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Improved ferrocement jacketing for restrengthening of square RC short column

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HIGHLIGHTS

- ▶ We carried out tests of RC short column without and with ferrocement jacketing.
- ▶ We propose square jacketing with single layer wire mesh and rounded column corners.
- ▶ Single layer wire mesh with shear keys at the center faces of column is also used.
- ▶ Single layer wire mesh and two extra layers mesh at each corner is applied.
- ▶ Proposed improved techniques shows better confinement over conventional jacketing.

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ABSTRACT

Conventional square ferrocement jacketing (square jacketing with single or multiple layers wire mesh) cannot provide lateral confinement effectively in restrengthening of square RC column due to stresses concentration at the column corners. Therefore, improvement of conventional square ferrocement jacketing technique is focused in this study. Three new square ferrocement jacketing techniques such as square jacketing with single layer wire mesh and rounded column corners (RSL); square jacketing using single layer wire mesh with shear keys at the center of each face of column (SKSL) and square jacketing with single layer wire mesh and two extra layers mesh at each corner (SLTL) are considered for this purpose. Entire study was carried out experimentally. A total number of 41 scaled down non-jacketed and ferrocement jacketed column specimens were tested under both concentric and eccentric modes of loading. Test results and the crack patterns of tested specimens show that all three improved square ferrocement jacketing techniques are effective to overcome the stress concentration problem of conventional square ferrocement jacketing. Among all jacketing techniques considered in this study SLTL type jacketing shows the best performance in carrying concentric loading, however, in case of eccentric loading, best performance is found in RSL type ferrocement jacketing.

1. Introduction

Reinforced concrete (RC) is used abundantly as a construction material in the city centers and the remotest areas of both the developing and developed countries. The structures made with this material often suffer damages due to overloading, natural disasters (like earthquake, Tsunami, Cyclone, Flood, etc.), fire, various environmental effects (like corrosion), change in building usage, etc., before reaching their intended design life. These damages may cause failure of structural elements to meet the functional requirements for its designed service life. If proper attention is not paid in this regard, entire structure could fail to carry its design load and catastrophe could happen.

Failure of the most authoritative structural element such as column may lead to total collapse of a frame-structured building as it is the only structural element that conveys the total vertical loads of the building to the earth. This member could loss its strength and stiffness due to damages occurred in its service life. Therefore, repair or reconstruction is necessary in case of noticeable crack for further carrying out loads and transmitting them to the ground [1].

One of the state-of-the-art methods used to carry structural loads by partially damaged column is the restrengthening of the column. Replacement of structurally weak concrete; fiber warps technique; external jacketing are normally used to restrengthen the RC columns according to their application [2]. Replacement

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of structurally weak concrete requires removal of deteriorated concrete and casting of new concrete in the same place. Fiber warps technique for restrengthening of RC column requires external warping with reinforced plastic fibers. Restrengthening of RC column using external jacketing is based on the well established fact that the lateral confinement of concrete core substantially enhances its compressive strength and ultimate axial strain [3]. RCC jacketing, steel jacketing, ferrocement jacketing, etc., are usually used as external jacketing of RC column.

In developing countries like Bangladesh, ferrocement jacketing can be an effective restrengthening tool for RC columns as its raw materials are readily available in these countries [4]. Application of this jacketing to RC column is very easy and needs no advanced techniques [5]. Due to uniform distribution of reinforcement, it has many improved engineering properties such as tensile and flexural strengths, toughness, fracture, crack control, fatigue resistance and impact resistance [6]. Low material cost, special fire and corrosion protection features made it an ideal means of jacketing in developing countries [7,8]. A recent study also shows that the ductility of ferrocement jacketed column is higher than that of FRP confined column [9].

Circular RC column subjected to axial compression, the concrete core is uniformly confined by the external jacketing (Fig. 1a) and the behavior of such uniformly confined concrete core with different confining materials has been studied extensively [10–17]. Lateral confinement for square column by different types of confinement techniques has also been studied by many researchers for the last few years. Abdullah and Takiguchi tested square column using both square and circular ferrocement jacketing under simultaneously compressive and seismic loads [18]. Tsai and Lin have proposed octagonal and modified octagonal shaped steel jacket for restrengthening rectangular reinforced concrete column [19–21]. They mentioned that both the octagonal and modified octagonal shaped jackets are also applicable for restrengthening of square RC column.

Among all jacketing techniques used to restrengthen square RC column, square jacketing is the most time saving and a low cost solution. Other jacketing techniques require shape modification which is time consuming as well as costly with respect to square jacketing. Square jacketing only provides confinement pressure at the corners, thus only a portion of the cross section gets effective confinement (Fig. 1b) [22–25]. Existing studies on steel confined concrete [22,26,27] and FRP confined concrete [28–32] affirm that the concrete in a square or rectangular section is confined by the external jacket through arching action (Fig. 1b).

Recently, researchers are also trying to overcome the drawbacks of square jacketing technique through both experimental and analytical studies. Some of investigations have been carried out to reduce the stress concentration at the corners using FRP restrengthening technique in square RC columns [33,34]. Jacketing with rounded column corner is among of them that gives certain degrees of confinement through reducing stress concentration at corners of the square RC column.

Studies on conventional square ferrocement jacketing of square RC column with plenty of merits/demerits are found in literature. No studies so far are reported in literature to overcome the drawbacks of square ferrocement jacketing. In this study, all possible approaches for ferrocement jacketing are adopted experimentally to get an efficient square ferrocement jacketing technique in restrengthening of square short RC column. These types of jacketing could be a representative of improving strength of existing substandard column and improving load carrying capacity of previously cast column that requires for vertical extension of existing structure and for other anticipated phenomena.

2. Experimental studies

Experimental investigations were carried out on non-jacketed, conventional ferrocement jacketed and improved ferrocement jacketed square RC short column specimens to see the effect of improved ferrocement jacketing over the non-jacketed and conventional ferrocement jacketed specimens. Entire study was done in two phases under monotonically increasing load. In the first phase, 17 scaled down (length, L = 600 mm, breadth, b = 100 mm with L:b = 6:1) column specimens with normal tie were tested under concentric mode of loading. In the second phase, 24 scaled down (L:b = 6:1) column specimens with seismic tie were tested under concentric mode of loading as well as eccentric mode of loading. Among 24 specimens of second phase, 12 specimens were tested under concentric mode of loading and the rest of 12 specimens were tested under eccentric mode of loading. The concept of scaled down was adopted from the work of Kondraivendhan and Pradhan [4]. Among all tested specimens, five specimens in the first phase and six specimens in the second phase were tested without any jacketing and were denoted as NJ. Four types of ferrocement jacketing were taken into consideration in this study. These are: (i) Square jacketing with single layer wire mesh (conventional square ferrocement jacketing denoted as SL); (ii) Square jacketing with single layer wire mesh and rounded column corners (denoted as RSL); (iii) Square jacketing with single layer wire mesh and shear keys at the center of each faces (denoted as SKSL) and (iv) Square jacketing with single layer wire mesh and two extra layers mesh at each corner (denoted as SLTL). Corner radius in type RSL was considered as approximately 12 mm in the first phase and 24 mm in the second phase. In type SKSL specimen, 2 mm (dia.) steel nails with nailing depth of 25 mm were used as shear keys at a vertical spacing of 50 mm along the length of the column specimens. Details of all ferrocement jacketing techniques are shown in Fig. 2. In the first phase of experimental study, all four types of ferrocement jacketed column specimens were tested. However, in the second phase of testing, only type SL, RSL and SLTL jacketed column specimens were tested. SKSL type ferrocement jacketing was omitted in this phase because of its performance was found very low in restrengthening of square RC column during first phase of testing. Number of test specimen was three for all types of ferrocement jacketing in both first and second phases of studies.

2.1. Materials for test specimens

Fresh Ordinary Portland cement (OPC) of grade 43 conforming Type I of ASTM C-150 [35] was used for making both concrete and ferrocement mortars. Locally available 12 mm downgraded crushed stone was used as coarse aggregate in mak-

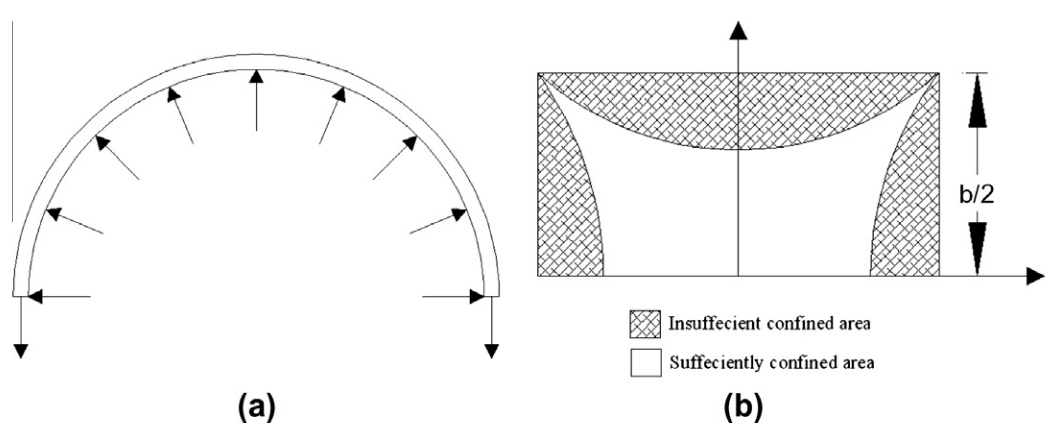

Fig. 1. Confinement of jacketed column, (a) circular jacketing, and (b) square jacketing (Teng et al. [23]).