State of Art on the Research of Light Weight Ferrocement

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Abstract – Lightweight ferrocement is a composite material consisting of cement-sand mortar (matrix) along with light weight fine aggregate as a replacement of sand in some quantity reinforced with layers of small diameter wire meshes and closely spaced small-diameter steel rods rebar. It has been regarded as a highly versatile construction material having unique properties of strength and serviceability. Its advantageous properties such as strength, toughness, water tightness, lightness, durability, fire resistance and environmental stability cannot be matched by any other thin construction material. Ferrocement is a promising composite material for prefabrication and industrialization of the building industry. The three major problem areas in light ferrocement construction are mortar mixing, mortar application, and curing. The mortar must be dense and compact. A trained supervisor can teach the mixer operator to judge mortar quality from the way it tumbles or rolls off the mixer blades. The desired shape may be built from a multi-layered construction of mesh, supported by an armature or grid, built with rebar and tied with wire. For optimum performance, steel should be rust-treated, (galvanized) or stainless steel. Over this finished framework, an appropriate mixture (grout or mortar) of Portland cement, sand and water and/or admixtures is applied to penetrate the mesh. The economic advantage of light ferrocement structures is that they are stronger and more durable than some traditional building methods. 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.

Index Terms – Lightweight ferrocemnt, fabricated and construction technology.

1. INTRODUCTION

As modern engineering practices become more demanding, there is an increasing need for a wider spectrum of construction materials with novel properties. It includes developing existing materials into ones with modified properties in combination with other suitable materials. Cement concrete is a processed construction material of immense importance not only in the field of civil engineering but also in the history of mankind.

Light weight ferrocement is a composite material consisting of cement-sand mortar (matrix) reinforced with layers of small diameter wire meshes and BFS. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. Usually steel bars are used in addition, to form a steel skeleton, which helps in retaining the required shape of the ferrocement components until the cement mortar hardens. It differs from conventional reinforced concrete primarily by the manner in which the reinforcement is arranged within the brittle matrix. Since its behavior is quite different from that of conventional reinforced concrete in performance, strength and potential applications, it is classified as a separate material.

The use of ferrocement was first started as early as in 1848. It took the form of rowing boat constructed by Jean Louis Lambot. The boat, still in a remarkably good condition, is on display in a museum at brig holes, France. Since then, ferrocement was mainly used in the marine environment.

In the early 1940s, Pier Luigi Nervi resurrected the original ferrocement concept when he observed that reinforcing concrete with layers of wire mesh produced a material possessing the mechanical characteristics of an approximately homogeneous material and capable of resisting impact. After the Second World War, Nervi demonstrated the utility of ferrocement as a boat-building material. His firm built the 165-ton motor sailor Irene with a ferrocement hull about 36mm thick.

Light weight ferrocement has high resistance against cracking; also many of its engineering properties such as toughness, fatigue against resistance, and impermeability etc. are improved when compared to reinforced concrete

In India, Light weight ferrocement is used often because the constructions made from it are better resistant against earthquakes. Earthquake-resistance is dependent on good construction technique and additional reinforcement of the cement.

2. ADVANTAGES AND DISADVANTAGES OF LIGHT FERROCEMENT

2.1. Advantages

Light Ferro cement is particularly suited to developing countries for the following reasons:

1) Its basic raw materials are available in most countries.

2) It can be fabricated into almost any shape to meet the needs of the user; traditional designs can be reproduced and often improved.

3) For properly fabricated, it is more durable than most woods and cheaper than imported steel, and it can be used as a substitute for these materials in many applications.

4) The skills required for Light ferrocement construction are quickly acquired, and include many skills traditional in developing countries. Ferrocement construction does not need heavy plant or machinery; it is labour intensive. Being labour intensive, it is relatively inexpensive in developing countries. Except for sophisticated and highly stressed designs, as those for deep water vessels, a trained supervisor can achieve the requisite amount of quality control using fairly unskilled labour for fabrication.

5) In case of damage, it can be repaired easily.

The beauty of Light ferrocement was that it could appear in any shapes. Only imagination could limit the forms and shapes of this beautiful and cheap material. Further unskilled labour could be employed to construct the structure. The material and labour required are plentiful in the developing countries, especially in rural areas. These factors make it a very appropriate material for national developments.

2.2. Disadvantages

The disadvantage of Light ferrocement 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.

3. APPLICATIONS OF LIGHT FERROCEMENT

Since the Light ferrocement has very high tensile strength-to weight ratio and superior cracking behavior, it is ideally suited for thin-walled structures such as boats and water retaining structures. The possible areas of applications of ferrocement and their performance are highlighted below.

1) Light Ferrocement is an excellent material for roofing because of its relatively low cost and durability. Ferro cement elements being thin, they derive their strength and rigidity through form and shape.
2) Light Ferrocement has been successfully used for casting domestic overhead water tanks. The tank being light and flexible can be transported and hoisted without much difficulty. Ferrocement tanks can also be used as septic tank units, grain silos, and gobar gas plants.
3) Properties of Light ferrocement make it an ideal material for boat building.
4) Light Ferrocement man hole covers is becoming very popular to replace cast iron man whole cover over sewers around domestic building where they are not subjected to heavy vehicular traffic.
5) Light Ferrocement is a suitable material for pressure pipes. It will be much lighter compared to normal reinforced concrete pipes.

3.1. Light Ferrocement Construction Process

As thin structural elements, light weight ferrocement has been used in numerous applications ranging from engineered structures to architectural applications such as sheets, boards, shells, hulls, and also sandwich type construction using thin skins, and constructions where the reduction of self-weight, improved water permeability and development of very fine crack Widths are essential.

3.2. Light weight ferro-cement houses

In many cities as well as small towns the building plots are small and it is important to have thin walls for two- and three storey buildings. In addition, the construction time should be minimized due to social and financial reasons. Conventional construction cannot respond to those demands. Big industry has developed many different systems to deal with those conditions, but they invariably respond to a complicated technological level and depend on sophisticated equipment and workmanship. They are usually geared to large projects and do not respond to the demands of small constructions. Very often the plot is already being occupied by a shack or a substandard house and it is important to erect the new building within days and with labor from the same neighborhood, but at an affordable cost.

Figure 1: The technology adapts to local design culture

3.3. Sandwich Structural Elements/Members

A sandwich panel is a three-layer element, comprising two thin, flat facing plates of high-strength material and between which a thick lightweight core of low average strength is attached. Figure 2.1 presents a few types of sandwich panel elements. Such sandwich structures have gained widespread acceptance within the aerospace, naval/marine, automotive and general transportation industries as an excellent way to obtain extremely lightweight components and structures with very high bending stiffness, high strength and high buckling resistance (Mahfuz *et al.*, 2004; Liang and Chen, 2006).

(a) Foam core sandwich

(b) Honeycomb sandwich

(c) Web core sandwich

(d) Truss core sandwich

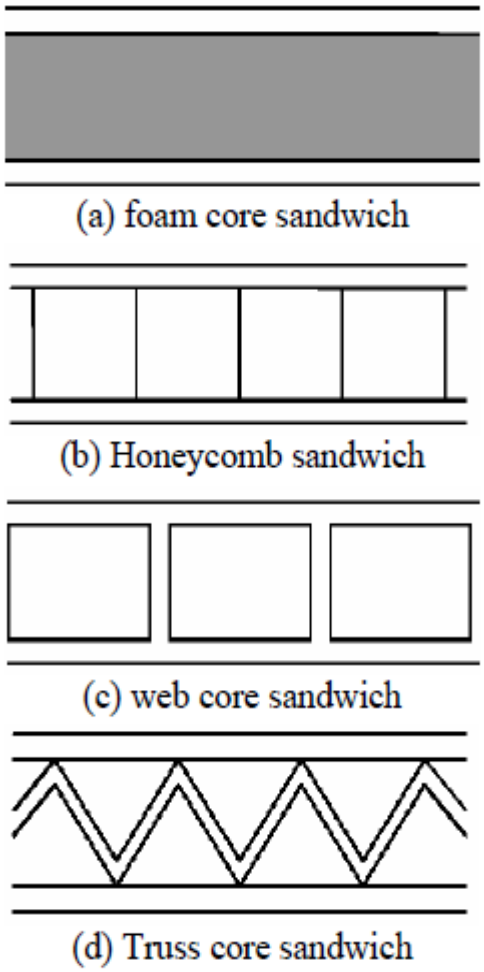

Figure 2: Types of sandwich elements

3.4. Precast Concrete Sandwich Panels

PCSP consists of two layers of concrete called Wythes separated by a thick, lightweight and very low strength core layer. The concrete wythes are connected to each other by concrete webs, steel connectors or the combination of the two, called as shear connectors. PCSP with shear truss connectors is typically fabricated of two concrete wythes tied together with truss-shaped shear connectors equally spaced along 10 the length of the panel as depicted in Figure 3. While Figure 4 shows the PCSP, where the wythes are connected by webs. It is generally accepted that this type of panels has been in use for more than 40 years in North America. Their application, however, has been restricted as cladding panels. Now a days, many sandwich panels in use in the North America and Europe are proprietary but very limited is available, because the producers are reluctant to share information with their competitors (PCI, 1997; Bush and Zhigi, 1999). The first prefabricated panels were of non-composite type and consisted of a structural wythe (layer) and a non-structural wythe separated by a layer of insulation, whereas composite type panels were manufactured later (Benayoune *et al.*, 2007a).

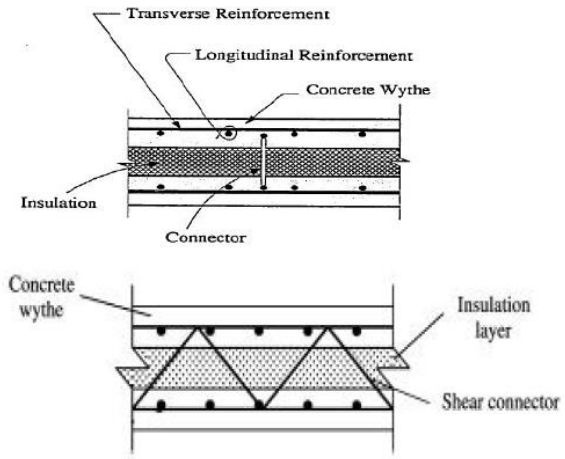

Figure 3: Sections of PCSP with shear connectors (Lindsay, 2003)

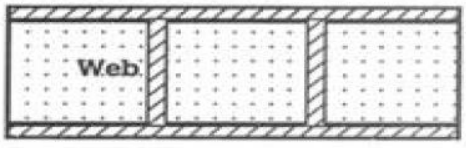

Figure 4: Sandwich elements with webs

Although PCI (1985; 1989) propose the wythe thickness ranging between 15mm to 75 mm, however it is mentioned that the appropriate thickness of the Wythes be decided as per the requirement of the structure. The structural behavior of the panel depends greatly on the strength and stiffness of the

connectors, while the thermal resistance of the insulation layer governs the insulation value of the panel. The arrangement and spacing of shear connectors in PCSP vary depending on several factors, such as desired composite action, applied load, span of the panel and type of shear connectors used. Various types of connectors used are shown in Figure 5.

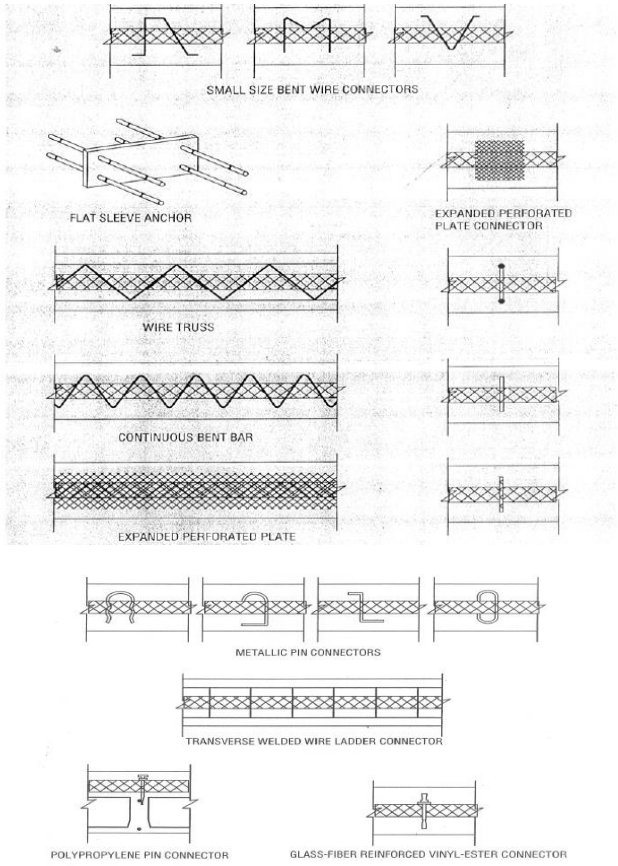

Figure 5: Types of shear connectors

4. CONCLUSION

This study has brought out that light weight ferrocement is an innovative,

1. Material and the ready availability of materials and ease of construction make it suitable in developing countries for housing, and water and food storage structures.
2. Light weight Ferrocement is found to be a suitable material for repairing or reshaping the defective RCC structural elements and enhancing its performance.
3. The applications of ferrocement are capturing almost all the fields of civil engineering but there is some of research backing and a rationale design base to construction of light weight ferrocement structures.
4. As the performance of ferrocement is greatly dependent on the characteristics of the reinforcing mesh, there is a need to determine and specify an optimum range of properties for the mesh, such as wire spacing, wire diameter, and the characteristics of the mesh system.
5. The standard methods of ferrocement construction and effect of shape due to which novel forms are generated have to be researched upon and benefits brought out.
6. Considering the unique features, ferrocement will no doubt be one of the most important structural alternatives for RCC and a repair material in the future and thus has a great potential for developing and developed countries alike.

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