The Effect of Thickness and Mesh Spacing on the Impact Resistance of Ferrocement Slab

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Abstract. This paper investigates the effect of the thickness and mesh spacing on the impact of ferrocement for the concrete slab of 300mm x 300mm size reinforced 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 height of 150 mm, 350mm, and 500mm has been used in this research work. The objective of this research is to study the relationship of impact resistance of ferrocement against slab thickness and mesh reinforcement spacing. There is a good linear correlation between impact resistance of ferrocement against slab thickness and its mesh spacing. The first and ultimate crack impact resistance for 40 mm slab are 2.00 times and 1.84 times respectively against the 20 mm slab with the same mesh spacing. The first and ultimate crack impact resistance for 40 mm slab with 20 mm mesh spacing are 2.24 times and 3.70 times respectively against 50 mm mesh spacing with the same slab thickness. The mesh with higher content of reinforcement provides more contribution to the slab resistance as compare with the thickness.

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. Important structures such as vessels, dams, military defense structure, power plant and so on is very crucial to impact events as if the structure does not have enough impact resistance, it might cause serious lost in property, human life, and economic lost.

The fact that ferrocement has a good ability to resist impacts and damage occur in a localized region, Al-Rifaie proposes several applications of this composite material where conventional reinforced concrete can be replaced hence maximizing obvious economic advantages of ferrocement. The positive characteristics of ferrocement upon impact are its resistance against disintegration, damage occurs in localized fashion and damage is easy to repair [1]. The review paper on impact resistance on concrete target has been published by Z Che Muda et al [2]. The combination of mortar and steel mesh results in the composite ferrocement element. Throughout literature, it can be noted that ferrocement has favourable characteristics in impact, as collisions between boats or with rocks are numerous [3]. Ferrocement has high strength, crack resistance, high ductility and energy absorption characteristics, all useful to be used in a dynamic environment and application media [4]. The drop weight impact test which is recommended by the ACI Committee 544 [5] is the simplest method. Impact resistance of oil palm shells lightweight concrete slab reinforced with geogrid has been studied by Z Che Muda et al. indicate an impact resistance improvement for first and ultimate crack up to 5.9 times and 20.1 times against the control sample without geogrid [6].

The objective of this research is to study the impact on service (first) and ultimate (failure) crack resistance against the thickness and mesh spacing of ferrocement slab.
2. Materials and Test Set-up.

Ordinary Portland cement is complying to ASTM Type I cement. The square steel welded mesh as shown in Figure 1(a) has a 1 mm diameter with a spacing of 20 mm, 40 mm and 50 mm and the tensile strength of 450 MPa.

The properties of the fine aggregates used is in the cement mortar matrix was selected according to the ACI Committee 549, (1997). The sieve analysis of the sand shows that the different sand grain sizes are within the limit of a zone 2 of a well graded aggregate sizes with the fineness modulus was found to be 2.3.

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

**TABLE 1 Mix Design for Mortar**

| Cement (Part by weight) | Fine Aggregates (Part by Weight) | Water/cement Ratio | Slump Class to BS8500 (Range) | Compressive Strength (N/mm²) |
|------------------------|---------------------------------|-------------------|-------------------------------|-----------------------------|
| 1                      | 2                               | 0.50              | 180 mm Class S4 (160-210 mm) | 24.25                       |

The study used a self-fabricated low velocity drop-weight impact test rig is shown in Figure 1 (b) using a steel ball weighing 1.236 kg with drop height of 570 mm impacting the ferrocement slab of size 300mm x 300mm with a thickness of 20 mm, 30 mm, and 40 mm with ferrocement welded mesh of 1mm diameter @ 20mm, 40mm and 50 mm spacing. The test sample is mounted on the steel rack frame with 1-way simply supported and a test up procedure is given in Figure 1(c).

(a) Square Wire Mesh with 1 mm diameter with a spacing of 20mm, 40mm and 50mm
(b) Low-velocity Drop-weight Impact Test Rig (c) 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];

\[ N^*e = R_a^* l_c^* d_c^* w_c \]  \hspace{1cm} (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, \( R_a \) = Ultimate crack resistance

A total of 63 sample slabs of size 300mm x 300mm with 30 mm, 40 mm and 50 mm thickness were casted with at control (no fibre), 20mm, 40 mm and 50 mm spacing of 1 mm diameter welded mesh. Each set of data have 3 samples in order increase its accuracy and its average value taken. The wire mesh is place at mid-depth of the slab.
A drop height of 150 mm is used for control (no reinforcement) or thin slabs, 350 mm drop is for medium slab thickness and 500 mm drop height is used for thicker slab. The drop was targeted at the centre of the slab and for each drop the bottom surface - the tension zone - was checked for cracks.

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

4. Results and Discussion

4.1 Crack Resistance for Control Samples

The service (first) and ultimate crack resistance are shown in Table 2. The crack resistance increases with the increase in thickness.

| Control Sample No | 25M/20T/0R | 25M/30T/0R | 25M/40T/0R |
|-------------------|------------|------------|------------|
| Thickness of Control Sample | 20 mm | 30 mm | 40 mm |
| Service Crack Resistance | 22.62 N/mm² | 56.08 N/mm² | 91.43 N/mm² |
| Ultimate Crack Resistance | 30.16 N/mm² | 84.12 N/mm² | 109.72 N/mm² |

4.2 Relationship between Crack Resistance and Slab Thickness

There is a good linear correlation for service and ultimate crack resistance against its thickness as shown in Figure 2 with a minimum $R^2=0.97644$. As the slab thickness increases, the service and ultimate crack resistance increases proportionally.

The highest value of first crack and ultimate crack resistance obtain is 147.36N/mm² and 405.23N/mm² respectively for 40 mm thick slab with 20 mm mesh spacing. The first crack and ultimate crack impact resistance for 40 mm slab with 20 mm mesh spacing are 2.00 times and 1.84 times respectively against the sample 20 mm slab with the same mesh spacing and 1.61 times and 3.69 times respectively as against its control sample 25M/40T/0R.

4.3 Relationship between Crack Resistance and Mesh Aperture Spacing

There is a good linear correlation for service and ultimate crack resistance against its mesh spacing (aperture) as shown in Figure 3 with a minimum $R^2=0.9574$. The highest value of first crack and ultimate crack resistance obtain is 147.36N/mm² and 405.23N/mm² respectively for 40 mm thick slab with 20 mm mesh spacing. The first crack and ultimate crack impact resistance for 40 mm slab with 20 mm mesh spacing are 2.24 times and 3.70 times respectively against the sample 20 mm slab with the same mesh spacing and 1.61 times and 3.69 times respectively as against its control sample 25M/40T/0R.
5. Conclusion

The following conclusions can be derived from the experimental results:
- There is a good linear correlation with minimum $R^2 = 0.97644$ between the crack resistance and slab thickness.
- There is a good linear correlation for service and ultimate crack resistance against its mesh spacing (aperture) with a minimum $R^2 = 0.9574$.
- The first crack and ultimate crack impact resistance for 40 mm slab with 20 mm mesh spacing are 2.00 times and 1.84 times respectively against the 20 mm slab with the same mesh spacing.
- The first crack and ultimate crack impact resistance for 40 mm slab with 20 mm mesh spacing are 2.24 times and 3.70 times respectively against 50 mm mesh spacing the slab with the same thickness.
- There is no significant gain of first crack and ultimate crack resistance for large 50 mm mesh spacing.
- The mesh with the smallest spacing of 20 mm provides more contribution to the impact resistance than the slab thickness.

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