An Overview of Kenaf Fibre as a Bio Composites Material in Fabrication Process for Sustainable Construction

Julius Onuwe
Federal University of Technology Minna

Ezekiel Babatunde Ogunbode
Federal University of Technology Minna

Jamaludin Mohamad Yatim
Universiti Teknologi Malaysia, Johor Bahru, Malaysia

Shettima U Ali
Universiti Teknologi Malaysia

An Overview of Kenaf Fibre as a Bio Composites Material in Fabrication Process for Sustainable Construction

Onuwe J. O.[1], Ogunbode E. B.[2,*], Jamaludin M. Y.[3], Shettima A. U.[4]
[1]Department of Architecture, School of Environmental Technology,
Federal University of Technology Minna. PMB 65 Niger State, Nigeria
[2]Department of Building, School of Environmental Technology,
Federal University of Technology Minna. PMB 65 Niger State, Nigeria
[3]Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai Johor, Malaysia,
[4]Department of Civil Engineering Technology, Federal Polytechnic Damaturu, Yobe State, Nigeria
ezekielogunbode@futminna.edu.ng

The construction industry has been concerned with improving the social, economic and environmental indicators of sustainability in the past decades. This has led to the emergence of bio fibrous composites in cement and polymer science. Bio fibrous composites are non abrasive and biodegradable compared to synthetic and glass composites. Though, the hydrophylic propensity and the poor fibre-matrix interface bonding of bio fibres have repeatedly reduce its potential for composite production. Kenaf fibre have been identified as a probable bio fibre with tremendioous potentials and properties for composite production. The aim of this review is to examine previous research on Kenaf fibre, its composites, and its development for building construction material production. This will assist in the evaluation of the current status and to outline the key challenges concerning the fibre, its matrix and the resulting bio-composite product.The survey also reflect the key milestones accomplished in research articles with different most widely used matrix forKenaf fibrousbio composites development over the last decade. A review of literature between 2005 and 2017 was done for the purpose of achieving the aim of this research. Hence, it can be stated that the application of Kenaf fibre is fundamental to sustainability and improvement in building and construction materials. The possibiity of substituting synthetic and glass fibre with cellulose fibre contributes to the effort to reduce global warming, promotes a bio base economy and achieve a cleaner environment.

Keywords: Bio composite, Fibre matrix Interface, Hydrophilic, Kenaf fibre, Sustainable construction

Introduction

Sustainable development is a strongly considered issue in all nations across the globe. The interest of the united nation on human environment and adequately addressing the global environmental challenges led to the institution of World Commission on Environment and Development (WCED) in 1987. The outcome of the commisionwas summarized in a documents titled “Our Common Future”. WCED also made a declaration describing sustainable development as meeting the needs of the present without jeopardizing the ability of future generations to meet their own needs (Brundtland, 1987). Also,Vollenbroek (2002) in a bid to expatiate on this subject matter, stated that sustainable development is a balance between the available technologies, strategies of innovation and the policies of governments. However, the state of the worlds environment and the practice in construction industry made Sachs and Warner (1995) affirmed that 21st century big challenge will be sustainable development.

In Malaysia, the craving towards contributing towards the course of

Sustainable development had made government agencies such asMalaysian Agricultural Research and Development Institute (MARDI) directed by National Economic Advisory Council (NEAC) to undertake, and co-ordinate an intensive fast track research and development (R&D) on Kenafcropproject. The agency as a mandate to also promote and develop the Kenaf industry (National Kenaf and Tobacco Board Bill, 2008). Government of Malaysia recognized the diverse possibilities of commercially exploitable derived products from Kenaf and its being a favourable replacement over local tobacco (Mohd *et al*., 2014). The government allocated RM12 million for research and further development of the Kenaf-based industry under the 9th Malaysia Plan (2006–2010) as a recognition of Kenafbeing a commercially viable crop.The Plantation Industry and Commodities Ministry (KPPK) as also identified Kenafcrop as a new source of economic contributor for Malaysia's commodity sector.

The improving social, economic and environmental indicators of sustainable development are drawing attention to the construction industry, which is a globally emerging sector, and a highly active industry in both developed and developing countries (Industry and environment, 2003; CSIR Building and Construction Technology; 2004).Socially and economically, the European Commission (2006) stated that 11.8 million operatives are directly employed in the sector and it is Europe's largest industrial employer, accounting for 7% of total employment and 28% of industrial employment in the EU-15. About 910 billion euros was invested in construction in 2003, representing 10% of the gross domestic product (GDP) and 51.2% of the Gross Fixed Capital Formation of the EU-15 (CICA, 2002). By contrast environmentally, this sector is responsible for high-energy consumption, solid waste generation, global greenhouse gas emissions, external and internal pollution, environmental damage and resource depletion (Melchert, 2005).

At present, research effort on Kenafhas been trending on bio composite materials biofuel production, and bio products (Aminah *et al*., 2004). This is as a result of its three basic useful components such as seed, leave and stem. The by products of this crop components are fibre strands, proteins, oils, and allelopathic chemicals (Webber III *et al.*, 2002).Furthermore, the fibre and core produced from the stem of the Kenaf has the potential to be made into environmentally friendly products for biofibrous concrete, automotive components, bio-composites, pulp and paper and many more. The production of building materials based on quality Kenafconcrete, mortar or polymer composite had successfully attracted attention. For Kenaf polymer composite (KPC), their use are commonly applicable in the living room, ceilings, wall panels and stairways.Based on the awareness for environmentally friendly products, companies producing KPC for use in the interior of buildings, have ensured that it fulfills the needs of the green building index (GBI).This means it has to be recyclable, water and heat resistant and non-toxic, as well as having anti-termite properties.

Therefore, in order to improve sustainability in the construction industry and overcome the increasing concern of today's resource depletion in both developed and developing countries. Bio composites products has to be adopted for the development and production of building construction materials. However, it has been noticed that the Published research work on Kenaf, its ensuing composite and its international accessibility are limited. These has been hampering the awareness, knowledge and acceptance of Kenaf bio composites application, particularly in the concrete structure application.The aim of this review is to carefully examine previous research on Kenaffibre and its composites, its development for building construction material production. This will assist intheevaluation of the current status and to outline the key challenges concerning the fibre, its matrix and the resulting bio-composite product.

Bio Fibre Composites

Bio-composites are a combination of natural fibres such as wood fibres (hardwood and softwood) or non-wood fibres (such as Kenaf, wheat, hemp, jute, sisal, and flax) with cement or polymer matrices to achieve both renewable and non-renewable sources. In classifying bio-composites, their application in the construction industry must be considered first in order to group them appropriately into structural and non-structural bio composites (Han *et al*., 1997; Rowell, 1995). Structural bio composites include those required for carrying loads in uses such as walls, stairs, roof systems and sub-flooring. Structural bio-composites comprise both high performance and low performance materials. On the other hand, bio composite which are not load bearing are simply referred to as non-structural bio composite. Such are usually made with thermoplastics, wood particles, and textiles. It is also usually utilized in the manufacture of ceiling tiles, furniture, windows and doors.

Kenaf fibre and its matrices

The matrix and matrix phase plays a fundamental role in the performance of Kenafcement/concrete and polymer composites. The cement, thermoplastics and thermosets are attractive as matrix materials for Kenafbio composites (Saheb *et al.*, 1999). In thermoset composites, formulation is complex because ofenormous number of components involved such as base resin, curing agents, catalysts, flowing agents, and hardeners. These composite materials are chemically cured to a highly cross-linked, three-dimensional network structure. These cross-linked structures are highly solvent resistant, tough, and creep resistant. The fibre loading can be as high as 80% and because of the alignment of fibres, the enhancement in the properties is notable.

Thermoplastics presentsnumerousbenefits over thermoset polymers. One of the advantages of thermoplastic matrix composites is their low processing costs. Another is design flexibility and ease of molding complex parts. Simple methods such as extrusion and injection molding are used for processing of these composites. In thermoplastics, most of the work reported so far deals with polymers such as polyethylene, polypropylene, polystyrene, and poly (vinyl chloride).

The processing temperature constraint to temperatures beneath 200^{o}C is the reason for the wide application of polymer in thermoplastic. This is to evade thermal degradation of the biofibres used (Saheb *et al*., 1999). Fibre distributionin composites is also an imperativefactor to attain consistency in thermoplastic composites. Thermoplastic composites are flexible, tough and exhibit good mechanical properties.

However, the percentage loading is limited by the processability of the composite. The fibre orientation in the composites is random and accordingly the property modification is not as high as it is observed in thermoset composites. Properties of the fibres, the aspect ratio of the fibres, and the fibre–matrix interface govern the properties of the composites. The surface adhesion amongst the fibre and the polymer plays an important role in the transmission of stress from matrix to the fibre and thus addsto the enactment of the composite. Another important aspect is the thermal stability of these fibres. These fibres are lignocellulosic and consist of mainly lignin, hemicellulose, and cellulose.

The cell walls of the fibres go through pyrolysis with growing processing temperature and add to char formation. These charred layers help to insulate the lignocellulosic from more thermal degradation. Since most thermoplastics are processed at high temperatures, the thermal solidity of the fibres at processing temperatures is essential. Thus, the vitalconcerns in progress of bio reinforced composites includes (i) thermal stability of the fibres, (ii) surface adhesion features of the fibres, and (iii) dispersion of the fibres in the case of thermoplastic composites.

Figure 1 display the percentage weight of research effort on the usage of various available matrix for Kenaf fibrous composite.Table 1 shows a list of several published research articles with different most widely used matrix for Kenaf fibrous composite. Observation from Table 1 shows that cement adoption in the fibre matrix interface of Kenaf fibre is on the low platform compared to poly (lactic) matrix. The research on Kenaf fibrous concrete and its application is still limited. Thiswithout doubt explains the need for more indepth research using cement as a matrix for Kenaf fibrous compositeso as to have better understanding of the product (Akil *et al.*, 2011; Elsaid *et al.*, 2011; Ogunbode *et al.*, 2015). Polyethylene, Rubber and thermosetting matrices such as polyester and epoxy are gaining wide adoption as matrices in the production of Kenaf fibrous composites than its conterpart cement matrix as can be seen from the compile published papers related to Kenaffibres and various matrices within the period of 2005 and 2018.

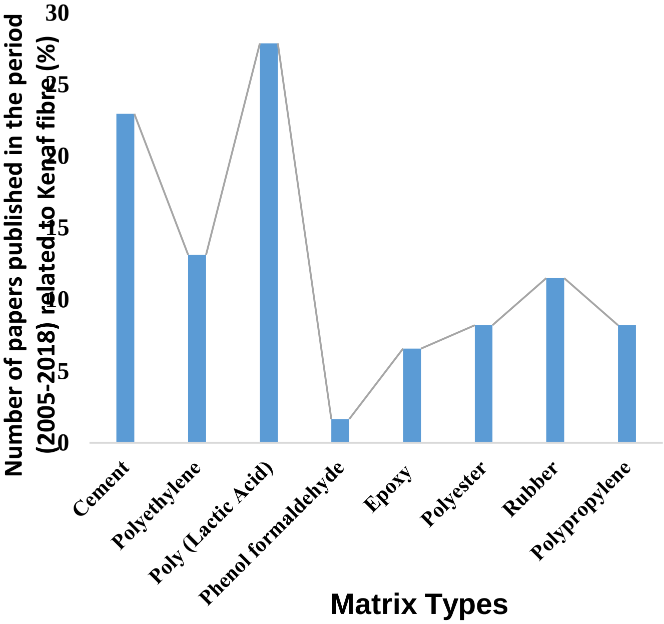

Figure 1: Percentage weight of research effort on the usage of various available matrix for Kenaf fibrous composite

Table 1: Number of papers published in the period (2005-2018) related to Kenaf fibres

Matrix	2005-2008	2009-2011	2012-2015	2016-2018	Total
Cement	Rohny (2006).	(Elsaid *et al.*, 2011);	(Hasan *et al.*, 2015; Lam and Jamaludin, 2015; Moses *et al.*, (2015); Udoeyo and Adetifa, (2012); Kim, *et al.* (2014); Zanjani and Bobko, (2014), (Lam and Jamaludin, (2014)	Ogunbode *et al.*, (2016a, 2016b, 2016c, 2016d); Ogunbode *et al.*, (2018)	14
Polyethylene		Tajeddin, *et al.*,(2009); Behjat, *et al.*, (2009); Rohani, *et al.*, (2010)	Yakubu, *et al.*, (2014); Viet, *et al.*, (2012); Mohamad, *et al.*, (2013),Yakubu, *et al.*, (2012)Salleh, *et al.*, (2014).		8
Poly (Lactic Acid)	Serizawa, *et al.*, (2006); Ben *et al.*, (2007); Huda *et al.*, (2008);Mau rizio,*et al.*,	Lee *et al.*, (2009); Yussuf, *et al.*, (2010);Anuar, *et al.*, (2010). Ibrahim,*et al.*, (2010).Graupner and Müssig	Asep and Sanro (2012);Anuar and Zuraida (2012); Kwon, *et al.*, (2014)(Tawakkal *et al.*, (2012)	Manolis *et al.*, (1997)	17

	(2008); Ochi, (2008)	(2011). NurAimi *et al.*, (2011);Rosnita, (2011)			
Phenol formaldehyde		Sultan, (2010).			1
Epoxy		Abu Bakar *et al.*, (2011)	Abdullah, *et al.*, (2012); Abu Bakar, *et al.* (2012), Mahjoub *et al.*, (2014a)		4
Polyester		Ahmad, *et al.* (2011), (Yuhazri *et al.*, 2011)	Abdul Khalil, *et al.*, (2012).Atiqah, *et al.* (2014)	Mahjoub *et al.*, (2016)	5
Rubber	Raju, *et al.*,(2008); Anuar, *et al.*,(2008)	Ahmad, *et al.* (2011); Hanafi, *et al.* (2011)	Viet, et al., (2012); Nurul Aizan, *et al* (2013); Abu Bakar, *et al.* (2012).		7
Polypropylene	Mirbagheri, *et al.* (2007a). Mirbagheri, *et al.* (2007b). Ghasemi, *et al.* (2008), Zampaloni *et al.*, (2007)		Ismail, *et al.* (2013).		5

Kenaf bio fibrous composites

Construction material designers and engineers must understand the properties and application of Kenaf fibre, its matrix and composites, not only to meet consumer demands for environmentally friendly products, but also to increase the productivity and competitiveness of the green construction markets. For this reason, this review appraise Kenaf fibrous composites, the application of Kenaf fibre in the production of bio composites, to encourage a broad acceptance of the fibre as a reinforcing agent for cement/concrete, polymer, hybridization of glass fibre etc., and also to improve environmental processes and services.

The following are the different types of matrices found compatible and used by several researchers in the production of Kenaf bio fibrous composites.

i. Cement matrices
ii. Thermoset matrices
iii. Thermoplastics matrices
iv. Rubber matrices

Kenaf fibre reinforced Cement matrices

The explosive interest in bio fibre due to its low cost, low density, eco friendliness and its reinforcing ability which has been proven in cement matrix as an effective alternative to inorganic synthetic and steel fibres is growing in it application as building materials (Agopyan *et al.*, 2005; (John *et al.*, 2005; Ramakrishna and Sundararajan, 2005; Sivaraja *et al.*, 2010). Limited studies are still available on Kenaf fibre reinforced cement composites and most of the works focused on short term mechanical properties(Elsaid *et al.*, 2011; Hasan *et al.*, 2015; Lam and Jamaludin, 2015; Ogunbode *et al.*, 2016c). Elsaid *et al.* (2011) and Ogunbode *et al.*, 2016c in their work reported that Kenaf fibres yielded improved mechanical strength of the cement based composites and the resultant concrete exhibits more distributed cracking and higher toughness than plain concrete. The fibrme –matrix interfacial bond was adequate from the study of the composite under the SEM's (Elsaid *et al.*, 2011). They concluded that Kenaf fibrous concrete composite is a promising 'green' construction material which could potentially be used in a number of different structural applications.

Reviewing the literature, it remains difficult to disperse the Kenaf and other natural fibre into cement matrix. Also their long term durability in cement matrix and long term performance (time dependent deformation) of the composite under mechanical loads is yet to be adequately investigated (Tonoli, *et al*. 2009; Ogunbode *et al*., 2015).

Kenaf fibre reinforced thermoset matrices

Aziz, *et al*., (2005) observed composites containing Kenaf fibres reinforced with four different polyester resins. Out of the four matrices, One was used as an unsaturated polyester while the others were modified by alkali surface treated fibre using 6 % NaOH solution to improve the adhesion to natural fibres (i.e. Make them more polar). And subsequently a composites with 60 volume % fibre content was produced and tested in bending. The outcome of their study showed a Modified polyester that exhibits good flexural properties. Nishino *et al*., (2003) examined the mechanical properties of a composite made of Kenaffibre and poly-L-lactic acid (PLLA). Young‛s modulus (6.3 GPa) and tensile strength (62 MPa) of the Kenaf/PLLA composite (fibre content 70 vol. %) were comparable to those of traditional composites. The effects of the molecular weight of PLLA, and orientation of the Kenaffibres in the sheet on the mechanical properties of the composite were also investigated. This composite showed superior mechanical and thermal properties based on the strong interactions between the Kenaffibres and PLLA matrix.

Unsaturated four different polyester resin formulations A, B, C and D were used for Kenaf fibres composites (Aziz, *et al*. 2005). The molecular structure of polyester B was based on polyester A modified to make it more polar in nature to better react with the surface of natural fibres. Polyester resin A was a conventional unsaturated polyester resin in styrene monomer, Crystic 2-406PA. Composite with 60 vol. % fibres content has been produced and tested in bending. One of the composites, reinforced with 56 vol. % of fibre content, had respectively almost 2 and 3 times higher flexural modulus and strength in comparison to an unmodified composite with higher fibre content (63 vol. %).A moisture absorption test showed a weight increase divided by 3 if compared unmodified (±60 %) and modified polyester composites (±20 %). The biodegradable polymer, poly-L-lactic (PLLA) was used to produce Kenaf fibre reinforced composites with a 70 vol. % of fibre content (Dansiri *et al*., 2002). Interesting tensile properties were reported and were attributed to the strong bonding among Kenaf fibres and PLLA.

Kenaf fibre reinforced thermoplastic matrices

Polyethylene and polypropylene matrix are good examples of the most commonly used thermoplastic in natural fibres reinforcement (Joseph, *et al*., 1993a and b; Joseph, *et al.*, 1994; Karmaker, 1997; Garkhail, *et al*., 1997). Unidirectional (UD) composites of polyethylene and Kenaf fibres studied was treated using coupling agent. Tensile properties of the UD composites were tested and it was reported that Kenaf fibres enhanced the tensile properties of polyethylene. A UD composite with 57 % fibres content exhibited a tensile modulus 7 times as much as tensile modulus of polyethylene, while its tensile strength was 4 times greater (Chen and Porter, 1994).

Kenaf fibre reinforced rubber matrices

Raju *et al*., (2008) incorporated Kenaf fibre into the rubber matrix. The outcomes indicated that Kenaf fibre has the ability of improving the properties of the resulting composites with the addition of the dry bonding agent system. Nurul Aizan *et al*. (2013) investigated the effect of Kenaf fibre on cure characteristics and mechanical performance of Kenaf fibre reinforce natural rubber composites. The composite was prepared by incorporating different loadings of Kenaf fibre using two roll mill machines. The compound was then vulcanized at 150°C according to their respective cure time. The result showed that the higher fibre content in composites led to shorter optimum cure time, t_{90}. It was also observed that the tensile strength and elongation at break gradually decreased with an increment in fibre loadings.

However, the trend was not similar to the hardness where the hardness value was increased by the increment of fibre loadings. The study has exhibited that the optimum fibre loading for the best performance of the composite achieved was 10 per hour (phr). The Scanning electron microscope (SEM) micrograph clarified that fibre dispersion and adhesion were weak, thus resulting in low tensile strength and elongation at break (Nurul Aizan *et al*., 2013).

Kenaf and synthetic hybrid fibrecomposites

The hybridization of Natural fibres with synthetic fibres for usage as reinforcements for composite is attracting interest for a wide range of industries (Magurno, 1999; De Bruijn, 2000). Natural fibres are lighter and cheaper than glass fibres (Saheband Jog, 1999). However, one drawback of natural fibre is their lower mechanical properties compared to glass fibres. Currently, most studies on natural fibres are concerned with the fundamental understanding of their behaviour as reinforcement for composites. However, very few studies exist on the use of hybrid solutions with lay-up containing both glass and natural fibres.

Cicala *et al* (2009) studied the hybridization of glass fibres with Kenaf, and some other natural fibres for applications in the piping industry. The tensile and flexural properties of hybrid glass/Kenaf and some natural fibre reinforced epoxy composites in the forms of lamina and laminates were tested. It was found that the lamina prepared with natural fibre mat showed lower mechanical properties compared to laminas with glass mat. In addition, the researchers observed a cost reduction of 20% and a weight saving of 23% compared to the current commercial solution at the adoption of this hybrid fibre composite. They conclusively put it that the use of hybrid lay-up leads to a pipe which fulfilled the requirements of mechanical resistance for the intended use.

Long term performance of Kenaf bio fibrous concrete composites under controlled and tropical climate

The clamour for bio fibrous concrete composites has never been as prevalent as it is currently (Aji *et al*., 2009; Akil *et al*., 2011; Ali *et al.*, 2012a). Bio fibres offer both cost savings and a reduction in density when compared to glass, steel and carbon fibres(Al-bahadly, 2013; Jawaid *et al*., 2010; Mazuki *et al*., 2011). A major goal of bio fibre composites is to alleviate the need to use expensive glass fibre ($3.25/kg) which has a relatively high density (2.5 g/cm³) and is dependent on non-renewable sources (Ogunbode *et al.*, 2015). However the strength of cellulous fibres is not as pronounced as glass, the specific properties are of course equivalent (Jianchun, 2006; Ogunbode *et al.*, 2015; Van Rijswijk *et al.*, 2001; Sethunarayanan and Chockalingam, 1989; Tolêdo Romildo *et al.*, 2003). Two basic issues associated with bio fibres are matrix compatibility and water absorption. Presently several research has investigated this paucity and various appropriate outcomes as addressed it (Hafizah *et al.*, 2014; Khalid *et al.*, 2011; Mahjoub *et al.*, 2014b; Yatim *et al.*, 2011). Research on bio fibrous concrete composites has existed since the early 1900's but has not received much attention until late 1980's though(Ali *et al*., 2012b; Elsaid *et al*., 2011).

The inclusion of Kenaf fibre as reinforcement in fibrous cement/concrete composites has intensified boundless curiosity and anticipations amongst cement/concrete materials scientists, engineers and governments (Ogunbode *et al.*, 2016a). Realizing the immense potential and interest generated by Kenaf fibre in the construction material industry, automobile industry, wood-based sector, textile industry (Mohd *et al*., 2014). Malaysian government and some other developing nations has pursued various measures to promote downstream value added processing of Kenaf as well as its cultivation among small holders and estate owners. To some extent, a number of experimental and theoretical researches have been carried out to understand the performance of Kenaf bio-fibrous concrete composite (KFCC) recently (Elsaid *et al.*, 2011; Lam and Jamaludin, 2014; Ogunbode *et al.*, 2016a).

Most of these studies are limited to the short term performance of Kenaf bio-fibrous concrete composites under sustained static loads. However, long term performance of KFCC under sustained static loads, theoretical/numerical prediction models for estimation of shrinkage and creep properties of KFCC to understand it time dependent behaviour as attracted none or little attentions. Therefore a detail study is proposed. Furthermore, the long term performance of this composite system in temperate and tropical climate has been of interest due to its need for the calculation of stresses, deflection, cracking, bulking and failure of structures made from KFCC subsequently. This is to avail material engineers and structural designers' knowledge and data on the material properties and structural behaviour pertaining to serviceability performance. A detail assessment and discussion of this salient issues will be the focus in our subsequent publications.

Conclusions

The present review presents the key milestones accomplished in research articles with different most widely used matrix for Kenaf fibre reinforced bio composites development over the last 12 years, from 2005-2017. It deals with the properties of Kenaf fibre reinforced composites, highlighting different types of matrices found compatible and used by several researchers in the production of Kenaf fibre reinforced composites. Such matrices include cement matrices, thermoset matrices, thermoplastics matrices and rubber matrices. Innovatively, bio composite is recognized to improve sustainability in the construction industry throughout all stages of the structure. It can be seen from the literature reviewed that there still exist a gap of knowledge and research on Kenaf fibrous cement or concrete composites. The limited works available focused more on short term mechanical and physical properties. The uniform disperse of the Kenaf fire and other bio fibre into cement matrix had remain a major challenge in the bio fibrous concrete technology. Also, a lacuna still exists on the long-term durability and deformation behaviour under both environmental load (shrinkage) and mechanical load (creep) of fibrous concrete (time dependent properties). Fracture toughness, fracture mechanisms of Kenaf fibrous concrete composites do not seem to have been studied in any depth in previous published works. Therefore, an in-depth research is requisite, if this new improved construction material is to be developed for safe usage to improve the service, social and economy life of the society and reduce the life cost of the structure.

References

Aji, I.S., Sapuan, S.M., Zainudin, E.S., and Abdan, K. (2009). *Kenaf Fibres as Reinforcement for Polymeric Composites : A Review.* International Journal of Mechanics and Material Engineering. *4*, 239–248.

Akil, H., Omar, M., Mazuki, A., Safiee, S., and Ishak, Z. (2011). *Kenaf fiber reinforced composites: A review*. Material Des.

Al-bahadly, E.A.O. (2013). *The Mechanical Properties Of Natural Ekhlas Aboud Osman Al-Bahadly The Mechanical Properties of Natural Fiber Composites.*

Ali, M., Liu, A., Sou, H., and Chouw, N. (2012a). *Mechanical and dynamic properties of coconut fibre reinforced concrete.* Constructuction and Building Materials. *30*, 814–825.

Ali, M., Liu, A., Sou, H., and Chouw, N. (2012b). *Mechanical and dynamic properties of coconut fibre reinforced concrete.* Constructuction and Building Materials. *30*, 814–825.

Aminah, A. C. and Hashim, I. (2004). *Kenaf fibre production as affected by plant population and plant age on bris soil*.

Brundtland, G.H. (1987). *Our Common Future: Report of the World Commission on Environment and Development* (Oxford University Press).

Cicala G., Cristaldi G., Recca G., Ziegmann G., El-Sabbagh A., Dickert M. (2009). *Properties and performances of various hybrid glass/natural fibre* *composites for curved pipes*. Materials and Design. 30 (7), 2538-2542.

Elsaid, A., Dawood, M., Seracino, R., and Bobko, C. (2011). *Mechanical properties of Kenaf fiber reinforced concrete. Constr*. Build. Mater. *25*, 1991–2001.

Hafizah, N.A.K., Hussin, M.W., Jamaludin, M.Y., Bhutta, M.A.R., Ismail, M., and Azman, M. (2014). *Tensile Behaviour of Kenaf Fiber Reinforced Polymer Composites.* Jurnal Teknologi. *69*, 11–15.

Han, J.S., Rowell, J.S., Rowell, R.M., Young, R.A., and Rowell, J.K. (1997). *Paper and composites from agro-based resources* (Boca Raton 1: CRS Press).

Hasan, N.S., Sobuz, H.R., Auwalu, A.S., and Tamanna, N. (2015). *Investigation into the Suitability of Kenaf Fibre to Produce Structural Concrete.* Advance Material Letters.

Jawaid, M., Khalil, H.A., and Bakar, A.A. (2010). *Mechanical performance of oil palm empty fruit bunches/jute fibres reinforced epoxy hybrid composites*. Material Science and Engineering. *527*, 7944–7949.

Jianchun, Z. (2006). *Natural Fibres in China*. Natural Fibres. 53–61.

John, V., Cincotto, M., Sjöström, C., and Agopyan, V. (2005). *Durability of slag mortar reinforced with coconut fibre. Cement and Concrete.*

Khalid, N., Yatim, J., and Abdul, W. (2011). *Temperature Effects on Tensile Properties of Kenaf Bast Fiber. In 10th International Annual Symposium* (UMTAS 2011).Terengganu, Kuala Terengganu, Malaysia., pp. 287–288.

Lam, T.F., and Jamaludin, M.Y. (2014). *The Effects of Fiber Content and Fiber Length on The Mechanical Properties of Kenaf Fibrous Concrete.* In The 6th International Conference of Asian Concrete Federation, (21-24 September, 2014, Seoul, Korea).

Lam, T.F., and Jamaludin, M.Y. (2015). *Mechanical properties of Kenaf fiber reinforced concrete with different fiber content and fiber length*. Journal of Asian Concrete Federation. *1*, 11–21.

Mahjoub, R., Yatim, J.., Sam, A.R.., and Raftari, M. (2014a). *Characteristics of continuous unidirectional Kenaf fiber reinforced epoxy composites.* Material and Design. *64*, 640–649.

Mahjoub, R., Yatim, J.M., Mohd Sam, A., and Hashemi, S.H. (2014b). *Tensile properties of Kenaf fiber due to various conditions of chemical fiber surface modifications*. Construction and Building Materials. *55*, 103–113.

Mahjoub, R., Yatim, J.M., Sam, A.M., Zulkarnain, N.A., and Raftari, M. (2016). *The Use of Kenaf Fiber Reinforced Polymer to Confine the Concrete Cylinder*. Material Today Procedings. *3*, 459–463.

Manolis, G., Gareis, P., Tsonos, A., and Neal, J. (1997). *Dynamic properties of polypropylene fiber-reinforced concrete slabs.* Cement and Concrete.

Mazuki, A.A.., Akil, H.., Safiee, S., Ishak, Z.A.., and Bakar, A.. (2011). *Degradation of dynamic mechanical properties of pultruded Kenaf fiber reinforced composites after immersion in various solutions.* Compososite Part B Enginering. *42*, 71–76.

Melchert L. (2005). *The Age of Environmental Impasse? Globalization and Environmental Transformation of Metropolitan Cities*. Development and Change. 36 (5), 803 – 823.

Mohd, H.A.B., Arifin, A., Nasima, J., Hazandy, A.H., and Khalil, A. (2014). *Journey of Kenaf in Malaysia: A Review*. Science Resource and Essays. *9*, 458–470.

Moses, O.T., Samson, D., and Waila, O.M. (2015). *Compressive strength characteristics of Kenaf fibre reinforced cement mortar*. Advance Materials. *4*, 6–10.

Nishino T., Hirao K., Kotera M., Nakamae K., Inagaki H. (2003). *Kenaf reinforced biodegradable composite*. Composites Science and Technology. 63(9):1281-1286

Ochi, S. (2008). *Mechanical properties of Kenaf fibers and Kenaf/PLA composites*. Mechanics and Materials.

Ogunbode, E.B., Jamaludin, M.Y., Ishak,

M.Y., Razavi, M., and Razavi, M. (2015). *Potential of Kenaf fibre in bio-composite production:* A review. Jurnal Teknologi. *77*, 23–30.

Ogunbode, E.B., Jamaludin, M.Y., Yunus, I.M., Hamid, H.A., Azmahani, A.A., and Masoud, R. (2016a). *Compressive Creep of Kenaf Bio-Fibrous Concrete Composite Under One Dimensional Stressing.* Malaysian Journal of Civil Engineering. *28*, 279–289.

Ogunbode, E.B., Jamaludin, M.Y., Ishak, M.Y., and Razavi, M. (2016b). *Creep Peformance of Kenaf Bio Fibrous Concrete Composite Under Uniaxial Compression*. In The 11th International Seminar of Civil Engineering Research -The 1st International Symposium on Expertise Engineering Design (SEPKA-ISEED'16), At Universiti Teknologi Malaysia, pp. 10–19.

Ogunbode, E.B., Jamaludin, M.Y., Ishak, M.Y., Meisam, R., Masoud, R., and Norazura, M.A. (2016c). *Preliminary Investigation of Kenaf Bio Fibrous Concrete Composites.* In 2nd Int. Conf. Sci. Eng. Soc. Sci. (ICSESS '16). Universiti Teknologi Malaysia, pp. 248–249.

Ogunbode, E.B., Jamaludin, M.Y., Ishak, M.Y., Hazlan, A.., and Azmahani, A. (2016d). *Demeanour of Cracked Kenaf Bio Fibrous Concrete Composite under Sustained Load.* In ICSEMSS 2016, at Universiti Teknologi Malaysia, (Johor Bahru, Malaysia).

Ogunbode, E.B., Jamaludin, M.Y., Meisam R., Ishak M. Y., Norazura M. A. (2018). *Experimental Study of Kenaf Bio Fibrous Concrete Composites.* Advanced Science Letters. *24 (6)*, 3922-3927

Ramakrishna, G., and Sundararajan, T. (2005). *Impact strength of a few natural fibre reinforced cement mortar slabs : a comparative study*. *27*, 547–553.

Rowell, R.M. (1995). *A new generation of composite materials from agro-based fibre* (Springer).

Saheb, D.N., Jog, J.P., Nabi Saheb, D., and Jog, J.P. (1999). *Natural Fiber Polymer Composites : A Review*. Advance Polymer Technology. *18*, 351–363.

Sethunarayanan, R., and Chockalingam, S. (1989). *Natural fiber reinforced concrete*. Transportation Resource.

Sivaraja, M., Velmani, N., and Pillai, M. (2010). *Study on durability of natural fibre concrete composites using mechanical strength and microstructural properties*. Bulletin of Material Science.

Tawakkal, I.S.M.A.., Talib, R.A.., Abdan, K., and Ling, C.N. (2012). *Mechanical and physical properties of Kenaf-derived cellulose (KDC)-filled polylactic acid (PLA) composites*. BioResources *7*, 1643–1655.

Tolêdo Romildo, F.R., Ghavami, K., England, G.L., and Scrivener, K. (2003). *Development of vegetable fibre-mortar composites of improved durability*. Cement and Concrete Composite. *25*, 185–196.

Tonoli G.H.D., de Souza Almeida A.E.F., Pereira-da-Silva M.A., Bassa A., Oyakawa D., and Savastano Jr H. (2010). *Surface properties of eucalyptus pulp fibres as reinforcement of cement-based composites*. Holzforschung. 64, pp. 595–601

Udoeyo, F.., and Adetifa, A. (2012). *Characteristics of Kenaf Fiber-Reinforced Mortar Composites.* International Journal of Resource and Review. Applied Science. *12*, 18–26.

Van Rijswijk, K., Brouwer, W., and Beukers, A. (2001). *Application of natural fibre composites in the development of rural societies* (Delft).

Vollenbroek F.A. (2002). *Sustainable development and the challenge of innovation.* Journal of Cleaner Production. 10 (3), 215-223.

Webber III, C.., Bhardwaj, H.., and Bledsoe, V.. (2002). *Kenaf production: fiber, feed, and seed.* Trends in New Crop. New Uses 327–339.

Yatim, J., Khalid, A., and Mahjoub, R. (2011). *Biocomposites for the construction materials and structures.*

Yuhazri, M., Sihombing, H., Jeefferie, a R., and Rassiah, K. (2011). *Mechanical Properties of Kenaf / Polyester Composites.* Internation Journal of Engineering Technology. *11*, 127–131.

Zampaloni, M., Pourboghrat, F., Yankovich, S.A., Rodgers, B.N., Moore, J., Drzal, L.T., Mohanty, A.K., and Misra, M. (2007). *Kenaf natural fiber reinforced polypropylene composites:* A discussion on manufacturing problems and solutions. Composite Part A Applied Science and Manufacturing. *38*, 1569–1580.