Impact Resistance Behaviour of Light Weight Rice Husk Concrete with Bamboo Reinforcement

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Abstract. This paper investigate the performance of lightweight rice husk concrete (LWRHC) with varied bamboo reinforcement content for the concrete slab of 300mm x 300mm size reinforced 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 0.65 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 bamboo reinforcement and slab thickness. A linear relationship has been established between first and ultimate crack resistance against bamboo diameters and slab thickness by the experiment. The linear relationship has also been established between the service (first) crack and ultimate crack resistance against the bamboo reinforcement diameter and slab thickness. 5\% RH content exhibit better first and ultimate crack resistance up to 1.80 times and up to 1.72 times respectively against 10\% RH content.

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. There is lack of research investigation been carried out on impact resistance of light weight rice husk concrete. 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. The review paper on impact resistance on concrete target has been published by Q.M. Li et al. [2]. 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 [3].

The objectives of this research are:

i. To establish relationship between impact resistance against diameter of bamboo reinforcement.

ii. To establish a relationship between impact resistance against slab thickness.
2. Materials and Test Set-up.

Buloh kuning (*Bambusa vulgaris* Schrad) is used to prepare the bamboo reinforcement material. The bamboo are splice and cut into the required diameters of 2.5 mm, 5 mm and 7.5 mm diameter and tied to form a mesh at a constant spacing of 50 mm.

Rice husk (RH) is taken from the rice production mill in Sarawak. Thus out of the 2.2 Million tons of paddy available in Malaysia (2007 statistics), 121 thousand tons of rice husk ash can be produced. This huge renewable resource should not be wasted and if not used poses disposal problems [4].

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 concretes are 0.6 Water/Cement ratio and 2.0 Sand/Cement. There are two different RH/Cement ratios were used in the mix designed; 0.05 RH/Cement ratios and 0.10 RH/Cement ratios. The compressive strength and density of these mix design at 28 days are as shown in Table 1.

| RH Content (%) | Density (kg/m³) | Compressive Strength (N/mm²) |
|----------------|-----------------|-----------------------------|
| 5              | 1940            | 23.6                        |
| 10             | 1728            | 17.9                        |

The above results comply with the category 3-Structural light weight as classified by the American Concrete Institute (ACI) Committee.

The study used a self-fabricated low velocity drop-weight impact test shown in Figure 1 using a steel ball weighing 1.236 kg with drop height of 650mm 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. A total of 33 test sample slabs of size 300mm x 300mm with 30 mm, 40mm and 50mm thickness were casted and tested which is consist of 6 control samples and 27 samples with bamboo reinforcement.

![Figure 1 (a) Bamboo Reinforced RH mortar](image-a) ![Figure 1 (b) Low-velocity Drop-weight Impact Test Rig](image-b)

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];

\[ N \times e = R_u \times l_c \times d_c \times w_c \]

(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
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 Bamboo diameter

The relationship of impact resistance against bamboo diameter are as shown in Figure 2 and Figure 3. Generally the first and ultimate crack resistance increases with increasing diameter. For 5% RH, with the given thickness, crack resistance increase by up to 1.43 times for first crack and up to 1.24 times for ultimate crack as the bamboo diameter increases. For 10% RH, crack resistance increase by up to 1.53 times for first crack and 1.58 times for ultimate crack as the bamboo diameter increases for the given thickness.

Generally, a good linear correlation between the first and ultimate crack resistance against the bamboo diameter is obtained from the graphs.

Figure 2 First and Ultimate Crack Resistance against Bamboo Diameter for 5% RH Content

![Figure 2](image)

Figure 3 First Crack and Ultimate Crack Resistance against Bamboo Diameter for 10% RH Content

![Figure 3](image)

4.2 Relationship between Crack Resistance and Slab Thickness

There is a linear relationship between the crack resistance and slab thickness as shown in Figure 4 and Figure 5. Increase in crack resistance is more substantial as the thickness increases as compared to the increases in the diameter. For 5% RH, with the given bamboo diameter, the first crack resistance increase up to 3.09 times and 2.8 times for ultimate crack resistance as the slab thickness increases. For 10% RH, with the given bamboo diameter, the first crack resistance increase up to 3.9 times and 3.32 times for ultimate crack resistance. Thickness of the slab has more effect on the crack resistance as compare to the diameter of the bamboo reinforcement. Generally, a good linear correlation between the first and ultimate crack resistance against the thickness is obtained from the graphs.
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 bamboo diameter.
- For 5% RH, crack resistance increase by up to 1.43 times for first crack and up to 1.42 times for ultimate crack with the increase in bamboo diameter for 30 mm slab thickness. For 10% RH, crack resistance increase by up to 1.77 times for first crack and 1.58 times for ultimate crack as the bamboo diameter increases for 30 mm slab thickness.
- For 5% RH, the first crack resistance increase by up to 3.09 times and 2.8 times for ultimate crack resistance with the increase in the slab thickness for 2.5 mm bamboo diameter. For 10% RH, with the given bamboo diameter, the first crack resistance increase up to 3.9 times and 3.32 times for ultimate crack resistance

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] Q. M. Li, S.R. Reid, H.M. Wen, A. R. Telford, Local impact effects of hard missiles on concrete targets. International Journal of Impact Engineering, Volume 32, August 2005.
[3] 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.
[4] Jha, J.N. and K.S. Gill Effect of rice husk ash on lime stabilization. J. Inst. Eng., 2006,87: 33-39.
[5] CK Kankam . Impact Resistance of palm kernel fibre-reinforced concrete pavement slab. J Ferrocement 1999;29(4):279-86. Oct