IMPACT ENERGY AND FLEXURAL STRENGTH CHARECTIRISTICS OF WIRE-MESH AND STEEL FIBRES FERROCEMENT ROOF PANELS

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ABSTRACT

One of the greatest humanitarian challenges today is that of providing safe, adequate and affordable shelter. This is more serious in poor nations of the world with increasing population. This research work is aimed at developing a roof ferrocement panel with locally available materials. Laboratory tests and procedures were used for the research work. Wire-mesh and 8mm mild steel fibers were used for the plate specimens. The impact energy test showed that 14,450 Joules of energy was needed for the panels reinforced with wire mesh to fail, while the panels reinforced with 8mm steel rod failed at 7,423 Joules. The total failure load on the panel reinforced with wire-mesh was 25 KN/m^2 and the ultimate design load is 2.23 KN/m^2. Observations of the failed plates showed that the width of cracks developed in the wire-mesh specimens were tinier than the ones in the steel fiber plate. The stress-strain curves show that the strain developed in wire-mesh specimens is about 52 percent higher than the 8mm steel fiber specimens.

Keywords: Ferrocement, Flexural Strength, Impact Energy, Roof Panel,

1. INTRODUCTION

Shelter is one of the basic needs of human being but more than 80 percent of people in developing countries suffer from housing shortages resulting from population growth, internal migration and natural disaster, etcetera (Divekar, 2011). Most houses in rural areas are made of cheap, local materials, examples low quality wood (which is easily attacked by termites), scrap metal, thatch or earth products like clay mud, sand, rock and stone which are often, temporary and unsafe. That is why there is an urgent need to explore a building material that is structurally efficient, at the same time, light, eco-friendly, cost-effective (Divekar, 2011).

Ferrocement can be seen as a thin reinforced concrete laminates, commonly constructed by hydraulic cement mortar reinforced with layers of continuous, relatively small size wire mesh. The conventional construction materials such as steel and concrete have exhibited signs of deterioration over the years in their long-term performance, which can be attributed to either the inherent nature of the materials or the weak resistance offered by materials to adverse environmental condition and natural disasters such as fire and earth quake (Masood, 2003). Shah (1974) defined Ferrocement as a composite made with mortar and a fine diameter continuous mesh as reinforcement, which has higher bond due to its smaller size and a larger surface area per unit volume of mortar. Ferrocement is a type of thin wall reinforced concrete, commonly constructed of hydraulic cement mortar, reinforced with closely spaced layers of continuous and relatively small wire diameter mesh. Mesh may be of metallic or other suitable materials (Kaushi, 20013).

In developing countries like Nigeria, the raw materials for ferrocement construction are easily available and also it could be constructed in any complicated shape. The skill required is of low level and it has superior strength properties as compared to conventional reinforced concrete (Waheed, 2003).

Ferrocement is considered easy to be produced in a variety of shapes and sizes such as shell roofs, swimming pools, tunnel linings, silos, tanks, pre- fabricated houses and thin panels or sections with less than 25 to 30mm thick. Ferrocement is very high in quality; they are pre-fabricated product, making it readily available. The main advantage of ferrocement is low cost, the low level of skills required for hull construction and reduced maintenance with increased resistance to rot and corrosion when compared to wood and steel. Ferrocement behaves like reinforced concrete in its load bearing capacity and characteristics, with the essential difference being that crack development is retarded by the dispersion of the reinforcement in fine form through the mortar. It has been established that when cracks take place, it results in a wide distribution of fine cracks and in combination with the high alkalinity of the cement rich mortar. The main disadvantage of ferrocements is its weight. However, these disadvantages only restrict the application of the material which can be checkmated and need not detract it from its potential uses (Divekar, 2011).

The use of ferrocement was first started as early as 1848. It took the form of a rowing boat constructed by Jean Louis Lambot. The boat is still in a remarkably good condition in a museum at Brigholes, France. This is the first made ferrocement to be used in the marine environment. Ferrocement gained wide acceptance in the early 1960s in United Kingdom, New Zealand and Australia (Biggs, 1968).

Ferrocement is particularly suited to developing countries for the following reasons (Kaushi, 2013);

i. its basic raw materials are available in most countries
ii. it can be fabricated into almost any shape to meet the needs of the user; traditional designs can be reproduced and often improved
iii. it is more durable than most woods and cheaper than imported steel, it can be used as a substitute for these materials in many applications
iv. the skills required for ferrocement construction are quickly acquired and include many skills which are locally available in developing countries. Ferrocement does not need heavy plant or machinery, it is labour intensive, and therefore, relatively inexpensive in developing countries, except for sophisticated and highly stressed designs, like deepwater vessels.
v. in case of damage it can be repaired easily.

A structure is subject to great deal of pounding, twisting and bending during its life time resulting in cracks and fractures unless sufficient steel reinforcement is introduced to absorb these stresses. The degree to which this fracturing of the structure is reduced depends on the concentration and dimension of the embedded reinforcement (Irans, 1987). Ferrocement possesses a degree of toughness and crack resistance that is considerably greater than that found in other forms of concrete construction. These properties are achieved in structures with a thickness that is generally less than 25–30mm, a dimension that is nearly unthinkable in other forms of concrete construction and a clear improvement over conventional reinforced concrete (Yousry, 2003).

Hago (2005) indicated that the stress level at which the first crack appeared and the crack spacing were a function of the specific surface of reinforcement. The ultimate load of the ferrocement specimen was the same as the load carrying capacity of the reinforcement in that direction. This should be expected since the load is carried by the reinforcement itself after the mortar has cracked. A typical stress-strain curve of ferrocement is shown in Figure 1.

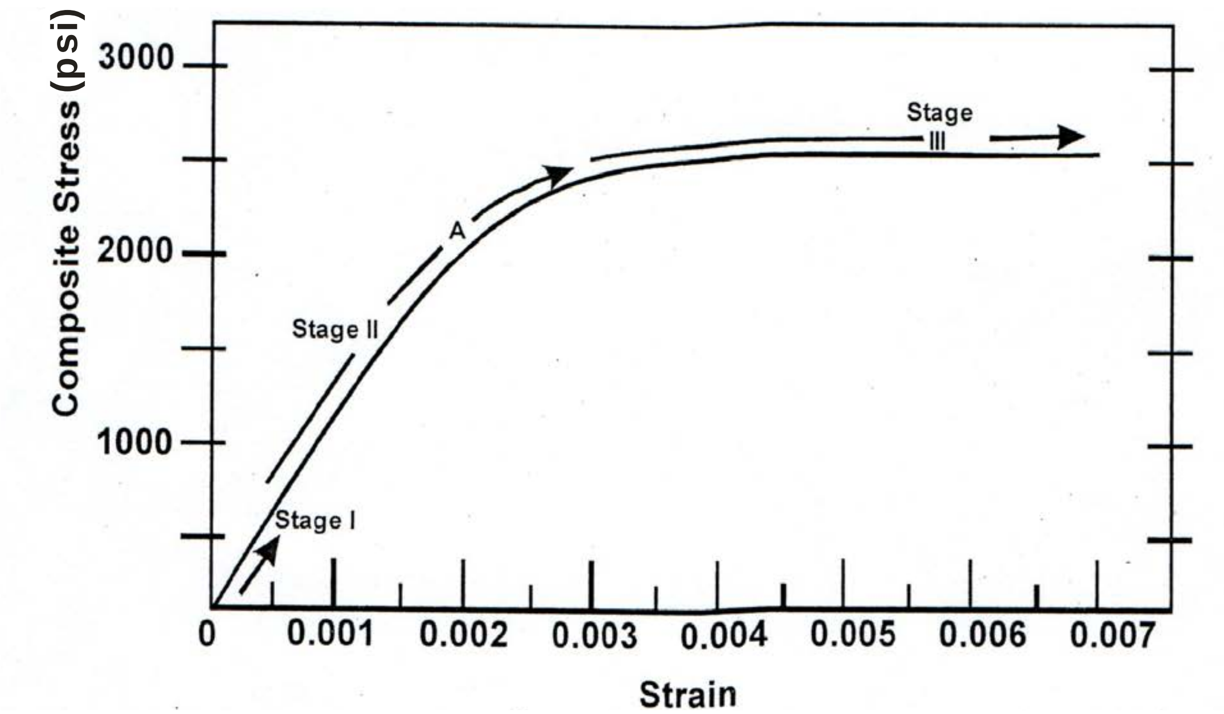

Figure 1: Stress-Strain Curve of a Ferrocement Panel (Source: *Hago*, 2005)

Shah (1984) tested 12mm thick ferrocement slabs using an impact tester. They concluded that the higher the specific surface of the mesh, the higher the strength of the mesh, and the lower the damage due to impact loading. A problem unique to ferrocement is potentially poor fire resistance because of the inherent small thickness of its structural form and the abnormally low cover given to the reinforcement (Ezzat and Yousry, 2003).

When ferrocement is exposed to aggressive environment, its successful performance depends on a great extent, on its durability against the environment than on its strength properties (Ezzat and Yousry, 2003).

2. MATERIALS AND METHOD

2.1 Materials

The materials used for the research work include steel wire-mesh (wire diameter of 0.75mm), 8mm mild-steel rods, Ordinary Portland cement (OPC), ‘fosroc’ admixture (an accelerator), River sand (River Benue sand) and pipe-borne water (from Civil Engineering Laboratory, Makurdi) and metal plate mould measuring 400x300x3mm (length, width and thickness respectively).

2.2 Methods

2.2.1 The Production of Reinforced Concrete Plates

The inside of the mould was coated with oil. The reinforcement was then placed in it. Mortar of 1:2 mixes at 0.4 water-cement ratios with a blend of the admixture was prepared manually. The concrete was then poured into the mould, and the wire-mesh adjusted to the centre of the mould. The compaction of the concrete was done with a hand trowel, in two layers. The concrete surface was then levelled and made smooth using the trowel. The concrete plate was removed from the mould after 24 hours and then covered with polythene sheet for another 24 hours. It was then transferred to curing tank in the laboratory. It was cured at room temperature, for 28 days. The same procedure was used for the production of the rest of the reinforced concrete plates.

2.2.2 Impact Test

The sketch of the arrangement of Impact Test set up is shown in Figure 3.1.

The impact test was carried out as follows; a 3kg steel ball was released from a height of 1200mm (1.2m) to the centre surface of the plate (specimen). This process was repeated until failure of the plate. The total number of bows (impact) which caused the appearance of the first visible crack(s) and failure of the plate were noted. This procedure was repeated for all the rest of the plates.

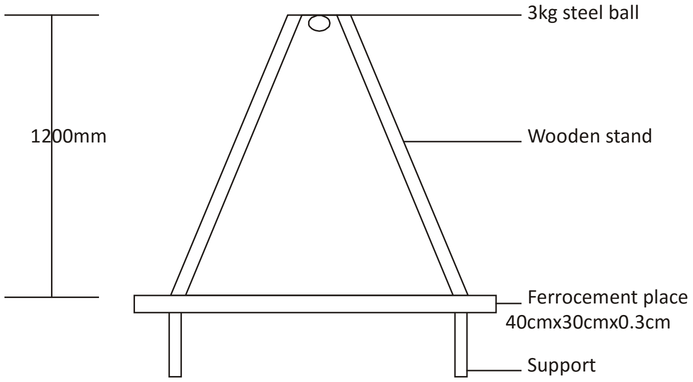

Figure 2.1: Impact Test Experimental Setup

The energy absorption value (E) is obtained by (Biggs, 1968):

E = NxWxH (joules) (1)

E is the energy in joules, W is weight in Newton, H is the drop in height in meters and N is number of blows (impact).

2.2.2 Flexural Stress

A concrete beam of size 150 x 150 x 500mm was reinforced with 0.75mm wire-mesh. The concrete ratio was 1:2:4 at 0.4 water-cement ratio. The same procedure was used to replicate 2 more of the beam specimens. Another three beams reinforced with 8mm mild steel bars were cast, using the same procedure. All the beam specimens were cured for 28 days then subjected to flexural test as prescribed by British Standard (BS) 1881: Part 118: 1983.

Flexural strength = $\frac{Pl}{bd^3}$ (2)

P is load, l is span length, b is width of beam and d is depth of beam.

3. RESULTS AND DISCUSSION

The results of Impact Energy tests on the plate specimens are shown on Table 3.1. The average energy absorbed by the wire-mesh ferrocement plates is about 94.7 percent higher than that of the 8mm steel rod ferrocement specimen. This result was buttressed by the earlier findings of Shah (1984). Higher energy absorption observed could be traced to wire-mesh in controlling the developed cracks. It is more ductile and elastic than the 8mm steel fibers. The difference in the crack magnitude is reflected in the failed plates shown in Plate 1. Figures 3.1 and 3.2 show the flexural stress-strain curves for the wire-mesh and 8mm steel ferrocement beams. As expected, the strain in the wire-mesh ferrocement specimens was higher than that in the 8mm steel ones. This is a major advantage of wire-mesh ferrocements. The members can easily be formed into any desired shape due its flexibility.

Table 3.1: Results of Impact Energy

Plate Type	Plate No.	N_1	N_2	E_1(Joules)	E_2 (Joules)
Wire-mesh	1	17	33	7428	14462
	2	16	31	7419	14438
	3	18	34	7422	14449
	Mean	17	33	7423	14450
8mm-steel	4	11	18	4080	7428
	5	12	17	4160	7423
	6	11	17	4120	7418
	Mean	11	17	4120	7423

Key:

N_1 is number of blows at first crack; N_2 is number of blows at failure

$E_1$and E_2 is impact energy at first crack and failure respectively.

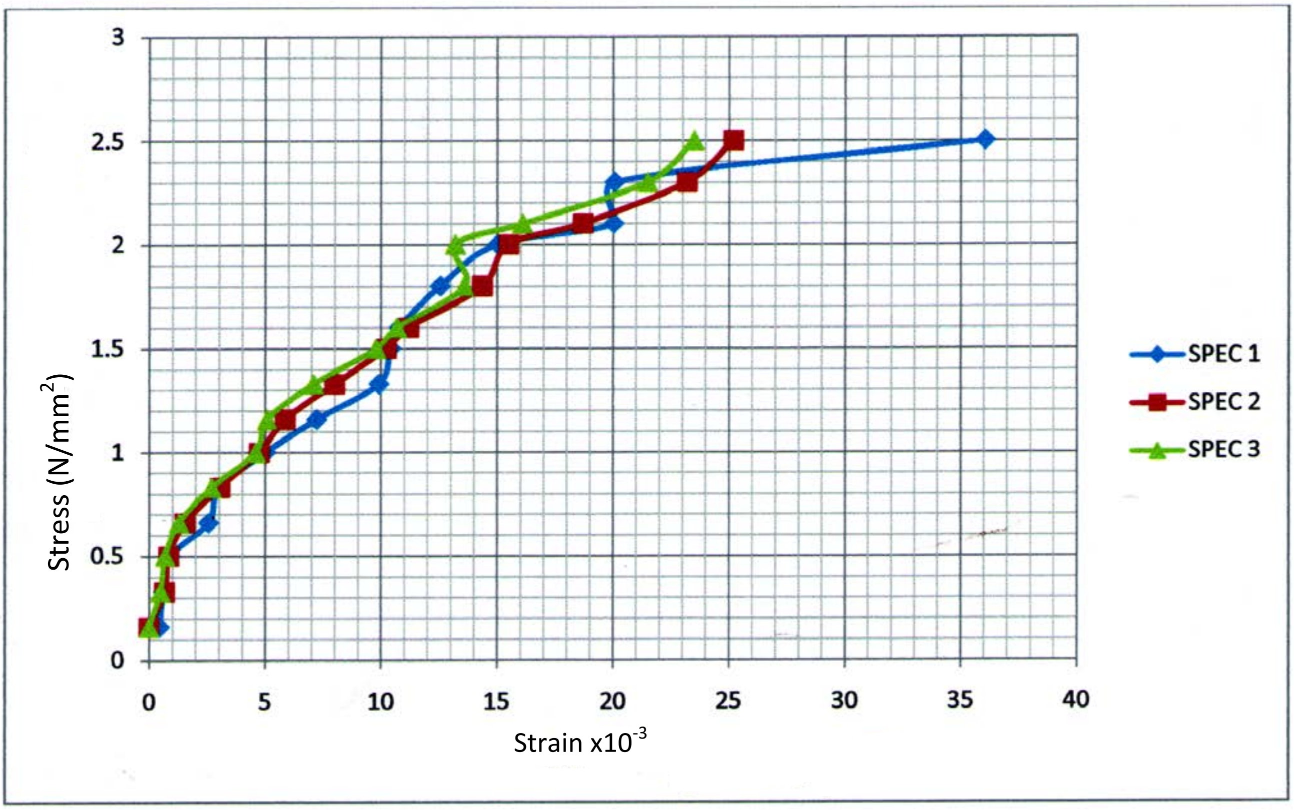

Figure 3.1: Flexural Stress versus Strain (0.75mm wire-mesh reinforced beams)

International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-6,June 2016
ISSN: 2395-3470
www.ijseas.com

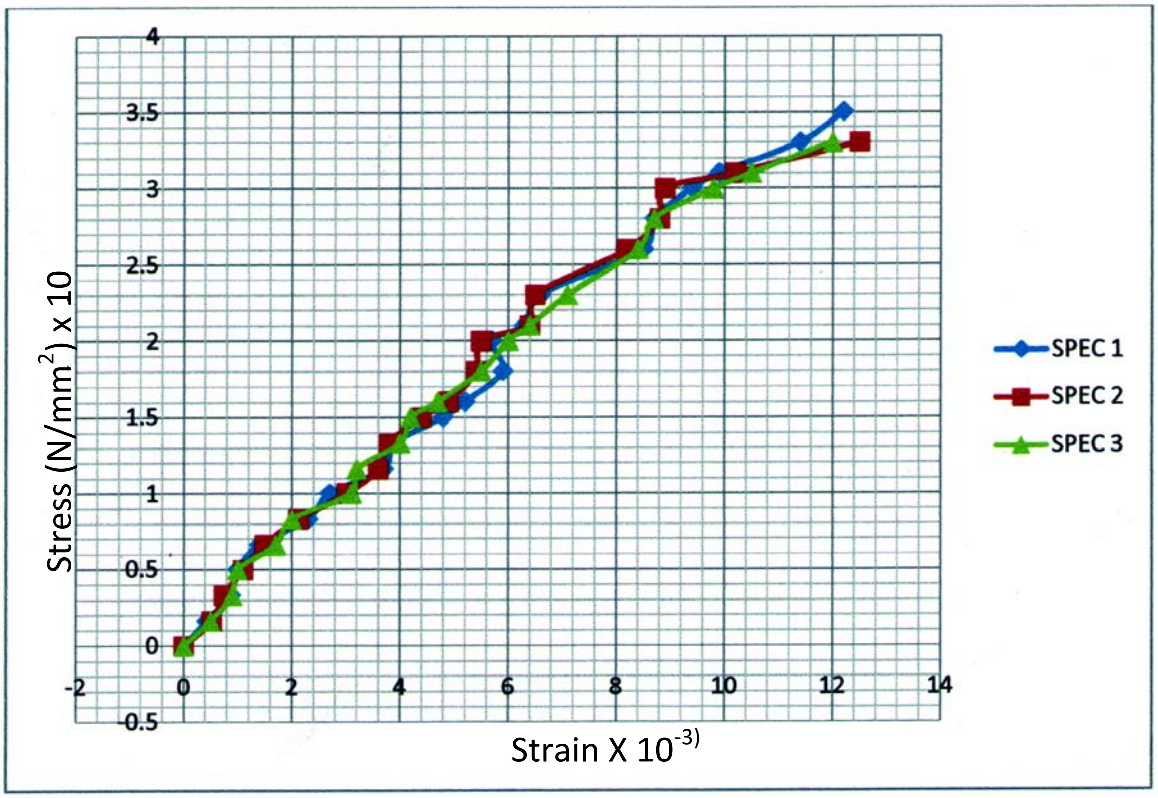

Figure3.2: Flexural Stress versus Strain (8mm steel reinforced beams)

a. Wire-Mesh Reinforced plate

b. 8mm Steel Reinforced plate

Plate 1 (a and b): Appearance of Crack Pattern in the Tested Plate specimens

Design for Load Carrying Capacity of the Plate (Roof Plate)

Dead load (KN/m^2):

Self-weight = 0.03x24 = 0.72

Fittings = <u>0.01</u>

0.73

Imposed load = 0.75

Design Load = $1.4G_k + 1.6Q_k$

1.4x0.73+1.6x0.75

= 2.23 KN/m^2

Actual Load carried by member: $\frac{3.0}{0.4}$ = 25.00 KN/M^2

Ultimate bending moment, M = $\frac{WL^2}{8} = \frac{2.23x(0.4)^2}{8}$ = 0.05KNm

4. CONCLUSION

The growing housing needs, especially in developing countries, makes the search for cheap and adequate building units attractive. Ferrocement building elements could be a viable area. Ferrocement consist of two main components: the matrix and the reinforcement. The Matrix is hydraulic cement binder, which may contain fine aggregates and admixtures to control shrinkage and set time, and increase its corrosion resistance. The reinforcement of ferrocement is commonly in the form of layers of continuous mesh, fabricated from an assembly of continuous single strands filaments. Specific mesh types include woven and welded mesh, expanded metal lath and perforated sheet products (Mansur and Ong, 2011).

Laboratory experimental methods were used to determine the Impact Energy and Flexural Stress-Strain characteristics of the ferrocements. The results showed that the wire-mesh specimen absorbed more energy than the 8mm ferrocement plate. The former is also more flexible. Designed calculations indicated the adequacy of the two ferrocement elements to adequately withstand the loads it is expected to be subjected to when in service as roofing panels. In terms of weight, the 0.75mm wire-mesh ferrocement plate is lighter and hence, preferable.

The beauty of ferrocement is that it could appear in any shapes. Only imagination could limit the forms and shapes of this beautiful and cheap material. Furthermore, unskilled labour could be employed to construct its structure.

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