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Impact Resistance Behaviour of Banana Fiber Reinforced Slabs

Zakaria Che Muda¹, Agusril Syamsir¹, Kamal Nasharuddin Mustapha³, Muhamad Rifdy Samsudin², Sivadass Thiruchelvam⁴, Fathoni Usman¹, Salmia Beddu¹, Nur Liyana Mohd Kamal¹, Md Ashraful Alam¹, Ahmed H Birima¹, O S Zaroog⁴

¹Centre of Sustainable Technology and Environment, Universiti Tenaga Nasional, Malaysia

²Former Student of Universiti Tenaga Nasional, Malaysia

³Centre of Forensic Engineering, Universiti Tenaga Nasional, Malaysia

⁴Centre of Innovation and Design, Universiti Tenaga Nasional, Malaysia

mzakaria@uniten.edu.my

Abstract. This paper investigate the performance of banana fibre reinforced slabs 300mm x 300mm size with varied thickness subjected to low impact projectile test. A self-fabricated drop-weight impact test rig with a steel ball weight of 1.25 kg drop at 1 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 BF contents and slab thickness. A linear relationship has been established between first and ultimate crack resistance against BF contents and slab thickness by the experiment. The linear relationship has also been established between the service (first) crack and ultimate crack resistance against the BF contents for a constant spacing for various banana fibre reinforced slab thickness. The increment in BF content has more effect on the first crack resistance than the ultimate crack resistance. The linear relationship has also been established between the service (first) crack and ultimate crack resistance against the various slab thickness. Overall 1.5% BF content with slab thickness of 40 mm exhibit better first and ultimate crack resistance up to 16 times and up to 17 times respectively against control slab (without BF)

1. Introduction

The search of sustainable green materials for the construction industry has reached its critical time to mitigate the negative impact of the climatic change. It is critical to study the impact strength characteristics and assess its performance for eco-green construction materials for various potential use in the building industry. Concretes with natural fibers such as Banana fibers (*Musa Sepientum*) as reinforcement one of the most promising building materials, represent a variety of an extensive class of composite materials presently widely used in various branches of the industry. There is lack of research investigation been carried out on impact resistance of banana fiber reinforced slab. 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. The review paper on impact resistance on concrete target has been published by Q.M. Li et al. [1]. 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 [2]. An investigation on the effect of polyolefin, polyvinyl alcohol and steel fibers on the fracture energy due to low velocity projectile impact on concrete slabs has been carried out by K.C.G. Ong et al. [3].

The objectives of this research are;

- i. To establish relationship between impact resistance against banana fibre (BF) content
- ii. To establish a relationship between impact resistance against slab thickness.



2. Materials and Test Set-up.

Ordinary Portland cement complying with ASTM Type I cement are used with 2% of super plasticizer is used in the design mix to achieve the desired workability. Banana fibers (BF) are used to reinforce concrete slab is splice and cut into the required length of 20 mm, 30 mm and 40 mm. The basic mix design for the concretes is 0.6 Water/Cement ratios and 2.0 Sand/Cement. There are three different BF/Cement ratios were used in the mix designed; 0.5%, 1.0%, and 1.5% BF/Cement ratios. The compressive strength and density of these mix design at 28 days are as shown in Table 1.

Table 1 Compressive strength and density at 28 days for 0.5%, 1.0% and 1.5% BF content cubes.

BF Content (%)	Density (kg/m ³)	Compressive Strength (N/mm ²)
0.5	1980	28
1.0	1840	27
1.5	1790	26

The above results comply with the category 3-Structural as classified by the American Concrete Institute (ACI) Committee [4] in according to its strength values 16-42 N/mm² and density between 1500-2000 kg/m³. The study used a self-fabricated low velocity drop-weight impact test shown in Figure 1 using a steel ball weighing 1.25 kg with drop height of 1000 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) Banana fiber (b) Low-velocity Drop-weight Impact Test Rig

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 [5];

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

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

Another dimensionless factor “impact crack resistance ratio” was also defined:

$$C_r = R_u * f_{cu} \quad (3.2)$$

Where, C_r = Impact crack resistance ratio, f_{cu} = Cube compressive strength

Residual impact strength ratio as defined in Equation 3.3 helps to evaluate the 'post – crack' behavior and use to measure the ductility of the banana fiber composite imparted in the OPS cement matrix.

$$\text{Residual impact strength ratio (Irs)} = \frac{\text{Energy absorbed at ultimate failure}}{\text{Energy absorbed at initiation of first crack}} \quad (3.3)$$

A total of 72 sample slabs of size 300mm x 300mm with 30 mm, 40mm and 50mm thickness were casted and tested with 0.5%, 1.5% and 1.5% BF.

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.

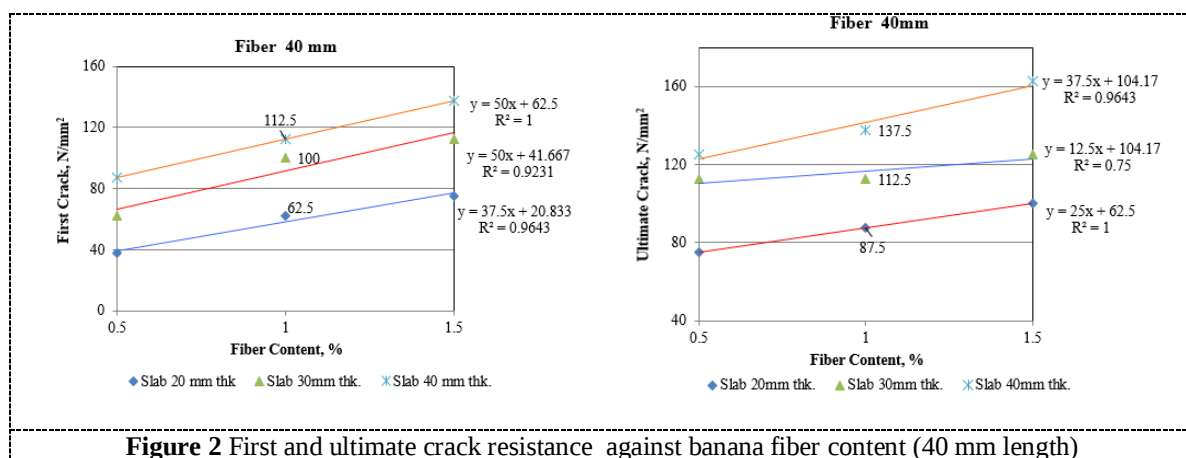
Table 2 First and Ultimate Crack Resistance of Control Sample without BF Reinforcement

Control Sample No	T20	T30	T40
Thickness of Control Sample	20 mm	30 mm	40 mm
Service (First) Crack Resistance	3.1 N/mm ²	5.35 N/mm ²	7.93 N/mm ²
Ultimate Crack Resistance	4.95 N/mm ²	7.49 N/mm ²	8.05 N/mm ²

The presence of the BF reinforcement for first crack resistance increases up to 16 times and ultimate crack resistance increase up to 17 times against its control sample without BF reinforcement for slab thickness of 40 mm.

4.2 Relationship between crack resistance and fibre content

There is a strong linear correlation between impact resistances against fiber as shown in Figure 2. Generally the first and ultimate crack resistance increases with increasing fiber content. The first crack resistance increase by 1.28 times and 1.57 times for fiber content of 1% and 1.5%, respectively compared to fiber content of 0.5%. The ultimate crack resistance increase by 1.1 times and 1.3 times for fiber content of 1% and 1.5%, respectively compared to fiber content of 0.5%. Comparing the first and ultimate crack resistance for fiber content 1.5%, the crack resistance increase by 1.2%. The slab with fibre content 1.5% show the best performance in resisting impact load for service and ultimate loading. Generally, a good linear correlation between the first and ultimate crack resistance against the bamboo diameter is obtained from the graphs.



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. Increase in crack resistance is more substantial as the thickness increases as compared to the increases in the BF content. For 0.5% fiber, the first crack resistance increase up to 2.33 times and 1.66 times for ultimate

crack resistance as the slab thickness increases. For 1% fiber, the first crack resistance increase up to 175% and 157% for ultimate crack resistance. For 1.5% fiber, the first crack resistance increase up to 200% and 137.5% for ultimate crack resistance. The slab with thickness of 40 mm show the best performance in resisting impact load for service and ultimate loading. Generally, a good linear correlation between the first and ultimate crack resistance against the slab thickness is obtained from the graphs.

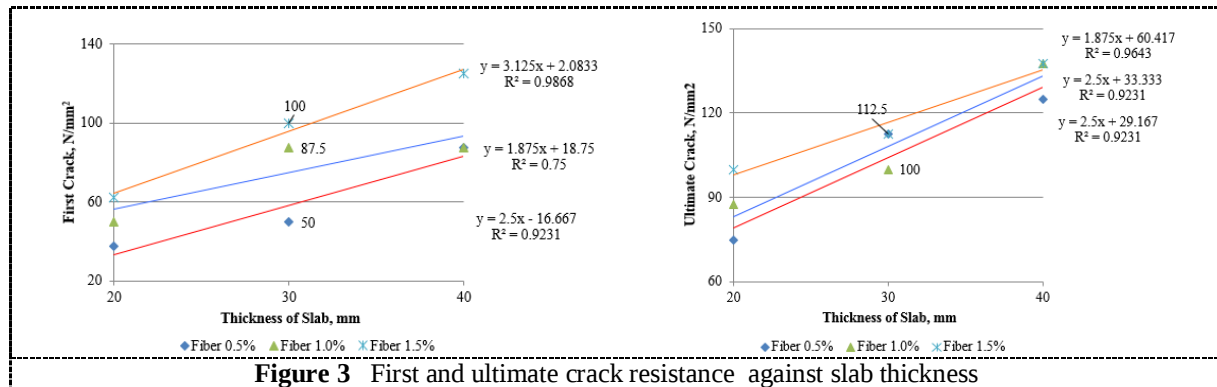


Figure 3 First and ultimate crack resistance against slab thickness

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 banana fiber content and the slab thickness are obtained.
- The slab with thickness of 40 mm and fibre content 1.5% show the best performance in resisting impact load for service and ultimate loading.

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