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The Effect of Mortar Grade and Thickness on the Impact Resistance of Ferrocement Slab

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Abstract. This paper investigate 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 the mortar grade and slab thickness. There is a good linear correlation between impact resistance of ferrocement against the mortar grade and the thickness of ferrocement slab. The first and ultimate crack impact resistance of mortar grade 43 (for 40 mm thick slab with mesh reinforcement) are 1.60 times and 1.53 times respectively against the mortar grade 17 slab (of same thickness with mesh reinforcement). The first and ultimate crack impact resistance for 40 mm thick slab (mortar grade 43 with mesh reinforcement) are 3.55 times and 4.49 times respectively against the 20 mm thick slab (of same mortar grade with mesh reinforcement).

1. Introduction

In the search of sustainable green materials, it is critical to study the impact strength characteristics of such construction materials for various potential uses in the building industry. Important structures such as vessels, dams, military defense structure and power plant is very crucial to impact loads to prevent the serious lost in property, human life, and economic lost.

Ferrocement has a good ability to resist impacts and damage occur in a localized region, where it could be easily 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 first and ultimate crack resistance against the mortar grade and the thickness of ferrocement slab.

2. Materials and Test Set-up.

Ordinary Portland cement used in this work 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 and the tensile strength of 450 MPa.

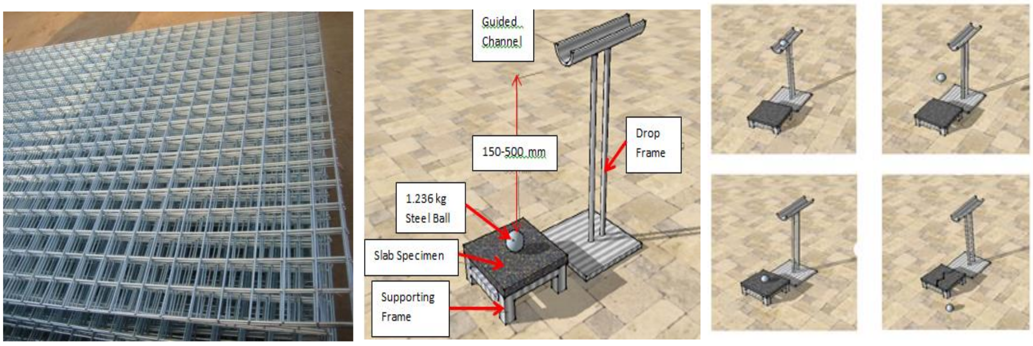
The properties of the fine aggregates used is in the cement mortar matrix was selected according to the ACI Committee 549, (1997). The sieve analysis of the sand shows that the different sand grain sizes are within the limit of a zone 2 of a well graded aggregate sizes with the fineness modulus was found 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	3	0.6	Class S3 (160-210 mm)	16.6
1	2	0.50	Class S3 (160-210 mm)	24.3
1	1	0.35	Class S4 (100-150 mm)	43.1

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 150 mm, 350mm and 500mm 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. 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) (b) (c)

Figure 1.
(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];

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

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 nine (9) sets for each slab of size 300mm x 300mm of mortar grade 16.6, 24.3 and 43.1 having 30 mm, 40 mm and 50 mm thickness with mesh reinforcement and nine (9) sets of control (no mesh reinforcement) for each grade and thickness were casted for 28 day curing strength. Each set of data have 3 samples in order increase its accuracy and its average value taken. The 1 mm diameter at 20 mm spacing wire mesh reinforcement 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 and ultimate crack, the total crack length, the crack width and its depth are measured with its total numbers of blows recorded.

4. Results and Discussion

4.1 Crack Resistance for Control Samples

The first and ultimate crack resistance for the control sample are shown in Table 2. The crack resistance increases with the increase in mortar grade and thickness. The first and ultimate crack impact resistance of mortar grade 43 control sample are up to 4.93 times and 5.82 times respectively against mortar grade 17 control sample of the same thickness.

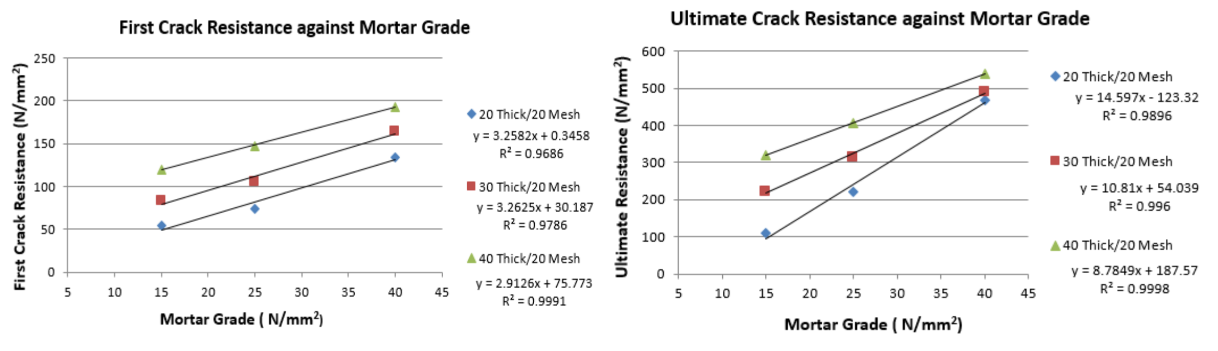
Table 2. First and Ultimate Crack Resistance of Control Sample (without Mesh Reinforcement)

Mortar Grade N/mm²		16.6			24.3			43.1	
Thickness of Control Sample (mm)	20	30	40	20	30	40	20	30	40
First Crack Resistance N/mm²	7.31	21.01	31.2	22.62	56.08	91.43	36.08	67.02	101.95
Ultimate Crack Resistance N/mm²	10.84	22.15	34.81	24.10	45.06	68.28	63.09	100.91	150.25

4.2 Relationship between Crack Resistance and Mortar Grade

There is a good linear correlation for service and ultimate crack resistance against its thickness as shown Figure 2 with a minimum R^2=0.9886. As the mortar grade increase, the service and ultimate crack resistance increases proportionally. The ultimate crack resistance values are converging as the mortar grade increases for the different thickness of slab.

The highest value of first and ultimate crack resistance obtain is 192.77 N/mm^2 and 539.75 N/mm^2 respectively for the grade 40 mortar with 40 mm thick slab. The first and ultimate crack impact resistance of mortar grade 43 of 40 mm thick slab with mesh reinforcement are 1.60 times and 1.53 times respectively against the mortar grade 17 slab of same thickness with mesh reinforcement. The gain in the service crack resistance gain is very significant as the mortar grades increases for each slab thickness, however the ultimate crack resistance values are converging as the mortar grade reach 40 regardless of its thickness. The ultimate resistance values indicate no significant gain at higher mortar grade of 43 with mesh reinforcement.

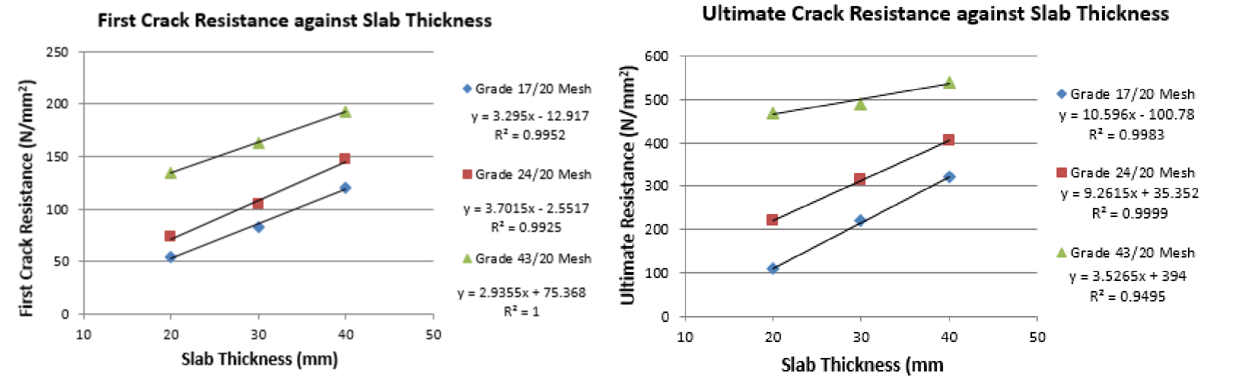


(a) First Crack (b) Ultimate Crack

Figure 2 First and Ultimate Crack Resistance Against Mortar Grade

4.3 Relationship between Crack Resistance and Slab Thickness

There is a good linear correlation for service and ultimate crack resistance against its thickness as shown Figure 3 with a minimum R^2=0.9495. The highest value of first crack and ultimate crack resistance obtain is 192.77 N/mm^2 and 539.75 N/mm^2 respectively for 40 mm thick slab with 20 mm mesh spacing. The first crack and ultimate crack impact resistance for 40 mm slab (mortar grade 43) with 20 mm mesh spacing are 3.55 times and 4.49 times respectively against the sample 20 mm slab (mortar grade 43) with the same mesh spacing. The first crack and ultimate crack impact resistance for 40 mm thick control sample for mortar grade 40 are 2.83 times and 2.38 times respectively against the control sample 20 mm thick slab of the same grade.



(a) First Crack (b) Ultimate Crack

Figure 3 First and Ultimate Crack Resistance Against Slab Thickness

5. Conclusion

The following conclusions can be derived from the experimental results;

- There is a good linear correlation with minimum R^2= 0.9886 between the crack resistance and mortar grade of the slab.
- There is a good linear correlation for service and ultimate crack resistance against the slab thickness with a minimum R^2=0.9495.
- The highest value of first crack and ultimate crack resistance obtain is 192.77 N/mm^2 and 539.75 N/mm^2 respectively for 40 mm thick slab with 20 mm mesh reinforcement spacing.
- The first and ultimate crack impact resistance of mortar grade 43 for control sample are up to 4.93 times and 5.82 times respectively against the mortar grade 17 control sample of the same thickness.
- The first and ultimate crack impact resistance of mortar grade 43 (for 40 mm thick slab with mesh reinforcement) are 1.60 times and 1.53 times respectively against the mortar grade 17 slab (of same thickness with mesh reinforcement).
- The first and ultimate crack impact resistance for 40 mm thick slab (mortar grade 43 with mesh reinforcement) are 3.55 times and 4.49 times respectively against the 20 mm thick slab (of same mortar grade with mesh reinforcement).

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