

# Impact Resistance Performance of Kenaf Fibre Reinforced Concrete

Zakaria Che Muda<sup>1</sup>, Nur Liyana Mohd Kamal<sup>1</sup>, Agusril Syamsir<sup>1</sup>, Chiam Yung Sheng<sup>2</sup>, Salmia Beddu<sup>1</sup>, Kamal Nasharuddin Mustapha<sup>3</sup>, Sivadass Thiruchelvam<sup>4</sup>, Fathoni Usman<sup>1</sup>, Md Ashraful Alam<sup>1</sup>, Ahmed H Birima<sup>1</sup>, O S Zaroog<sup>4</sup>

<sup>1</sup>Centre of Sustainable Technology and Environment, Universiti Tenaga Nasional, Malaysia <sup>2</sup>Former Student of Universiti Tenaga Nasional

<sup>3</sup>Centre of Forensic Engineering, Universiti Tenaga Nasional, Malaysia

<sup>4</sup>Centre of Innovation and Design, Universiti Tenaga Nasional, Malaysia

mzakaria@uniten.edu.my

**Abstract.** This paper investigate the performance of kenaf fibre mesh reinforced concrete (KFMRC) with varied kenaf fibre mesh reinforcement content for the concrete slab of 300mm x 300mm size reinforced with different mesh diameter at constant spacing with varied slab thickness subjected to low impact projectile test. A self-fabricated drop-weight impact test rig with a steel ball weight of 1.236 kg drop at 0.40 m height has been used in this research work. The main variables for the study is to find the relationship of the impact resistance against the amount of mesh reinforcement and slab thickness. A linear relationship has been established between first and ultimate crack resistance against kenaf fiber diameters by the experiment. The linear relationship has also been established between the service (first) crack and ultimate crack resistance against the slab thickness. The threshold (highest) values for service crack and ultimate crack is 47.9 N/mm<sup>2</sup> and 130.58 N/mm<sup>2</sup> respectively observed and computed for 50 mm slab with 7 mm diameter mesh.

## 1. Introduction

In the search of sustainable green materials, it is critical to study the impact strength characteristics and assess its performance for eco-green construction materials for various potential uses in the building industry.

There is lack of research investigation been carried out on impact resistance of kenaf fibre mesh reinforced concrete (KFMRC). Impact resistance represents the ability of concrete to withstand repeated blows and absorb energy without adverse effect to cracking and spalling. Impact scenario can also be classified into low velocity impact and high velocity impact. According to Dancygier [1], the nuclear structures are designed to resist impact loading caused by projectile or missiles travelling up to 1000 m/s. The response of reinforced concrete structures under impact loading is different from the static loading especially in the case of high velocity impact of rigid projectile. For impact velocities up to 10 ms<sup>-1</sup>, the failure modes are generally the same as the static failure, except there is increased tendency for local damage or shear failure to occur. A repeated impact test, a weighted pendulum Charpy-type impact test, a projectile impact test, and explosion-impact test, a constant strain rate test, a split Hopkinson bar test, and an instrumented pendulum impact test could be used to measure the impact resistance of fiber reinforced composites [2]. The impact resistance of material also can be measured by using the criteria such as the energy of fracture of the specimen, repeated impact tests, and the velocity and the size of the spall the specimen subjected to a blast loading surface [3]. However, the drop weight impact test which is recommended by the ACI Committee 544 [4] is the simplest method. The review paper on impact resistance on concrete target has been published by Z Che Muda et al [5]. Impact resistance of oil palm shells lightweight concrete slab with bamboo fibers has been studied by Z Che Muda et al. The results indicate that 2% volume fraction of bamboo fibers has an optimal performance



in first crack resistance and ultimate crack resistance regardless of its fiber length with a potential to be used as an impact resistance composite structures in the future [6].

The objectives of this research are;

- i. To establish relationship between impacts resistance against content of kenaf fibre mesh reinforcement.
- ii. To establish a relationship between impact resistance against slab thickness.

## 2. Materials and Test Set-up.

The kenaf fiber is obtained from private supplier MZM solution that based in Kedah. The kenaf fiber is graded as grade AA which is capable to produce the highest tensile strength of 900 MPa according to the supplier. The fibres are twisted into the required bundled diameters of 3 mm, 5 mm and 7 mm diameter as shown in Figure 1b and tied to form a mesh at a constant spacing of 50 mm and placed in the mid-depth of the slab

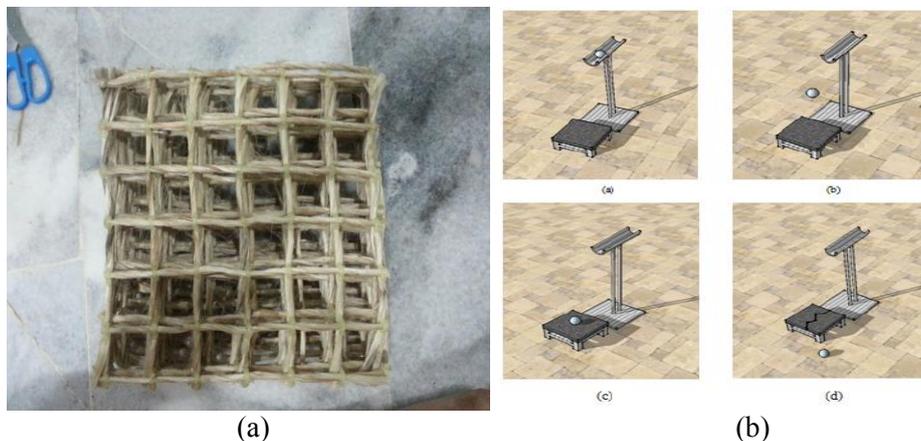
Ordinary Portland cement complying to ASTM Type I cement are used with 2% of super plasticizer is used in the design mix to achieved the desired workability.

The basic mix design for the KFMRC is shown in Table 1.

**Table 1.** Mix Design for Kenaf fibre mesh reinforced concrete (KFMRC)

Cement (kg/m <sup>3</sup> )	Fine Aggregates (kg/m <sup>3</sup> )	Course Aggregates (kg/m <sup>3</sup> )	Water/cement Ratio	Slump (mm)	Compressive Strength (N/mm <sup>2</sup> )
403	687	1030	0.6	72	31.7

The study used a self-fabricated low velocity drop-weight impact test set up are as shown in Figure 1b using a steel ball weighing 1.236 kg with drop height of 400 mm impacting the specimen of size 300mm x 300mm with thickness of 20 mm, 30 mm, and 40 mm mounted on the steel rack frame. The test sample is 1-way simply supported.



**Figure 1.** (a) Kenaf Fibre Mesh (b) Low-velocity Drop-weight Impact Test Set-up

## 3. Methodology

The potential energy due to the drop body is absorbed as strain energy, generating stresses that causes cracks in the target element. The width, depth, length of the crack developed and its failure mode is associated with the intensity of the energy, the amount of energy absorbed and the properties of concrete. It is assumed that the total computed energy imparted is fully absorbed by the specimens. The relationship of potential energy of a drop-weight projectile and the strain energy dissipated in cracks development is expressed as following formula as proposed by Kankam [7];

$$N^*e = R_u^* l_c^* d_c^* w_c \quad (3.1)$$

Where,  $N$  = No. of Blows,  $e$  = Energy per blow (Joules),  $l_c$  = Total length of all cracks,  $d_c$  = Maximum crack depth,  $w_c$  = Maximum crack width,  $R_u$  = Ultimate crack resistance

A total of 27 sample slabs of size 300mm x 300mm with 30 mm, 40mm and 50mm thickness were casted with 3 mm, 5mm and 7 mm bundled mesh diameter.

At the first crack and ultimate (failure) crack, the total crack length, the crack width and the crack depth measured by filler gauge with its total numbers of blows recorded.

#### 4. Results and Discussion

##### 4.1 Crack Resistance of Control Sample

Table 2 indicate the service (first) and ultimate crack resistance of control sample without mesh reinforcement.

**Table 2.** First and Ultimate Crack Resistance of Control Sample without Mesh Reinforcement

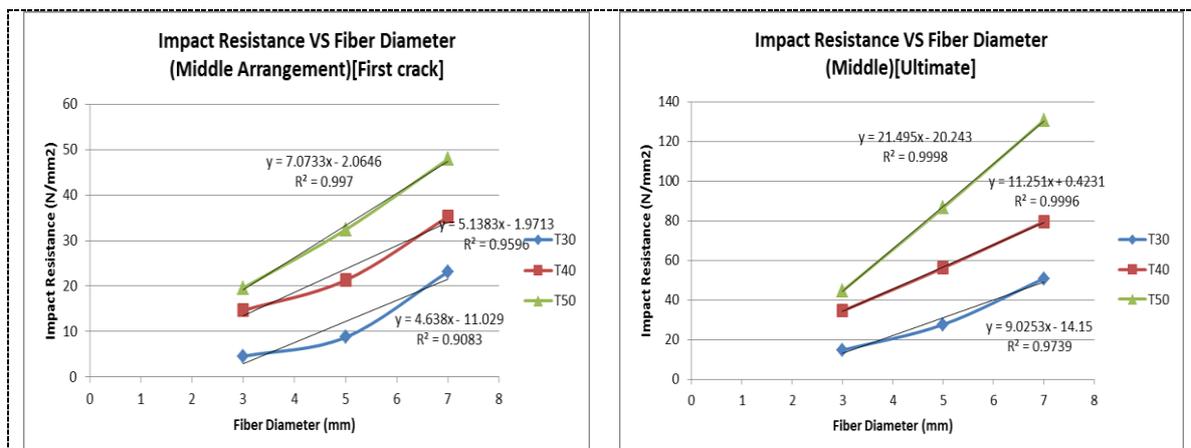
Control Sample No	T30	T40	T50
Thickness of Control Sample	30 mm	40 mm	50 mm
Service (First) Crack Resistance	2.15 N/mm <sup>2</sup>	2.33 N/mm <sup>2</sup>	3.86 N/mm <sup>2</sup>
Ultimate Crack Resistance	2.69 N/mm <sup>2</sup>	3.92 N/mm <sup>2</sup>	5.66 N/mm <sup>2</sup>

The presence of the mesh for first crack resistance increases up to 13.91 times and ultimate crack resistance increase up to 23.1 times against its control sample without mesh reinforcement.

##### 4.2 Relationship between Crack Resistance and Kenaf Mesh Diameter

There is a linear correlation between impact resistance against mesh diameter as shown in Figure 2. Generally the first and ultimate crack resistance increases with increasing diameter. The crack resistance increase by up to 5.04 times for first crack and up to 3.47 times for ultimate crack as the kenaf mesh diameter increases for the given thickness. The highest ultimate crack resistance of 130.58 N/mm<sup>2</sup> is observed for 50 mm slab thickness with kenaf mesh of 7 mm diameter whilst the lowest is 14.63N/mm<sup>2</sup> for 30 mm slab with 3 mm diameter kenaf mesh.

That means that the kenaf mesh has the ability to control cracks and resisted a lot of energy until the crack started to widen and propagate further and lose its bonding and tensile, which then lead to failure.

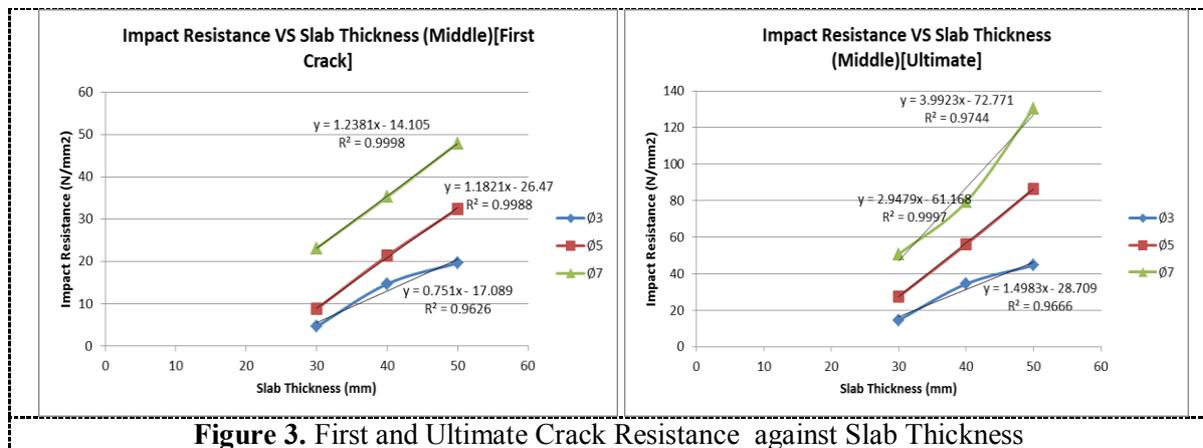


**Figure 2.** First and Ultimate Crack Resistance against Kenaf Mesh Diameter

##### 4.3 Relationship between Crack Resistance and Slab Thickness

There is a linear relationship between the crack resistance and slab thickness as shown in Figure 3. The crack resistance increase by up to 4.27 times for first crack and up to 3.13 times for ultimate crack as the slab thickness increases for the given mesh diameter. Figure 3 show clearly that the thickness of the slab has

an impact on the service and ultimate failure crack. The threshold (highest) values for service crack and ultimate crack is 47.9 N/mm<sup>2</sup> and 130.58 N/mm<sup>2</sup>, respectively.



## 5. Conclusion

The following conclusions can be derived from the experimental results;

- The good linear relationship for the first and ultimate crack resistances against the slab thickness and kenaf mesh diameter.
- The presence of the mesh for first crack resistance increases up to 13.91 times and ultimate crack resistance increase up to 23.1 times against its control sample without mesh reinforcement.
- The crack resistance increase by up to 5.04 times for first crack and up to 3.47 times for ultimate crack as the kenaf mesh diameter increases for the given thickness.
- The crack resistance increase by up to 4.27 times for first crack and up to 3.13 times for ultimate crack as the slab thickness increases for the given mesh diameter.
- The threshold (highest) values for service crack and ultimate crack is 47.9 N/mm<sup>2</sup> and 130.58 N/mm<sup>2</sup> respectively observed and computed for the thickest 50 mm slab with its biggest 7 mm diameter mesh.

## References

- [1] Dancygier, A N 1997 *Effect of reinforcement ratio on the resistance of reinforced concrete to hard projectile impact*. Nuclear Engineering and Design 172, pp. 233-245.
- [2] Gopalartnam, V. S., Shah, S. P., and John, R. A modified instrumented Charpy test for cement based composites." Exp. Mech. 1984; 24(2): 102–111.
- [3] Balaguru, P. N., and Shah, S. P. *Fibre-reinforced cement composites*, McGraw-Hill, London. 1992.
- [4] ACI Committee 544. *State-of-the-art report on fiber reinforced concrete*. ACI Committee 544 report 544.1R-96. Detroit: American Concrete Institute. 1996.
- [5] Zakaria Che Muda, Kong Sih Ying, Salah F A Sharif, Lariyah Bte. Mohd Sidek, Nawfal S. Farhan, *A Review - Local Failure On Concrete Target Due To Projectile Impact*. International Journal of Science and Engineering Research (IJSER) Volume 4, Issue 1, January 2013.
- [6] Zakaria Che Muda, Salah F A Sharif, Lariyah Bte. Mohd Sidek, Nawfal S Farhan, *Impact Resistance Of Oil Palm Shells Lightweight Concrete Slab With Bamboo Fibers*, International Journal of Science and Engineering Research (IJSER) Volume 4, Issue 1, January 2013.
- [7] CK Kankam. *Impact Resistance of palm kernel fibre-reinforced concrete pavement slab*. J Ferrocement 1999;29(4):279-86. Oct