Effect of Mesh Distribution on Impact Resistance Performance of Kenaf Fibre Reinforced Concrete

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Abstract. This paper investigates the effect of the mesh distribution on the impact performance of kenaf fibre mesh reinforced concrete (KFMRC) for the concrete slab of 300mm x 300mm size reinforced with varied thickness and mesh diameter 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 objective of this research is to study the effect of the mesh distribution on the impact resistance kenaf fibre mesh concrete for various slab thickness and mesh diameter. 2-layers one Top and one Bottom mesh distribution kenaf mesh is the most efficient in the ability to control crack formation and propagation against impact energy followed by 1-layer Middle mesh distribution and lastly the 1-layer Top mesh distribution is the least effective.

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 a lack of research investigation been carried out on kenaf fibre mesh reinforced concrete (KFMRC) and the effect of the fibre distribution on the impact resistance. 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 m/s⁻¹, 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]. The tensile properties of kenaf fibers for various condition of chemical fiber surface modifications has been studied by Mahjoub Reza et al. [4]. 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 the crack resistance regardless of its fiber length with a potential to be used as an impact resistance composite structures in the future [6].
The objective of this research is to study the effect of the mesh distribution on the impact resistance kenaf fibre mesh concrete.

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 1a shown a typical mesh arrangement at a constant spacing of 50 mm and placed in either 1-layer at the top only , 1-layer at mid-depth only and 2-layers one at top & one at bottom 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/m³) | Fine Aggregates (kg/m³) | Course Aggregates (kg/m³) | Water/cement Ratio | Slump (mm) | Compressive Strength (N/mm²) |
|----------------|-------------------------|----------------------------|--------------------|------------|-------------------------------|
| 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.

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];

\[ R_u = \frac{(N*e)}{(l_c*d_c*w_c)} \quad \text{(3.1)} \]

\[ \text{Impact energy (Resistance)} = N*e = N*m*g*h \quad \text{(3.2)} \]

Where, \( N \) = No. of Blows, \( e \) = Energy per blow (Joules), \( l_c \) = Total length of all cracks (mm), \( d_c \) = Maximum crack depth (mm), \( w_c \) = Maximum crack width (mm), \( R_u \) = Crack resistance, \( m \) = mass of ball (kg), \( g = 9.81 \text{m/s}^2 \), \( h \) = height of impact (mm).

A total of 108 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.
The following mesh distribution were investigated to study its impact on service (first) and ultimate (failure) crack resistance.

i. 1-layer top mesh  ii. 1-layer mid depth mesh  iii. 2 layers one at top and one at bottom

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 Relationship between Crack Resistance and Kenaf Mesh Distribution

Figure 2, Figure 3 and Figure 4 indicate 2-layers one Top & one Bottom mesh distribution kenaf mesh is the most efficient in the ability to control crack formation and propagation against impact energy followed by 1-layer Middle mesh distribution and lastly the 1-layer Top mesh distribution.

The crack resistance of 50 mm thick slab, 7 mm diameter for 2-layers one Top & one Bottom mesh arrangement increase by up to 1.31 times for first crack and up to 1.89 times for ultimate crack against 1-layer Middle distribution and increase by up to 1.47 times for first crack and up to 2.27 times 1-layer Bottom only mesh distribution. Whilst the 1-layer Middle only mesh distribution arrangement increase by up to 1.12 times for first crack and up to 1.21 times for ultimate crack against 1-layer Top mesh distribution.

The highest service crack of 62.84 N/mm² and ultimate crack resistance of 246.65 N/mm² is observed for 2-layers one Top & one Bottom mesh arrangement with 50 mm slab thickness and 7 mm mesh diameter whilst lowest service crack of 4.59 N/mm² and ultimate crack resistance of 14.63 N/mm² is observed for 1-layer Top mesh arrangement for 30 mm slab with 3 mm diameter mesh. The first crack resistance value indicate the initiation the first crack and the ultimate crack resistance value indicate the ultimate failure modes with its fracture zones.

![Figure 2](image1.png)

**Figure 2** First and Ultimate Crack Resistance of Top, Middle and Top & Bottom Mesh Distribution for 30 mm Thick Slab

![Figure 3](image2.png)

**Figure 3** First and Ultimate Crack Resistance of Top, Middle and Top & Bottom Mesh Distribution for 40 mm Thick Slab
2-layers one Top & one Bottom mesh distribution is the most efficient as compared to 1-layer Middle mesh and 1-layer Top distribution in 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. 1-layer Top mesh arrangement with 30 mm thick slab or 3 mm mesh diameter is the least efficient configuration to control service and ultimate crack resistance against impact energy.

5. Conclusion

The following conclusions can be derived from the experimental results;

- 2-layers one Top & one Bottom mesh distribution kenaf mesh is the most efficient distribution followed by 1-layer Middle mesh distribution and lastly the 1-layer Top mesh distribution which is the least effective.
- 2-layers one Top & one Bottom mesh arrangement has a first crack and ultimate crack resistance by 1.47 times and 2.27 times respectively against 1-layer Top mesh Middle distribution for 50 mm thick slab and 7 mm diameter mesh.
- 1-layer Middle mesh distribution has a first crack and ultimate crack resistance by 1.12 times and 1.21 times respectively against 1-layer Top mesh Middle distribution for 50 mm thick slab and 7 mm diameter mesh.
- The threshold (highest) values for service crack is 62.84 N/mm² and ultimate crack resistance is 246.65 N/mm² observed for 2-layers one Top & one Bottom mesh distribution.

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