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Review

Ferrocement composites for strengthening of concrete columns: A review

A.B.M.A. Kaish [a,*], M. Jamil [b,*], S.N. Raman [b], M.F.M. Zain [b], Lutfun Nahar [c]

[a] Department of Civil Engineering, Infrastructure University Kuala Lumpur, Kajang 43000, Malaysia
[b] Department of Architecture, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Malaysia
[c] Institute of Visual Informatics, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Malaysia

HIGHLIGHTS

- Behaviour of ferrocement jacketed concrete columns are reviewed and discussed.
- Confinement mechanism and models for ferrocement confined column are also reviewed.
- Research gaps are identified and suggestions for further development are proposed.

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ABSTRACT

The retrofitting and strengthening of concrete structures are becoming integral parts in construction and structural engineering practices owing to various situations that necessitate the enhancement in the capacity of structural members. Ferrocement composites are widely used for structural strengthening and rehabilitation in developing countries. The uniform distribution and high surface area-to-volume ratio of the reinforcement (wire mesh) of such composites improve the crack-arresting mechanism. Given these properties, ferrocement is an ideal material for repairing and strengthening old and deteriorated structures or structural members. Ferrocement composite has also been used as a jacketing material to strengthen axially loaded reinforced concrete (RC) members. Strengthening of concrete structures is an essential part of construction activities at present because these structures often suffer damage as a result of numerous environmental factors. The significance of these activities also increases with the insufficient capacity of structures that have been designed using old design codes. However, no codes have been developed for ferrocement composites as jacketing material to date. Moreover, a well-defined method for confining RC columns using ferrocement has not been established because of the lack of adequate research in this field. Thus, this study aggregates the current state of knowledge by reviewing available literature on the ferrocement jacketing of concrete columns and on ferrocement confinement effects. This study also determines research gaps in this field and suggests directions for future research to establish ferrocement composites as a feasible material for strengthening axially loaded concrete members.

Contents

* Corresponding authors.
E-mail addresses: amrul.cuet@gmail.com, amrul.kaish@iukl.edu.my (A.B.M.A. Kaish).

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1. Introduction

The strengthening and retrofitting of reinforced concrete (RC) structures are difficult but essential construction tasks [1]. Such activities are increasingly becoming significant because of the insufficient capacity of structures that have been designed using old design codes. In addition, RC structures are often damaged by numerous factors, such as natural disasters, fire or environmental effects. As a result, structures are weakened and must therefore be either strengthened or retrofitted. Effective and constructible techniques and materials should be used to improve deteriorated or substandard structural members. Deteriorated structural members must be examined and analysed carefully to determine its in situ condition prior to strengthening work. Furthermore, strengthening measures must be determined on the basis of the in situ condition of structures.

Columns are essential structural elements designed to support the vertical loads of frame-structured buildings. These elements significantly stabilise such structures vertically and laterally, especially high-rise buildings. RC columns require sufficient lateral confinement to sustain axial loads effectively. This confinement is facilitated by lateral ties in the form of individual rings or continuous spirals that run from the top to the bottom of the columns [2]. Lateral confinement is also necessary to enable large deformation during loading. In the case of a seismic event, a sufficiently confined concrete core can dissipate increased amounts of energy. Thus, the capacity of this core increases when subjected to such dynamic loading events. On the contrary, a poorly confined concrete column is brittle. As a result, a structure may fail suddenly and catastrophically [3]. Tsai and Lin [4] reported that the inadequate axial load capacity and axial ductility of columns are the fundamental factors that are responsible for the collapse of many RC buildings during the 1999 Chi-Chi Taiwan earthquake. Therefore, sufficient lateral confinement must be provided to existing RC columns. Furthermore, existing substandard or deteriorated columns should be retrofitted or strengthened through external confinement to increase ductility and load-carrying capacity.

Various materials and methods have been studied for strengthening substandard or deteriorated RC columns. Ferrocement is a long-established and promising material for use in strengthening concrete structural elements given its inherent toughness and crack-resistant capacity [5]. Nonetheless, research on ferrocement as a confinement material for column-like elements has been limited by the availability and evolution of fiber-reinforced polymer (FRP) composites. In the past two decades, considerable research has been conducted on FRP as a strengthening material for RC columns owing to the various advantages associated with this composite. However, FRP is a costly composite material and is occasionally unavailable in many developing countries given that it must be installed through highly skilled labour. FRP is also challenging to install in hot and humid weather and requires special measures. These disadvantages render FRP unsuitable for use in strengthening deteriorated or substandard structures in developing countries.

By contrast, ferrocement is a cost-effective technology in developing countries given that its raw materials are easily available. Moreover, this material need not be installed though highly skilled labour. Nonetheless, extensive research must be conducted on ferrocement to propose an efficient strengthening technology using this material. The present state of knowledge in this area must also be determined. Although the corrosion susceptibility of ferrocement is a topic of discussion for many years, this material is less vulnerable to corrosion compared with normal concrete as a result of the rich mix mortar that is encapsulated in the wire mesh. Nedwell et al. [6] stated that small-diameter steel wire mesh suffers reduced rate of corrosion and increased passivation whereas large-diameter steel bar shows increased corrosion and reduced passivation. Mansur et al. [7] suggested utilising silica fume in the mortar mix to eliminate the possibility of wire mesh corrosion in ferrocement. Therefore, ferrocement can be utilised to strengthen concrete structures in normal and marine environments, where corrosion susceptibility is particularly high. Several recent studies, which address the effects of concrete strength and the lap splice length of longitudinal reinforcements on the confinement behaviour of ferrocement-confined columns, have been conducted in this area. Researchers have also studied the behaviour of cracked or pre-loaded, square and rectangular ferrocement-confined RC columns. The current study presents a review based on findings regarding the ferrocement confinement of plain and RC concrete column-like elements. This review aims to determine the current state of knowledge in this area and to identify the areas where incurrent knowledge is lacking. This review also detects aspects of the subject that require future research to enhance the feasibility of ferrocement composites as a strengthening material.

2. Ferrocement technology and its advantages

Ferrocement is a composite construction material that consists of closely spaced single or multiple layers of steel mesh with or without skeletal steel support. This material is either completely infiltrated by or is encapsulated in mortar [8]. Naaman [9] defined ferrocement as RC in the guise of high-performing, thin elements with reference to the resistance of ferrocement to elongation, ductility and impact load. This composite material is sometimes referred to as thin-shell concrete.

Ferrocement was introduced as a construction material in 1848 by Frenchman Joseph Louis Lambot, who constructed a ferrocement boat. Although this composite material was created in Europe, it was enhanced further in developing countries owing to its low material cost and labour-intensive construction procedure [10]. No formwork is required for ferrocement construction, and it can be constructed as an extremely thin wall [11]. The tools required for manufacturing ferrocement are also particularly simple. Utilising this material in construction is advantageous because