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Low Cost Confinement of Masonry Columns

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Abstract

Masonry structures are prone to extensive damage followed by failure and collapse when subjected to static overloads or loads resulting from wind, earthquake and other natural or man-made events. Thus retrofitting and strengthening of masonry structures, in order to furnish structural ductility and additional strength is of primary importance. Recent earthquakes and terrorist acts have clearly demonstrated that the development of effective and affordable strategies for the strengthening of masonry is urgently needed. As a response to these challenges, fiber-reinforced polymer (FRP) composites may offer technically viable solutions. But because of the high cost, FRP's are not often used. In this study an effort has been made to replace FRP with the locally available low cost Tin sheets of the mustard oil containers for the confinement of masonry columns. Columns built with solid clay bricks, commonly found in India and many other countries in residential & historical buildings, were tested under compression static loads. Square masonry columns were tested taking into account the influence of several variables: different strengthening schemes, number of layers and aspect ratio. The results were good enough to make this study a success.

Keywords: retrofitting, fibre reinforced polymers, frps, confinement, masonry columns, fpr.

INTRODUCTION

Confinement is generally applied to members in compression, with the aim of enhancing their load bearing capacity or, in case of seismic upgrading, to increase their ductility. The confinement in seismically active regions has proven to be one of the early applications of FRP materials in infrastructure applications. Confinement may be beneficial in non-seismic zones too, where, for instance, survivability of explosive attacks is required or the axial load capacity of a column must be increased due to higher vertical loads, e.g. if new storey's have to be added to an existing building or if an existing bridge deck has to be widened. In any case, confinement with FRP may be provided by wrapping RC columns with prefabricated jackets or in situ cured sheets, in which the principal fiber direction is circumferential.[1,2,3]

One of the main problems connected with preserving and maintenance of historic buildings and existing dwellings is the need for strengthening and retrofitting of the masonry parts of the structures. The application of FRP materials is very beneficial having in mind its easy installation, low self-weight, high strength and ability to preserve the initial shape of the column. However, there are some factors limiting its frequent use such as:

1. Lack of design codes on FRP in many countries like India, &
2. Very high material cost.

In this study an effort has been made to replace FRP materials with low cost Tin sheets of the mustard oil containers & PVC pipes for the purpose of strengthening the masonry columns and PCC columns respectively. These containers are made of nickel coated tin sheets of ferrous metal.[2,4,5,6]

EXPERIMENTAL SETUP

Test Specimens

A total of 12 model masonry column specimens in two groups were constructed using clay bricks .The dimensions of bricks were 100mm width, 75mm height, and 225mm length, and were bonded together with mortar containing cement as binder, at cement: sand ratio equal to 1:4 and w/c ratio of 0.6. The cross-sectional area of the specimens in first group was 225mm × 225mm and for second group 350mm × 350mm .The height of model columns for both groups was 600mm. Each model column comprised bricks placed in seven rows with six bed joints in between and mortar thickness was kept 10mm in general, as shown below (Fig 1). The purpose was to find out the comparative study between the un-confined masonry columns & confined masonry columns.

Figure 1 (Pictures captured in structural lab during the construction of columns)

In order to get the required dimensions of the tin sheets used for the confinement of the masonry columns, the sheets were joined by the spot welding in the mechanical engineering laboratory (Fig 2). The sheets were cold-bended with an appropriate apparatus in the mechanical engineering lab to form a square section identical to the cross-sections of the masonry columns.

Figure 2a) Sheet bending by the swaging machine

Figure 2b) spot welding process

In the first two groups of masonry columns, two columns were unreinforced, another two columns were reinforced by wrapping the sheets of the tin in a single layer and the last two columns were reinforced by wrapping two layers of tin sheets. Wrapping of the Tin sheets took place after curing for at least 28 days in laboratory conditions. The tin sheets were wrapped around the columns horizontally. The application of the tin sheets was a simple and rapid operation. 50 mm long screws having 4 mm diameter and plastic conical anchorage was used to fix the tin sheets on the model column. Electric driller was used to make holes for the plastic conical anchorage.

Experimental Programme

The compression test of the model columns was carried out in three groups according to the shape and size of the columns. These groups were further divided into sub-groups according to the wrapping scheme.

Table 1 shows the experimental programme for the compression test.

TABLE 1: EXPERIMENTAL PROGRAMME FOR COMPRESSION TEST

S.NO.	*SHAPE*	*X-section (mm)*	*HEIGHT (mm)*	*WRAPPING SCHEME*	*SPECIMEN NAME*
GROUP 1 (MASONRY COLUMNS)					
1	*square*	*225x225*	*600*	*unconfined*	*MC-A0*
2	*square*	*225x225*	*600*	*Single wrap*	*MC-A1*
3	*square*	*225x225*	*600*	*Double wrap*	*MC-A2*
GROUP 2 (MASONRY COLUMNS)					
1	*square*	*350x350*	*600*	*unconfined*	*MC-B0*
2	*square*	*350x350*	*600*	*Single wrap*	*MC-B1*
3	*square*	*350x350*	*600*	*Double wrap*	*MC-B2*

RESULTS

Column specimens MC-A0 & MC-B0 were taken as reference specimens and underwent testing without any type of reinforcement. The load was applied at an interval of 30KN and the deformations were recorded for each interval of loading until the failure occurs. The control specimens MC-A0 & MC-B0 failed at a load of 9.1Ton & 23.0 Ton respectively, corresponding to compressive strengths of 1.79 N/mm^2 and 1.87 N/mm^2 respectively (Table 2). The compressive stress caused the columns to fracture with vertical cracks formed through mortar joints and solid clay bricks (Fig 3). The compressive strengths and the corresponding strains of all model columns are shown in Table 2.

The reinforcing action of the tin sheets was significant for both the reinforcing schemes (single layer and double layer wrap). As can be noted in Table 5.4, the average increase in strength was approximately 64% in the case of single layer wrap (MC-A1 & MC-B1) and 69.5% for double layer wrap (MC-A2 & MC-B2).

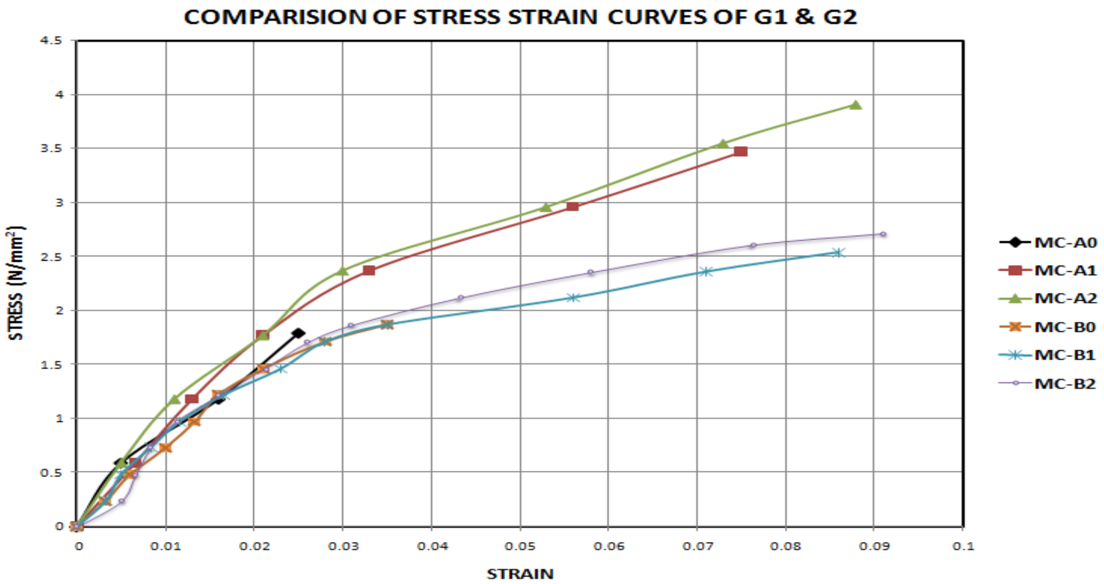
All reinforced specimens failed by the rupture of the tin sheet jacket due to hoop tension after the masonry had disintegrated (Fig 3). The failure was preceded by a visible transversal deformation of the specimen in about the middle.

Figure 3. Failure modes of unreinforced and reinforced masonry model columns.

TABLE 2 : COMPRESSION TEST RESULTS

S.NO.	***Specimens***	***Compressive load (KN)***	***Compressive strength (N/mm^2)***	***Deformation (mm)***	***Axial Strain***
GROUP 1 (MASONRY COLUMNS)					
1	*MC-A0*	*91*	*1.79*	*15*	*0.025*
2	*MC-A1*	*176*	*3.47*	*45*	*0.075*
3	*MC-A2*	*198*	*3.91*	*53*	*0.088*
GROUP 2 (MASONRY COLUMNS)					
1	*MC-B0*	*230*	*1.87*	*21*	*0.035*
2	*MC-B1*	*312*	*2.54*	*52*	*0.086*
3	*MC-B2*	*334*	*2.72*	*55*	*0.091*

Stress-strain curves from each interval of loading and the corresponding deformations were drawn for all the three group of model columns as shown below. The graphs were drawn by using MS Excel 2007.



Comparison of stress-strain curves of all masonry columns of Group1 and Group2

By examining the stress-strain curves in terms of strength and strain, it is observed that low cost tin sheet confinement significantly enhances both the strength and the deformability of masonry under axial load. Enhancement in deformability was much more pronounced than gain in strength, as the ultimate strain of confined masonry exceeded that of unconfined masonry. It is also observed from that effect of confinement decreases with the increase in cross-section of masonry columns.

CONCLUSION

The behavior of masonry columns before and after strengthening using low cost Tin sheets was investigated and following conclusions are drawn:-

- Tin sheets are effective in increasing the compressive strength of masonry columns. The tin sheets improved the compressive strengths by a factor up to 1.64 and 1.69 for masonry columns by the single layer wrapping and double layer wrapping respectively
- Low cost tin sheet confinement is also effective in increasing the ductility of masonry columns.
- The axial strength was improved significantly due to confinement. As expected, the effectiveness of confinement reduces with increase in cross-sectional area.

FUTURE WORK

Researches in strengthening old masonry structures are relatively new. Very few researchers are working hard to develop this field. In this research an effort has been made for strengthening the masonry columns with the low cost Tin sheets of mustard oil tin containers .Some fields which especially demand further research are listed below.

- Further research is needed to evaluate the optimal amount of reinforcement to strengthened square and rectangular columns, as it is found that there is almost proportional relation in increase in strength and number of layers applied.
- Further research is needed with the continuous wrapping of the tin sheets.
- Further research is needed to evaluate the aggressive environmental factors such as temperature, freeze-thaw cycles, UV exposure, alkalinity etc.

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