Naaman, A.E., "Ferrocement: An Extension of Reinforced Concrete Technology," Concrete International, Vol. 5, No. 11, Nov. 1983, pp. 9-11.

FERROCEMENT: An Extension of Reinforced Concrete Technology

by A. E. Naaman

According to the state-of-the-art report of ACI Committee 549, Ferrocement, (*Concrete International,* Aug. 1982): "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. The mesh may be made of metallic or other suitable materials." This definition encompasses the original idea of Lambot who patented ferrocement in 1847 and that of Nervi who in the early 1940s promoted the modern use of ferrocement for marine and structural applications. Nervi observed that the subdivision and uniform distribution of the reinforcement produced an approximate homogeneous composite with great elasticity, flexibility, ductility and impact resistance.

Numerous investigations carried on during the 1960s and the 1970s showed that, similarly to reinforced concrete, ferrocement cracks, but crack widths in service remain very small and almost invisible to the naked eye. In its state-of-the-art report, ACI Committee 549 attempted to preserve these characteristics of ferrocement by recommending limiting values of the mesh reinforcing parameters (volume fraction, specific surface, number of mesh layers, cover, etc.). However, some recent large-scale applications of ferrocement, as described in this issue, use large size meshes in combination with high strength reinforcing bars, steel fibers, and prestressing. They seem to span

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the range between what is today considered ferrocement and traditional reinforced concrete.

Describing them as ferrocement structures may be questioned strictly on the basis of the committee's 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. The following is a case in point: a 4 in. deep concrete slab containing 1 layer of square, deformed welded wire fabric with a wire spacing of 2 in. and a wire diameter of ¼ in. qualifies as a reinforced concrete slab. However, a 4 in. thick concrete shell containing 7 stacked layers of the same mesh could very likely be described as ferrocement. This is particularly true if fibers are added to the matrix to improve its cracking characteristics. This shows in effect that ferrocement should be also 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.

Ferrocement is often thought of as 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 has led to modifications of the traditional ferrocement technology, as mentioned earlier. 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 the cost of the mesh system. Some recent studies have shown that even in industrialized countries 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. A recent evaluation has shown that factory produced ferrocement elements using shotcreting instead of hand plastering and expanded metal mesh instead of woven wire mesh, cost 2 to 3 times less than conventional ferrocement elements of equivalent performance.

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The possible use of newly developed non-metallic meshes (such as polypropylene whose specific gravity is about ⅙ that of steel) and the development of a performance approach in the design of ferrocement may further lead to substantial reductions in its cost and contribute to its increased utilization.

Extensive research investigations have been undertaken during the last two decades on practically most aspects of the mechanical properties and construction characteristics of ferrocement. The International Ferrocement Information Center (IFIC) was founded in 1976 at the Asian Institute of Technology (AIT) in Bangkok to serve as a clearing house of and a dissemination center for information on ferrocement and related materials. There are still, however, some properties of ferrocement such as fire resis-

Want to keep up to date on ferrocement? The International Ferrocement Information Center (IFIC) serves as a clearing house for information on ferrocement and related materials.

IFIC was founded in October, 1976, at the Asian Institute of Technology as a result of recommendations made in 1972 by the U. S. National Academy of Sciences Advisory Committee on Technological Innovation. The center receives financial support from the Government of New Zealand and the International Development Research Center of Canada.

Basically, IFIC is an information disseminating organization. In cooperation with national societies, universities, libraries, information centers, government agencies, research organizations, and engineering and consulting firms all over the world, IFIC attempts to collect information on all forms of ferrocement applications. This information is identified and sorted and made available through IFIC's publication and on request through IFIC's reference and reprographic services.

The center also serves as a catalyst in initiating projects, finding resource persons for training courses, workshops, and seminars.

A quarterly publication, the Journal of Ferrocement, is the main information tool of the center. Numerous books and reports are available. For further information, contact: The Director, IFIC/AIT, P. O. Box 2754, Bangkok, Thailand.

tance and durability that need quantitative and rational evaluations through additional research. Currently the RILEM Committee on Ferrocement is conducting a technical survey on the durability and maintenance of ferrocement which will very likely lead to some definitive recommendations.

In summary, there is no question that ferrocement is good and sound and on its way to being increasingly used in industrialized countries, as well as in developing countries.

I wish to take this opportunity to thank all of those who have participated in the ACI Symposium on Ferrocement. I am especially indebted to the speakers, to members of ACI Committee 549 and, in particular, to Gordon Batson, Secretary of ACI Committee 549, for their cooperation and support throughout the symposium.

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It is often reported that the lack of guidelines or specifications on ferrocement hinders its acceptance by local building authorities. ACI Committee 549 is, at the time of this writing, actively working on a ferrocement guide for the design and construction of ferrocement structures. The guide includes chapters on materials requirements, design criteria, fabrication, and maintenance-prevention. It is hoped that the guide will be ready for presentation at the Second International Symposium on Ferrocement planned at the AIT in Bangkok in January 1985. The symposium is jointly organized by the IFIC and RILEM, and cosponsored by ACI.

The ACI Symposium entitled: "Ferrocement: Research, Design and Applications" took place during the ACI fall convention in Detroit in September 1982. The main intent of the symposium was to: (1) gather the latest research results and developments on ferrocement, (2) discuss design procedures, recommendations and standards of good practice, and (3) describe various applications, preferably large scale, with particular emphasis on reviewing improved and/or innovative methods of production. Large scale implied either large size structures or mechanized production of smaller elements.

The papers presented were divided into two groups, one related to research and design, the other to applications. Papers belonging to the first group are being considered for publication in the ACI Journal. The papers belonging to the second group were assembled for this special issue of *Concrete International* to present an overview of the state of the art of the applications of ferrocement. Applications that should be mentioned, but for which the final papers were not received, include the use of ferrocement as permanent molds to form reinforced concrete slabs and confining molds for columns, and the use of factory precast ferrocement elements to replace asbestos cement products such as corrugated roofing sheets, cylindrical water tanks and semicylindrical water irrigation channels.

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ACI Committee 549, Ferrocement, was organized in 1974 to study and report on the engineering properties, construction practices, and practical applications of ferrocement and similar materials; and to develop standards and safeguards for ferrocement construction.

Two publications, the "State-of-the-Art Report on Ferrocement," and "SP-61, Ferrocement — Materials and Applications," provide technical information on the mechanical properties, performance, and applications of ferrocement. For more information write: American Concrete Institute, P. O. Box 19150, Detroit, Mi.