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Prospect in Ferrocement Materials, Applications, and Technology†

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Let us take a giant step through the history and development of ferrocement, from the ferrocement of Lambot to today's ferrocement, and let us explore the future prospects of ferrocement starting by its very definition.

While we are used to thinking of ferrocement as a type of thin-wall concrete reinforced with closely spaced layers of meshes, some recent large-scale applications of ferrocement use large size meshes in combination with high strength reinforcing bars, steel fibers, and prestressing, leading to wall thicknesses larger than 50 mm. They seem to span the range between what is today considered ferrocement and traditional reinforced concrete.

Describing these structures as ferrocement structures may be questioned strictly on the basis of its definition. However, the current trend is a healthy one. It really shows that ferrocement is one extreme boundary of reinforced concrete and that the whole range between them should also be explored. Perhaps ferrocement should be simply seen as a system of reinforced concrete construction with reinforcement distributed throughout the depth of the member. Improved elasticity, cracking, extensibility and impact characteristics are achieved by proper control of the reinforcement parameters.

While ferrocement can benefit (code and specification wise) from its being considered an extreme boundary of reinforced concrete, it has and still is taking advantage from rapid developments in the field of composite materials including advanced composites.

By concrete standards, ferrocement can be thought of as a thin reinforced concrete construction with very high performance characteristics such as high-tensile strength, ductility, and impact resistance. While these characteristics are required for marine applications, they are not always necessary for building construction. This is leading to modifications of the traditional ferrocement technology.

One of the main factors that has so far hindered the full development of high performance ferrocement is its cost. The relatively high cost of ferrocement, in comparison to reinforced concrete, is mainly due to the labor intensive nature of its fabrication and at least equally, to the cost of the mesh system. Some recent studies have shown that even in the U.S. the cost of the reinforcement in high performance ferrocement is larger than the cost of labor. On an equal weight basis, the cost of steel mesh varies from 2.5 to 8 times that of conventional reinforcing bars.

There is, however, increasing evidence that even in industrialized countries, ferrocement can be cost competitive through mechanized fabrication and the proper choice of mesh reinforcement. For instance a factory produced ferrocement element using shotcreting instead of

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hand plastering and expanded metal mesh instead of woven wire mesh, may cost 2 to 3 times less than conventional ferrocement elements of equivalent performance.

The use of ferrocement in industrialized countries, particularly the U.S., has been minimal. This is perhaps due to the ready availability and relatively low cost of other construction materials such as wood and plywood which can be easily worked with by any unskilled labor. In the U.S. the main activity on ferrocement is generated by a group of dedicated researchers most of whom are members of the American Concrete Institute's Committee on Ferrocement. Their efforts have led to the ACI State-of-the-Art Report on Ferrocement published in 1982. They are currently finalizing a comprehensive "Design Guide for Ferrocement Construction" in which a particular emphasis was placed on simplifying design criteria. These publications provide the official reference and documentation needed by designers, and may pave the way to increased consideration of ferrocement as an alternative material in various applications. However, this is only a first step. To be competitive in the U.S., ferrocement has to find applications where either other materials are not cost competitive, or labor cost is not a constraint. Examples include the cement sheet business, applications where fire resistance is required, and increasingly, repair and retrofitting work.

What then are the prospects for ferrocement materials, applications and technology?

We are witnessing a considerable evolution in materials and materials' technology. At the matrix level, while the basic cement and sand components remain the same, an increasing number of additives is becoming available. These additives allow for many properties to be easily obtainable such as improved workability, setting time, strength, bonding, durability and the like. Very high mortar compressive strengths (of up to 100 MPa) can be readily achieved using superplasticizers and silica fumes.

At the reinforcement level, while steel meshes remain the primary reinforcing material, other materials such as fiberglass meshes and organic synthetic meshes, offer many advantages. In industrialized countries, including the U.S., synthetic meshes such as polypropylene meshes can be produced to specification and delivered to site at a cost substantially smaller than that of organic natural meshes (sisal, jute, bamboo). More recently tridimensional meshes of either steel or polymeric materials have become available. As a single tridimensional mesh may replace several layers of plane mesh substantial savings in labor cost are expected. Further savings can be achieved when the mortar matrix is mechanically applied as in shotcreting.

Applications of ferrocement in small size structures and structural elements have mushroomed in developing countries. They need not be listed anymore. More recently, however, some daring limits were attained in relatively large structures such as domes, barges, earth shelters, floating wharves, pontoons, roofing beams and oil tankers. In a way ferrocement is becoming an "all purpose" material and its potential combination with other materials (such as fibers and prestressing) is a testimony to its versatility. It is believed that increased utilization of ferrocement will continue. In industrialized countries this may take the form of mechanized production of small size elements such as cement sheets and pipes to replace asbestos cement products.

The technology of ferrocement will remain fairly simple requiring a small investment in tools and equipment. In its draft of the Ferrocement Guide ACI Committee 549 identifies several fabrication techniques, but hybrid techniques are being and will be used depending on

the means of the builder. After all, ferrocement is "everyone's" material; it will be continuously subjected to imaginative solutions. Examples include precast ferrocement elements bolted together like wood, rolled ferrocement sheets and the application of the oregami concept to ferrocement.

Construction technology of ferrocement has so far evolved faster than its design. In the U.S. for instance fire resistance requirements regarding minimum concrete cover to the reinforcement do not and cannot apply to ferrocement. Yet such requirements hinder its use. On the "analysis-design" side, in the future, particular attention should be given to simplifing the analytical involvement, providing design aids and reducing the total effort devoted to the "analysis-design" process. As the majority of users of ferrocement are non-technical, it is not realistic to assume that they will be able and willing to follow a complex design methodology, such as predicting flexural strength, crack widths or deflections. Some progress toward simplication has already been achieved but it is only the beginning.

In summary most experts and users agree that, in all respects, ferrocement is an excellent construction material of the future. However in spite of very significant advances in the last ten years, which are in great part due to the existence and efforts of the *International Ferrocement Information Center*, ferrocement is at a critical point of its development. It is hoped that the crucial support of various organizations to the Center will continue, and I for my part hope that you and I will be around to witness the widespread success of a material we believe in.