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Comparative studies of Engineering Properties of Ferrocement and Fibrecement Material

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KEYWORDS

Ferrocement, Fibrecement, Compressive Strength, Flextural Strength

A B S T R A C T

The paper compares the engineering properties of ferrocement and fibre cement materials. The engineering properties considered include the tensile, the compressive and the flexural strengths at 7, 28 56, 90,120, 180, 270, and 365 days curing periods. Results shows that the average tensile strength of ferrocement which is (0.36N/mm^2) is twice that of equivalent fibre cement (30N/mm^2) is slightly lower than that of equivalent fibre cement (32N/mm^2). However the compressive strength of both ferrocement and fibre cement is lower than the compressive strength non reinforced section while the flexural strength of ferrocement is high than equivalent flexural strength of fibre cement. It could then be concluded that fibre cement and ferrocement be limited to use in tensile and flexural members only.

Introduction

In recent years, there has been an increase in the application of ferrocement in construction industries in the developing countries. However the high cost of wire mesh used as reinforcement in its production, which in turn forms a major part of the overall cost of production, has been a major concern. An alternative tensile material that has similar engineering properties with that of wire mesh which can be sourced locally at cheaper rate needed to be considered. Natural fibre is considered as a possible reinforcing material for ferrocement production. When fibre is used instead of wire mesh, it is called fibre cement.

Ferrocement is a combination of ferrous materials such as wire mesh as reinforcement, with cement – sand mortar, resulting in very thin, stiff, homogenous structural materials. The "American Concrete Institute (ACI)" defined ferrocement as a type of thin wall materials reinforced with layers of continous and relatively small diameter mesh (ACI, 1989). This implies that the reinforcing material may not necessarily be a wire mesh it may be of other material that has similar properties as wire mesh. Example of such materials is fibre, any metallic and some non-metallic materials.

Ferocement can be considered as a special form of reinforced concrete. This is because the reinforcing material is made of very small diameter steel wire meshes, which are closely binded together. The reinforcing mesh is uniformly distributed throughout cement – sand mortar matrix. It may also contain admixtures to alter or improve one or more of the properties of the final product. These materials have been found to exhibit a behavior different form the conventional reinforced concrete in performance, strength and application. Ferrocement has been applied in various aspect of structural engineering. In its traditional form, it has been used in the construction of boat, fishing vessels and other marine structures in the late eighteen centuries. It has also been found applicable in structures such as roofs, vaults, water tanks, grain storage facilities and other similar structures. According to Paul and Pama (1978), Jean Lovis labot constructed a rowing boat using ferrocement in 1840. He also reported that between 1840-1890, ferrocement boats raging from 5m-27m span were built in countries like Bangladesh, Chiba, Malaysia, India, Trail and Sigapona. The economic advantage of ferrocement concrete structures is that they are stronger and more durable than some traditional building methods(Gani, 1969; Nedwell, 1994).

Depending on the quality of construction and the climate of its location, houses may pay for themselves with almost zero maintenance and lower insurance requirements. Water tanks could pay for themselves by not needing periodic replacement, if properly constructed of ferrocement (IFIC, 1976; Infolink, 2009). Ferro concrete structures can be built quickly, which can have economic advantages. In inclement weather conditions, the ability to quickly erect and enclose the building allows workers to shelter within and continue interior finishing. In India, ferro concrete is used often because the constructions made from it are more resistant to earthquake, (Paul and Pama, 1978). Ferrocement is a versatile construction material that has bright prospect and will definitely find better utilization in the near future and hence called for more research work on the material. The international ferrocement information centers (IFIC) at Asia Institute of Technology under the sponsorship of Institute of Structural engineering and construction and the library and regional documentation centre Bangkok, Thailand was established in October 1976 to carry out investigations into the use of ferrocement as well as other natural vegetable fibres as a possible reinforcement in building components, Cement, 2009; IFIC, 1976.

In the 1970s, designers adapted their yacht designs to the then very popular backyard building scheme of building a boat using ferrocement. Its big attraction was that for minimum outlay and costs, a reasonable application of skill, an amateur could construct a smooth, strong and substantial yacht hull. A ferrocement hull can prove to be of similar or lower weight than a fiberglass, aluminum and steel Gani, 1969, 1997. New methods of laminating layers of cement and steel mesh in a mold may bring new life to ferrocement boat-building, Paul and Pama, 1978.. A thorough examination of reinforced concrete and current practice would benefit the boat builder. An example of a well known ferro-cement boat is *Hardiesse*, the Falmouth sail-training ship.The disadvantage of ferro concrete construction is the labor-intensive nature of it, which makes it expensive for industrial application in the western world. In addition, threats to degradation (rust) of the steel components is a possibility if air voids are left in the original construction, due to too dry a mixture of the concrete being applied, or not forcing the air out of the structure while it is in its wet stage of construction, through vibration, pressurized spraying techniques, or other means. These air voids can turn to pools of water as the cured material absorbs moisture. If the voids occur where there is untreated steel, the steel will rust and expand, causing the system to fail.

In modern practice, the advent of liquid acrylic additives and other advances to the grout mixture, create slower moisture absorption over the older formulas, and also increase bonding strength to mitigate these failures. Restoration steps should include treatment to the steel to arrest rust, using practices for treating old steel common in auto body repair, Ward-Harvey, 2009. Ferrocement has a number of advantages over conventional reinforcement material. It has been found to have a relatively thinner section. Another very important advantage is that various shapes can easily be achieved since the reinforcement mesh materials are easily bent to the required shapes. The possibility of eliminating formwork during construction is an added advantage. The skill requires for its construction is relatively easy and the construction has been found to be cost effective. Today fibre cement is considered as a material physically suited for construction products such as cladding and roofing. In fibre cement there is a fibre reinforcement, which contributes to making the fibre-cement material even stronger. Fibre cement makes it possible to develop strong and long lasting concrete structures.

An anisotropic elastoplastic models to simulate the mechanical behavior of ferrocement plates are proposed. These models use elastic and inelastic properties derived from simple in-plane tension and compression experiments. Mindlin plate theory in conjunction with a layered approach is employed for analysis. Two different mathematical models, the homogeneous layered model and the mortar-ferrocement layered model, are considered. The former assumes all the layers to possess identical anisotropic material properties. The postelastic behavior is modeled using the anisotropic Hoffman criterion. In the mortar-ferrocement layered model, the plate is divided into "mortar" and "ferrocement" layers. The mortar layers are assumed to be isotropic and their postelastic behavior is simulated using isotropic Hoffman criterion (Gani, 1969; Ward-Harvey, 2009).

The ferrocement layers are modeled using two approaches: in the first, they are assumed to be transversely isotropic (transtropic) and in the second an orthotropic material idealization is employed. The analytical predictions are found to compare well with the experimental results. The mortar-ferrocement layered model with orthotropic ferrocement layers performs the best. It is concluded that a single set of material properties can be used to simulate the behavior of ferrocement plates under in-plane as well as out-of-plane loading, Gani, 1997 and Ward-Harvey, 2009. Studies were also carried on the suitability of natural fibres, (Terry, 2015; Eternity and Fibre, 2009; Infolink, 2009. It was observed that most of the natural vegetable fibres are suitable as reinforcement in cement based composite. Hence a vegetable fibre, coconut fibre that is very common in tropical countries is considered in this studies..

Research Methodology

Coconut fibres were esponged from coconut fruits, then extracted into strand by hand. Chicken meshes were brought from the market while river sand of specific gravity 2.64 was used with ordinary Portland cement as mortar.

The materials were weighted, mixed and casted in accordance with ASTM (1985) standards . For tensile strength tests, two sets of specimens were made; specimen for ferrocement TI and specimens for fibre cement TII. Three samples were made for each set of specimens per 7, 14 , 21, 28, 56, 90, 120, 180, 270s and 365 days curing periods; For tensile, compressive and flexural strength tests for ferrocment and fibrecement mortar respectively.

The compressive strength test, were carried out on the specimen using electric crush machine in the soil mechanics laboratory, Institute of technology, kwara state polytechnic. The Flexural and Tensile strength tests were carried out with automatic universal strength testing machine.

Result and Discussion

Tensile Strength

The result of the test on tensile strength are presented in table 1 and discussed accordingly.

Table.1 Ultimate Tensile Strength of Ferrocement (TI) and fibre cement III

Specimen	Curing period (days)	Tensile strength (N/mm^2)			Average N/mm^2
		Rep 1	Rep 2	Rep 3	
I	7	0.33	0.31	0.35	0.33
TII		0.15	0.17	0.14	0.16
TI	14	0.34	0.35	0.35	0.35
TII		0.17	0.18	0.18	0.18
TI	21	0.36	0.35	0.34	0.35
TII		0.17	0.18	0.18	0.18
TI	28	0.30*	0.36	0.36	0.36
TII		0.14*	0.17	0.18	0.18
T1	56	0.30*	0.36	0.36	0.36
TII		0.14	0.17	0.18	0.18
T1	90	0.28	0.33	0.34	0.33
TII		0.14	0.13	0.16	0.15
T1	120	0.29*	0.33	0.34	0.33
TII		0.14	0.14	0.14	0.14
TI	180	0.33	0.32	0.32	0.32
TII		0.13	0.12	0.13	0.13

**Values not use for computation of the average values.*

The result shows that the tensile strength of the two materials directly depends on the type of reinforcement used. The result (for a 28 days cured specimen) shows that ferrocement has an average tensile strength of 0.36 N/mm^2 while fibrecement has 0.18N/mm^2. This represents about 50% difference in tensile strength when the same percentage of wire mesh and fibre mesh are used for the specimen. Figure 1 shows that tensile stress increases as age of curing increased.

Table.2 Ultimate Compressive Strength of Ferrocement (CI) and Fibre Cement (CII)

Specimen	Curing period (days)	Tensile strength (N/mm^2)			Average N/mm^2
		Rep 1	Rep 2	Rep 3	
CI	7	24.00	25.00	26.00	25.00
CII		26.0	24.00	25.00	25.00
CI	14	26.00	28.00	27.00	27.00
CII		28.00	28.00	20.00*	28.00
CI	21	30.00	29.00	31.00	30.00
CII		31.00	32.00	33.00	32.00
CI	28	29.00	30.00	31.00	30.00
CII		31.00	33.00	33.00	32.00
CI	56	29.00	30.00	32.00	30.67
CII		31.00	33.00	33.00	32.33
CI	90	30.00	30.00	32.00	30.67
CII		31.00	33.00	33.00	33.33
CI	120	36.00*	30.00	30.00	30.00
CII		31.00	33.00	32.00	32.00
C1	180	29.00	30.00	28.00	29.00
CII		32.00	33.00	34.00	33.00
CI	270	30.00	32.00	31.00	31.00
CII		33.00	34.00	33.00	33.33
CI	365	30.00	32.00	33.00	31.00
CII		34.00	36.00	33.00	34.33

**Values not use for computation of the average values.*

The result show that the compressive strength of the specimen depends greatly on the age (curing period) of production. Generally the strength increase with increasing age. The reinforcement tends to reduce the compressive strength when compared with the unreinforced specimen and is more pronounced with ferrocement. There is about 33% reduction with ferrocement while it is about 27% with fibrecement when compared with unreinforced specimen. Flextural strength increases as the age of curing increased as seen in figure 2.

It was observed, based on the result of the test and the flexural strength depends on the age of the materials. The older the materials the higher the flexural strength. It was also observed that the flexural strength depends also on the type of the reinforecement. For 28 days cured specimens ferrocement has an average of 13.6N/mm2 flexural strength while fibrecement has 8.6 N/mm2. This represents about 37% difference in the flexural strength of the two materials having the same percentage reinforcement.

Table.3 Flexural Strength of ferrocement Slabs, SI, Fibre Cement Slabs, SII

Specimen	Age (day)	Flexural strength (N/mm^2)			Average N/mm^2
		Rep 1	Rep 2	Rep 3	
SI	7	11.0	10.7	10.9	10.53
SII		4.7	4.9	4.5	4.70
SI	14	11.5	11.2	11.4	11.37
SII		5.4	5.3	5.2	5.33
SI	21	12.3	12.7	13.0	12.67
SII		7.7	7.2	8.0	7.63
SI	28	12.9	13.0	13.9	13.23
SII		8.2	8.3	8.2	8.23
SI	56	13.4	13.6	13.5	13.63
SII		8.5	8.9	8.4	8.63
SI	90	13.2	13.4	13.3	13.30
SII		8.2	8.3	8.5	8.33
SI	120	13.5	10.7*		
SII		8.4	8.6		
SI	180	13.1	12.9		
SII		8.3	8.2		
SI	270	12.9	12.8		
SII		7.9	7.8		
SI	365	12.8	12.7	13.5	13.50
SII		7.6	7.2	8.5	8.50
				12.2	12.73
				8.2	8.23
				13.1	12.93
				7.4	7.70
				12.6	12.70
				7.5	7.43

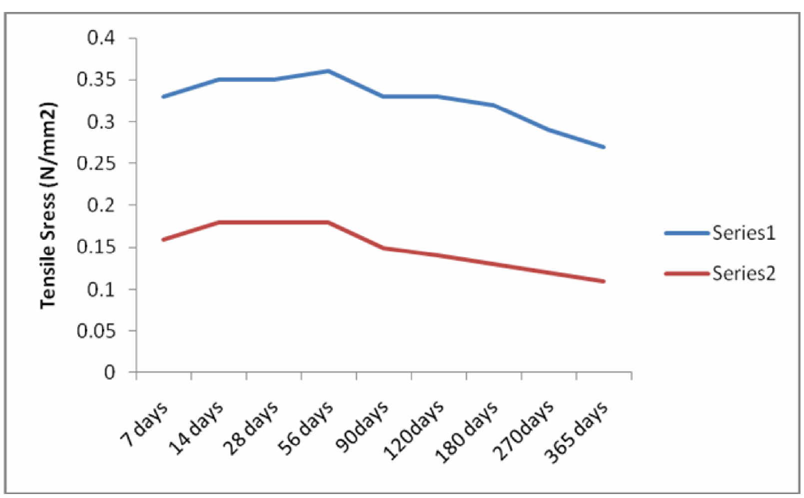

Figure.1 Effect of age of curing on Tensile Stress of ferrocement and fibrecement

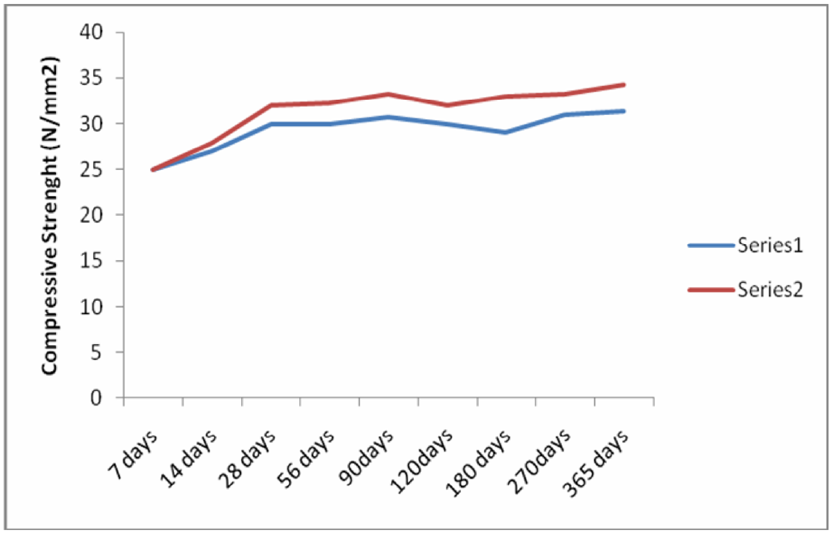

Figure.2 Effect of age of curing on compressive stress of ferrocement and fibrecement

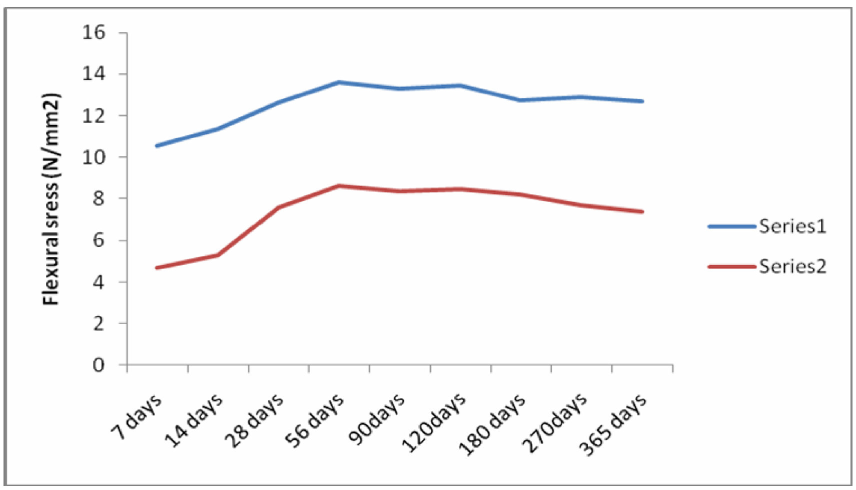

Figure.3 Effect of age of curing on Flextural Stress of ferrocement and fibrecement

Conclusion

Based on the results obtained, fibrecement can be used as a replacement for ferrocement for flexural and tensile members. It should however be noted, that a greater percentage by area of the fibre reinforcement will be required to achieved the same strength of a particular percentage wire mesh reinforcement in ferrocement.

For compressive member, the reinforcing mesh should be kept at the minimum of completely eliminated.

This is as a result strength of the two materials as evident in the result shown above.

Further research works should be carried out on the use of ferrocement and fibrecement materials.

These may include:

1. Subjecting the materials to different environmental conditions
2. The cost/economic comparisons

3. The use of other fibres such as coir, palm kernel fibre, jute, sisal etc
4. The effect of variation in the percentage of reinforcement on the strength of the materials.

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