistically significant effect on flexural creep deformation of steel fibrous concrete. However, fibre content in concrete influences the parameter of creep significantly based on the statistical analysis carried out in their study, higher fibre content in concrete increases its load bearing capacity without increasing its strain. In addition to their findings, they stated that the higher the slenderness of fibre in concrete, the lesser will be its creep, so the thickness of fibre or diameter of fibre has effect of the strain of concrete under sustained load. Their study outcome is hinged on the fact that fibre content, fibre slenderness and increasing load ratio statistically affect flexural creep strain significantly. Also, the study of Ana (2013), Arango *et al.* (2012) and Mouton & Boshoff (2012) also corroborated the findings of García-Taengua *et al.* (2014) on the influence of fibre on creep performance of concrete. However, it should be noted that their outcome was based on investigation using steel fibre. A study using natural fibre such as Kenaf fibre, jute fibre, coir fibre will be worthwhile, to give a broader understanding on the influence of fibre on creep performance of concrete and expand knowledge of fibre technology. Also, to better understand fibre contribution in creep performance of concrete, tensile and flexural creep of fibrous concrete has to be well explored.

Conclusion

The Fibre inclusion in concrete has made the understanding of creep of concrete possess a broader facet. Though, it has being noted that even when testing with fibre parameters only, FC creep behaviour is affected by several other combinations. These various factors such as age of loading, test configuration, temperature and humidity condition at time of testing, matrix constituent, duration of load, load intensity etc. changes the FC performance due to continuous load imposition. To a limited extent, researchers have succinctly put it that fibre inclusion in concrete provides a positive contribution to creep performance of concrete. The results analysed in this paper submit that the majority of study done and available in literature are on steel fibre, and there is no consensus on volume of fibre content put forward as the optimum. Rather, the researchers explain that the presence of fibre in concrete has a significant effect in reducing creep of concrete either in compression, tension or flexure. It is worthy to note that research work on the determination of the influence of bio fibre on the creep of concrete either in flexure, tension or compression is very limited in the literature. A well-established test procedure for executing and evaluating creep assessments for FC or bio-fibrous concrete under flexural load in particular is lacking. This deficiency makes correlating or extending published test results in articulating the tensile property which FC possesses very difficult. Fibre addition is believed to benefit the creep performance of concrete under compression, tension and flexural creep loading. Additionally, fibres slenderness has an important synergy effect with load ratio concerning the considered creep parameters: using fibres with high slenderness lessens the effect that load ratio has on creep strains. Consequently, adding fibres is a good strategy in order to control creep strains and, though they are not required in high amounts, the best choice is to use fibres with high slenderness. In contrast, the presence of natural fibres has not yet been proved to enhance the life of concrete creep either under compressive, tensile and flexural creep loading, when

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compared to steel fibre, and polypropylene fibre. Therefore, an in-depth study of creep behaviour of bio-fibrous concrete is expedient.

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