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論 文

[1085] A Study of Strength and Cracking Behavior of Ferrocement in Tension

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1. INTRODUCTION

Ferrocement is a composite structural material comprising a cement mortar matrix highly reinforced with layers of small diameter wire mesh uniformly distributed throughout a cross section of thickness not normally exceeding 50 mm. The arrangement of the reinforcement is such that the material exhibits behavior which is different from conventional reinforced concrete in strength, deformation and potential applications. Ferrocement began to be used in developed countries not only in boat industry, but also in submarine structures, shell structures, cylindrical silos, Sewer linings, water tanks, roof modules, pipes and irrigation conducts, and low cost housing. Several investigators have studied the behavior of ferrocement specimens in tension Naman[1], Walkus[2] and Johnston[3]. But little efforts have been done to investigate the effect of arrangement of mesh reinforcement and mortar cover on the cracking behavior of ferrocement sections under tensions. In this study these effects have been taken in to account and Six different arrangements, as shown in figure.1 have been adopted and tests were carried out in direct tension.

2. EXPERIMENTAL PROCEDURES

2.1 MATERIALS AND MIXING PROPORTIONS

The mortar matrix consisted of ordinary portland cement complying with BS 12 and wet river sand passed through a no.7 sieve, free from any deleterious substances. Grading of the sand was controlled in such a way that it would conform with the British Standard no. 882:1983. Table 2.1 shows the sieve analysis results of the sand.
The sand to cement and water to cement ratios by weight were, 2 and 0.4 respectively. To improve workability and also achieve a high strength with a very substantial reduction in the water/cement ratio, a superplasticizer of 0.8% of weight of cement was used. 0.5% of chromium trioxide was added to the water prior to the mixing to stop any reaction between the zinc and the cement which can produce hydrogen bubbles.

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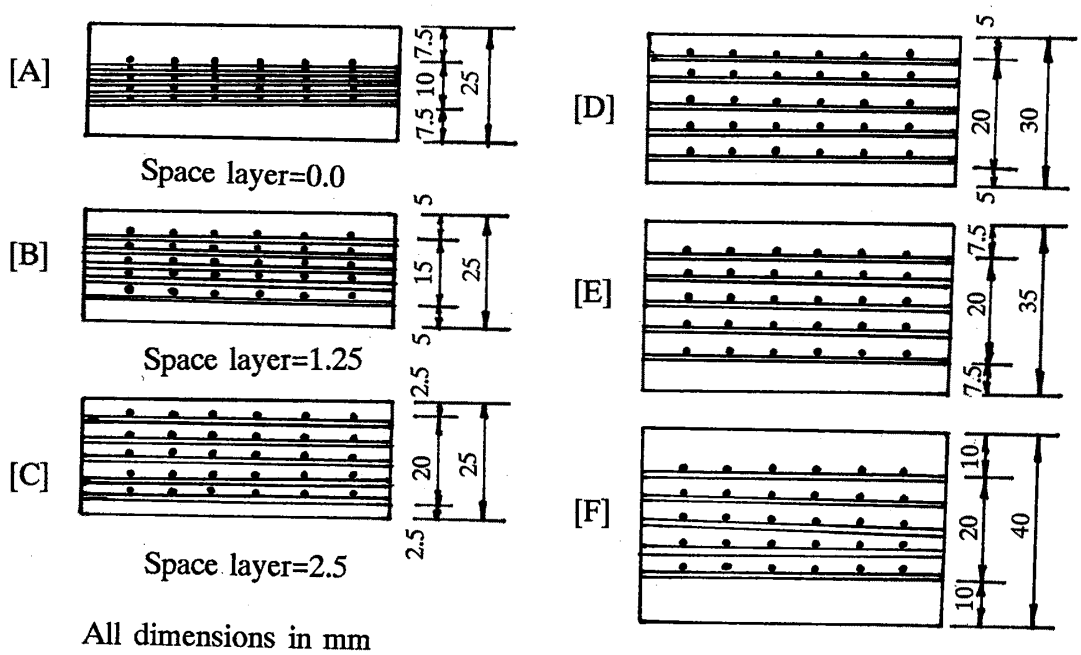
The reinforcing wire mesh used for all tests was of the square welded type having a wire diameter of 1mm and a mesh opening size of 10.5mm.

Table 2.1 *Sieve analysis results for the sand*

B.S. sieve size	Sieve opening	Percentage
7.00	2.36mm	100
14.0	1.20mm	75
25.0	600 μm	50
50.0	300 μm	25
100.0	150 μm	1.0



Specimen A bundling all the wire mesh layers at center and specimens B and C placing the wire mesh evenly across the cross section.
Specimens D, E and F placing of the wire mesh evenly across the cross section (space layer=2.5mm)

Figure 1 Details of reinforcement arrangements

2.2 TEST PROGRAM AND SPECIMEN PREPARATIONS

Two different sets of specimens were cast for each series of ferrocement specimens, the first set consisted of three mortar cubes of 100 mm sides which were cast for the purpose of quality control, and five dog bone shape specimens for monitoring tensile strength of mortar. For second set of specimens (Tension specimens) they were cast in plywood molds consisting of a base and two separable sides, 25 mm thick for specimen series A, B, and C. special steel molds with uniform thickness of 50 mm were designed for specimens D, E and F. A great deal of work was involved in preparing the specimens, especially in cutting the wire mesh and tightening them to gather in order to ensure even spacing between each layer of the mesh. The spacing between each layer was controlled by spacers made from wire mesh of the same quality used for the main reinforcement.

After 28 days the specimens were removed from the curing tank and prepared for testing. A center line of each face of the specimen was marked. lines were also marked at 100mm above and below the center line, and marked by the letters as shown in figure 2.1 This was done in order to facilitate crack location during the specimens, testing . This study concentrated on the area AEBF (face A) and CGDH, on the opposite face (face B). Demec points were stuck to the specimen at the above points in order to measure the elongation due to the increments of the load. After each increment of load the surface of the specimen was scanned to define the position of cracks and count the number of cracks and measure the number of maximum crack width within the central 200mm section using a hand held graduated microscope equipped with a micrometer. All dog boned shaped plain mortar specimens were tested in direct tension in accordance with the BS 12, part 2: 1971. Shape of specimens are shown in figures 2.1 and 2.2 .

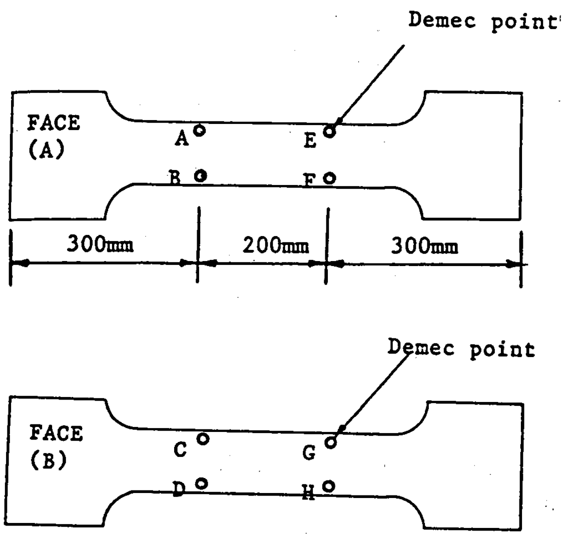


Figure 2.1 ferrocement tensile specimen

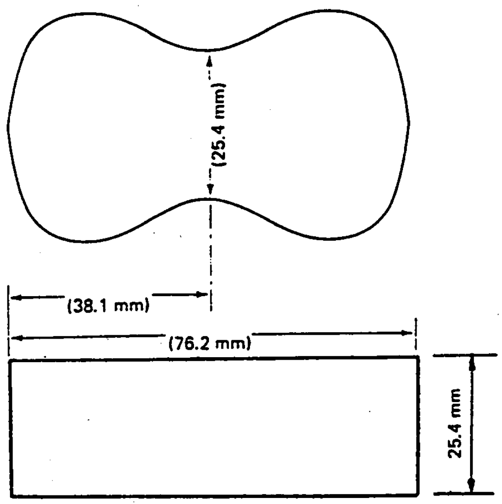


Figure 2.2 Plain mortar specimen

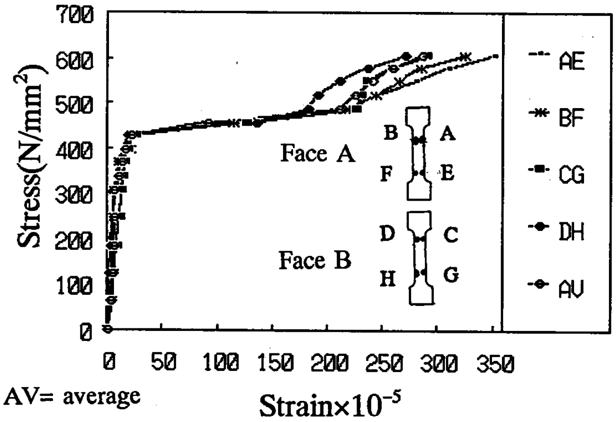
3. DISCUSSION OF RESULTS

3.1 COMPOSITE STRESS STRAIN CURVE

From experimental data stress strain curves were plotted and typical of these stress strain curve is shown in figure 3.1, from this figure three stages of cracking behavior(Pre cracking , Multiple cracking and Crack widening stage). was observed as expected. (This observation has also been reported by other researchers before).
From results of tensile tests on wire mesh, figure 3.2 ,it was observed that the yield stress of wire mesh used is about 685N/mm^2. and the young modulus is about 205 KN/mm^2.

The significant effect of the reinforcement arrangement on the cracking behavior is clear from the results of the tests shown in figure 3.3 , from this figure it can be seen that the crack width increases as the arrangement of reinforcement was changed from evenly distributed to bundled and placed them at the center of the specimens, For example for load of 15 KN the average maximum crack width for specimens A, B, C are 145, 115 and 20 micron respectively. Therefore, the most important advantage of evenly distributed –

reinforcement (specimens C) in comparison with center arrangement is the improved crack control (ie. smaller crack width) and hence durability. This is useful for water retaining structures as the crack width should be limited to the minimum possible. The result is similar to the result obtained by Paramasivam[5].



AV= average

Figure 3.1 Stress strain curve of Ferrocement specimen.

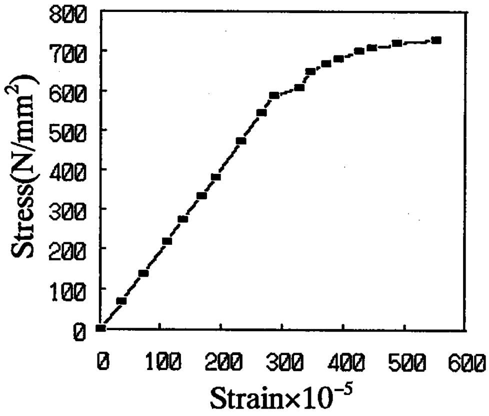
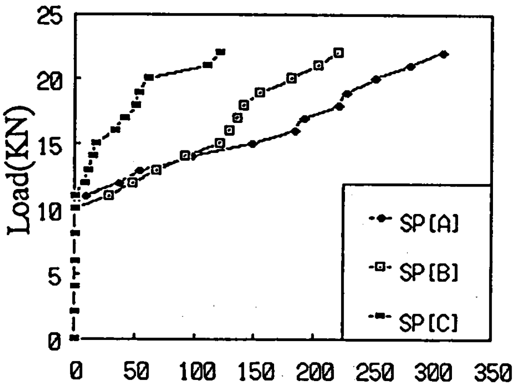


Figure 3.2 Stress strain curve of Wire mesh.

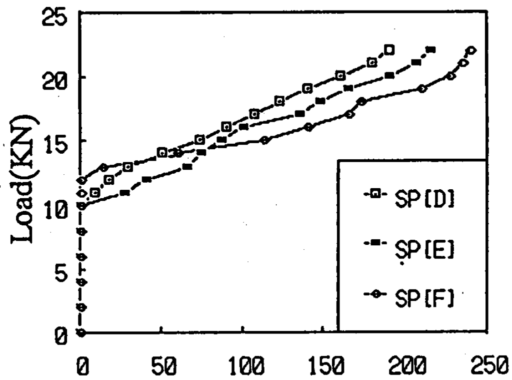
3.2 SPECIMEN THICKNESS AND MORTAR COVER

There is a direct relationship between specimen thickness and specific surface. An increase in thickness of specimen, causes a decrease in volume fraction. It was observed that, as the volume fraction and specific surface of reinforcement decreases, the maximum crack width increases. This effect becomes more apparent from figure 3.4 which show that for an applied load of 15 KN, the maximum crack width for longitudinal specific surface of 0.044/mm is about 75 microns. This increases to a value nearly 90 and 110 for longitudinal specific surface of 0.037/mm and 0.033/mm respectively.



Max crack width inside test area (μm)

Figure 3.3 Load against maximum crack width for specimens A,B,C

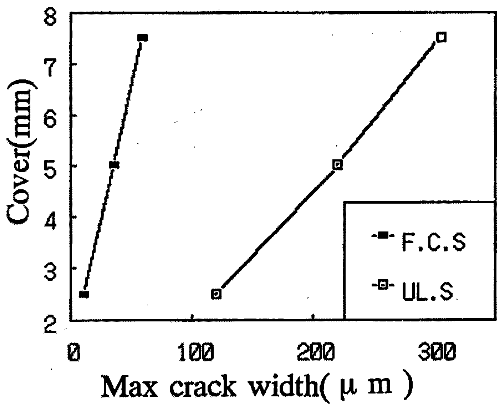


Max crack width inside test area(μm)

Figure 3.4 Load against maximum crack width for specimens D,E,F

μm= micron

Figures 3.5 and 3.6 illustrate the effect of mortar cover on the cracking behavior of composite specimens. It was observed that increasing the cover tends to decrease the number of small cracks and thus increases the maximum crack width. From these figures it can be seen that as the cover increased the maximum crack width also increased. from figure 3.5 it can also be seen that the change in maximum crack width at first crack for specimen A, B, C is not significant, while this change at failure stress is significant. It was also observed that the maximum crack width for specimen A at failure is 307 μm and this decrease to 220 and 120 for specimens B and C respectively. Figure 3.6 ,shows the number of cracks against applied load for specimen[B], it was found that the number of cracks increases as the reinforcement arrangement was changed from evenly distributed to the center arrangement.



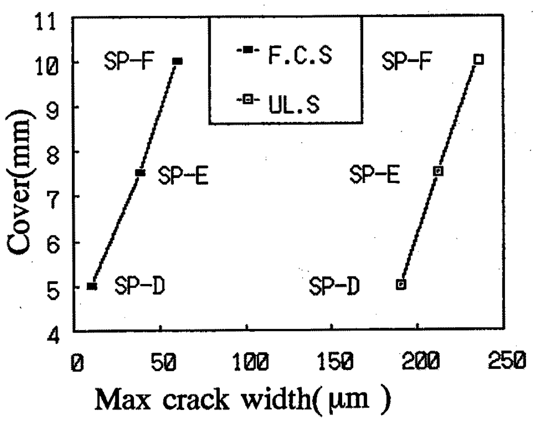


Fig 3.5 Fig 3.6

Figures 3.5 and 3.6 Average maximum crack width against cover

SP= Ferrocement specimen

F.C.S= First crack strength UL.S = Ultimate strength

Figure 3.7 ,shows the number of cracks against applied load for specimen[B], it was found that the number of cracks increases as the reinforcement arrangement was changed from evenly distributed to the center arrangement.

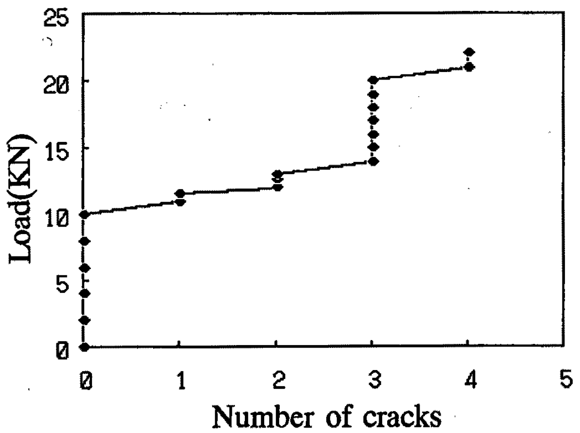


Figure 3.7 Load against number of cracks

4. CONCLUSIONS

An experimental program was carried out to study the effect of cover and arrangement of mesh reinforcement on the behavior of ferrocement in tension. From results of this experimental investigation, It is possible to draw the following conclusions.

1– It was observed that ferrocement having reinforcement evenly distributed with minimum cover, showed reduced crack width and an increased number of small cracks at failure compared with other arrangements of reinforcement.
2– The contributions of the tensile strength of the mortar and the specimen thickness on first crack strength is considered to be significant, while it can be considered negligible at ultimate strength.
3– It was observed that for specimens D, E and F the first crack strength increases as the specimen thickness and cover of wire mesh increases, but the ultimate strength decreases as the specimen thickness and cover of wire mesh increases.
4– An increase in specimen thickness results in a decrease in volume fraction and therefore specific surface. It was observed that as specimen thickness increases the number of small cracks decreases and the crack width increases.
5– The number of small cracks increased as the reinforcement arrangement was changed from evenly distributed to the center arrangement.
6– It was observed that for specimens D, E and F, deceasing the cover tends to increase the number of cracks and thus decreases crack width.

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