Journal of Engineering and Applied Sciences 14 (18): 6747-6752, 2019
ISSN: 1816-949X
© Medwell Journals, 2019

Load Carrying Capacity of Timber Columns Strengthening by Steel Jacket

Ragheed Fatehi Makki, Salah Talib Nimnim and Ashraf Aamir Mohamed
Faculty of Engineering, University of Kufa, Kufa, Iraq

Abstract: This study aims to offer the applicable strengthening technique for axially loaded timber columns using steel angles and battens. The columns which manufactured from timber in buildings oftentimes need strengthening for several reasons such as shortcoming in the columns themselves, having to prop up additional loads than those expected in the primary design or as the result of old age or occasional damage. Experimental work is achieve to study the behavior of timber columns strengthened from outside by steel jacket under axial loads effect. This search includes fabricate nine specimens of timber columns with the same square cross section of 89×89 mm and height of 1000 mm. These specimens classified to four categories, the first category (comprises one column) represents the comparative sample without any kind of reinforcing while second category (involves three columns) strengthened by different sizes of four vertical steel angles at column corners fastened by horizontal battens of the constant size and spacing, the study expanded to third category (comprises three specimens) strengthened by constant sizes of four vertical steel angles at column corners fastened by different sizes of steel plates at top and bottom of columns, the other variable was studied in the fourth category which (involves two columns) strengthened by constant sizes of four vertical steel angles at column corners fastened by (horizontal battens of constant sizes but different in spacing). The results indicated that the strengthening technique of timber columns by using outside steel jacket can improve the ultimate load by 38.7-112.9%.

Key words: Timber, columns, axial load, strengthening, steel jacket, ultimate load

INTRODUCTION

Timber and stone represents the oldest construction materials that have been used over the years in different countries because of their ability to resist external loads which made it the most complete choice in construction before the availability of steel. In last decades, the construction industry has resulted in an spacious use of steel and concrete resulting in a significant reduction in the availability of these materials and a dramatically increase in their prices. The researchers predict that repeated use will lead to the end of steel and concrete 1 day. So, it is very essential to evolve a more sustainable construction technology that utilizing advanced construction material, here the timber becomes an alternative and very suitable material because it is one of the materials used in construction that is naturally renewable and it is friendly environmental (Ahmad, 2010). Timber has several significant characteristics such as excellent strength to weight ratio, light weight, easy construction and transportation and it is considered an excellent economic alternative to concrete and steel. The main features required in timber to using as structural members are strength, stiffness and durability (Dolan *et al*., 1997).

Timber can be strengthened using steel cage to improve its mechanical properties, the capacity of timber column could be increased by adding confinement around the column. This technique is very efficient and dimensions of timber column are does not changed. Steel caging in which steel angles are placed at all column corners and fixed together by steel battens (Areemit *et al*., 2013). The purpose of this study is to evaluate the performance of using steel angles and battens in strengthening timber columns.

Pinto (2008) presented a study on stabilization, repair and strengthening techniques aiming at structural restoration of timber elements, his study was expanded to discussed the mechanical properties of the timber its historical use on buildings besides study the reasons for need strengthening of the timber elements in order to evaluate the presented strengthening process. The researcher focus on both conventional and neoteric methods by using various materials, their practical applications, median and long term response, resulted in an important summary of repair and strengthening techniques, according to, the recommendations of the modern philosophy of conservation and restoration.

Gonzalez-Bravo *et al*. (2012) discussed the behavior of cold formed steel segments regarding to mechanical

Corresponding Author: Ragheed Fatehi Makki, Faculty of Engineering, University of Kufa, Kufa, Iraq

properties such as deflection fundamentally. A cold formed steel segments was studied with constant thickness of (1 mm) to evaluate its ability as reinforcement of timber elements. Therefore, stresses and strains, deflection, temperatures were analyzed during the manufacturing operation of these segments, comparative study was performed between reinforced and unreinforced segments. The analysis has been performed by a finite element method using two dimensional program (DEFORM) during the simulation of manufacturing operation and (COPRA) program during the final calculations. Results presented entire data about the perfection and optimal response of these segments for timber enhancement.

Cai *et al*. (2012) presented the search data regarding on the response of timber columns with longitudinal cracks which testing under compression effect. In order to study the collapse patterns and the ultimate strength capacity of cracked timber column specimens by using the Fiber Reinforced Polymer (FRP) sheets, several tests of material properties and compression were performed. Different compositions of column geometry, crack dimensions, types and spacing of fiber reinforced polymer sheets were investigated. A numerical model of Finite Element Method (FEM) was improved and checked according on the grounds of the test results. The influence of many variables were studied by utilizing the confirmed model in addition effects of cracks measurement, kinds and distances of fiber reinforced polymer strips. the results stated that using of fiber reinforced polymer strips around cracked timber columns can retrieval their strength capacity by about 20%.

Chang (2015) provided a summary of recent techniques of repairing and strengthening on wood columns and walls under shear effect in both theoretical and practical applications. The two schemes together in the experimental measure and veritable repair/strengthening schemes were tested. It investigates two grades of issues: the repair and strengthening of timber specimens. The repair operation concentrates on deteriorated members and the reinforcement operation concentrates on improving the characteristics of the members. At first, the requirements to strength and repair wood columns and walls under shear effect is studied, then the comprehensive survey of recent technologies for strength and repair. Features and defects of various recent technologies were analyzed, so as, to stated and benefit in the following practical applications and research. At last, many significant cases such as restortion of strength and long term response were discussed.

MATERIALS AND METHODS

Column specimens and strengthening schemes: The test columns specimens have been manufactured at workshops of Engineering College University of Kufa. All columns specimens were 1 m in height and have cross section of 89×89 mm, the type of timber was chosen from the imported wood to Iraq which known as white wood. The wood columns comprises of four categories, the first category (involves one column) represents the control sample without any kind of strengthening, second category (involves three columns) strengthened by different sizes of four vertical steel angles at column corners (first size of L (20×20×2.5 mm), second size of L(25×25×2.5 mm) and third of L (30×20×2.5 mm) fastened by horizontal battens of the constant size and spacing, third category (involves three columns) strengthened by constant sizes of four vertical steel angles at column corners (all angles of size L (20×20×2.5 mm) fastened by different sizes of steel plates at top and bottom of columns while fourth category (includes 2 columns) strengthened by constant sizes of four vertical steel angles at column corners (all angles of size L (20×20×2.5 mm) fastened by (horizontal battens of the constant sizes but different in spacing). The four angles at top and bottom were connected together by using two methods: (first by tying horizontal steel battens and second by steel plates) both of 3 mm in thickness. Weld were used beside epoxy to connect both the tying horizontal battens and plates with the angles which fastened to timber by bonding using two types of epoxy resin (resin part A+hardener part B). The tying plates were different in length while tying battens were of constant size but different in spacing from column to another to inspect the effect of angles bond on the column load carrying capacity. Table 1 and Fig. 1 explains each category of columns with strengthening pattern and steel cage arrangement.

Table 1: The categories of columns specimens and strengthening arrangement

Categories/Specimen No.	Angles details (mm)	Tying plates details (mm)
Category A		
C1	None	None
C2	C (20×20×2.5)	6 plates (25×95×3)
Category B		
C3	C (25×25×2.5)	6 plates (25×95×3)
C4	C (20×30×2.5)	6 plates (25×95×3)
Category C		
C5	C (20×20×2.5)	2 plates (150×95×3)
C6	C (20×20×2.5)	2 plates (200×95×3)
C7	C (20×20×2.5)	2 plates (250×95×3)
Category D		
C8	C (20×20×2.5)	5 plates (25×95×3)
C9	C (20×20×2.5)	11 plates (25×95×3)

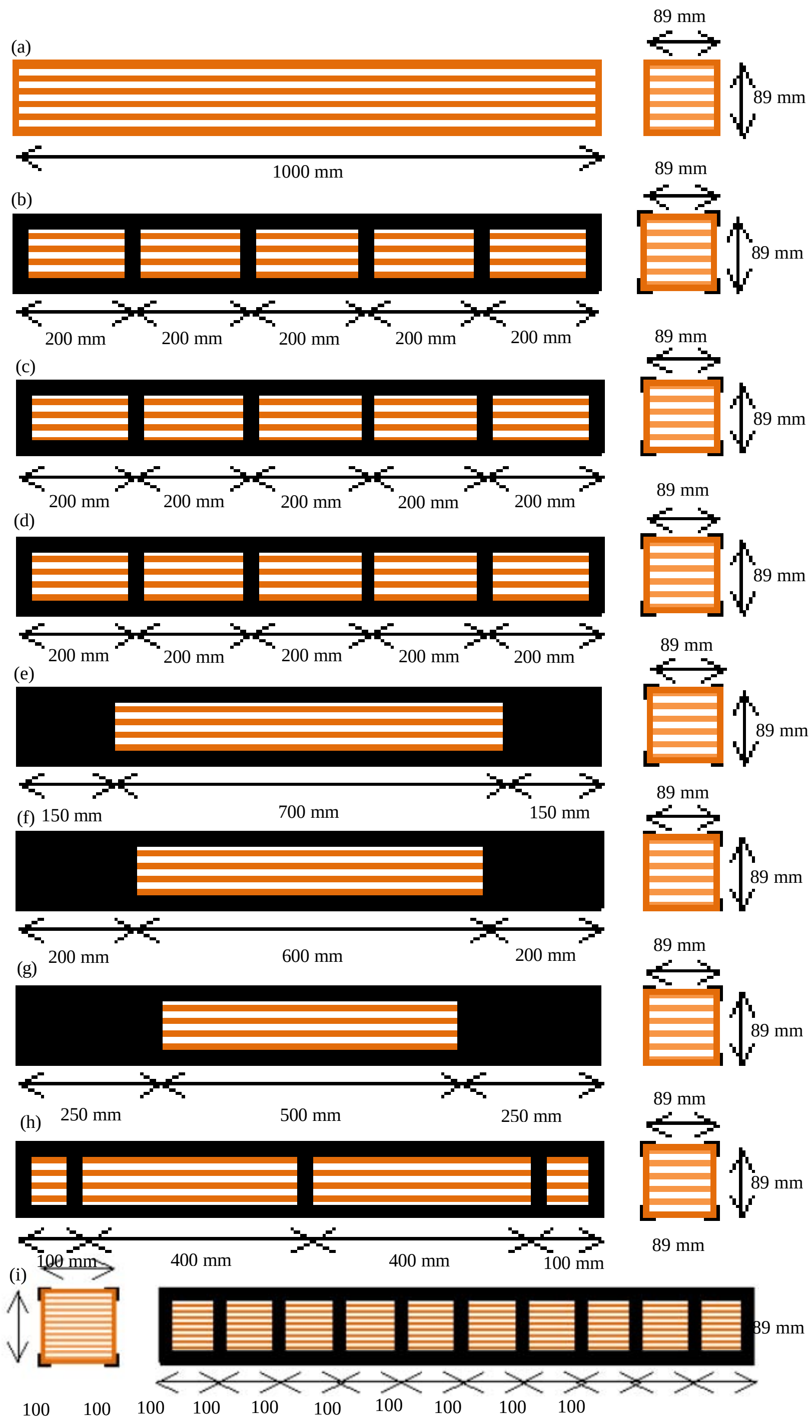

Fig. 1: Details of strengthening arrangements for column specimens: a) C1; b) C2; c) C3; d) C4; e) C5; f) C6; g) C7; h) C8 and I) C9

RESULTS AND DISCUSSION

All timber columns specimens are tested in a universal testing machine with a capacity of 2000 kN at the laboratory of structures in Engineering College of Kufa University. The test columns are rested on stiff steel frame, the load is applied axially and monotonically increasing up to failure. Firstly, control column is tested

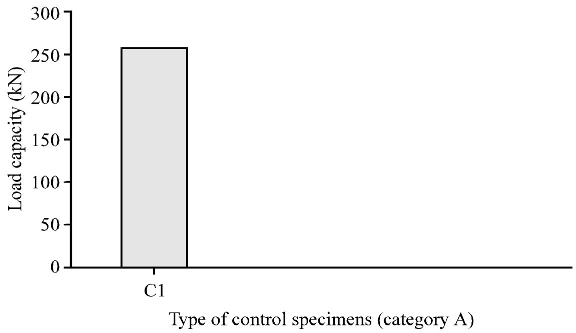

Fig. 2: Ultimate load capacity of control column

Table 2: Ultimate load capacity of tested columns specimens

Categories/Specimen	Ultimate load (kN)	Increase in ultimate load (%)
A		
C1	155	-
C2	260	67.7
B		
C3	305	96.8
C4	295	90.3
C		
C5	240	54.8
C6	255	64.5
C7	265	70.9
D		
C8	215	38.7
C9	330	112.9

up to failure and the output data is recorded, the results represents the values of ultimate loads which can be illustrated in Table 2.

When control specimen column is axially loaded parallel to timber grains each wood fiber works as individual hollow column which some support from neighboring fibers. When the axial load increasing, the longitudinal cracks will be appears in a parallel direction to the wood fibers at a distance of about one third or more of the top and bottom supports and gradually spread along the column, at the failure a number fibers buckle simultaneously producing a local reduction of strength causing to ductile failure, we can notice that the individual fiber beginning to separate and buckle under the compressive actual forces. The side deformation and vertical displacement are growing till failure. For the control specimen (C1), the results show that the ultimate axial load capacity is recorded as (155 kN) as shown in Fig. 2.

Strengthening effect of using steel jacket: The effect of strengthening the column specimens by the first pattern of strengthening (category B) which comprises of three columns by different sizes of four vertical steel angles at column corners (first size of L (20×20×2.5 mm), second size of L (25×25×2.5 mm) and third of L (30×20×2.5 mm) linked by horizontal battens of constant size and spacing is shown in Fig. 3. It is observed from the experimental data and the corresponding bar graph that strengthening leads to increase in the ultimate load carrying capacity from (155 kN) for the control column (C1), to 260, 305 and 295 kN for first category of strengthened Columns C2-C4, respectively. Thus, there is an increase in ultimate loads as 67.7% for C2, 96.8% for C3 and 90.3% for C4 comparing with control Column (C1), respectively as shown in Fig. 4. This noticeable increase can be attributed to the significant increase in stiffness due to the strengthening method by four steel angles of various sizes.

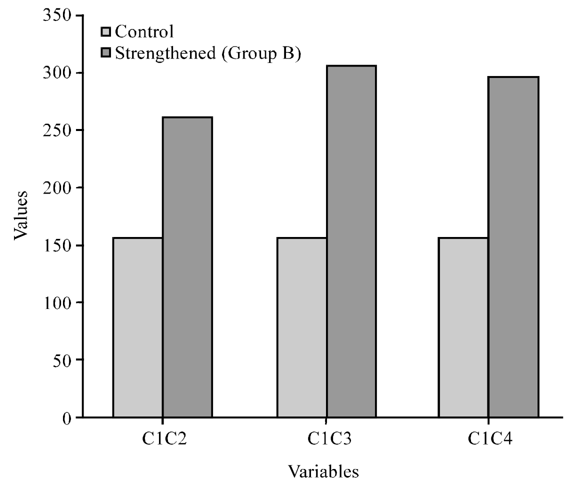

Fig. 3: Ultimate load capacity of strengthened columns (category B)

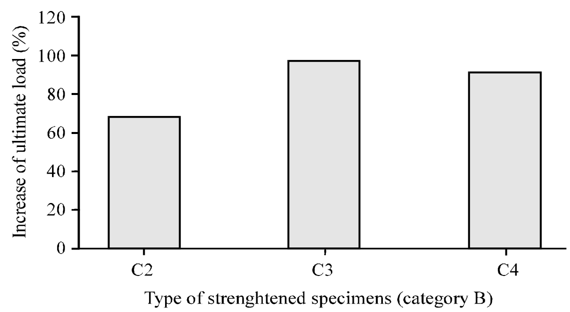

Fig. 4: Increase of ultimate load capacity for strengthened columns (category B)

The second pattern of strengthening the columns (category C) comprises of three columns strengthened by using constant sizes of four vertical steel angles at column corners (all angles of constant size L (20×20×2.5 mm) fastened by different sizes of steel plates at top and bottom of columns. It is noticed from the experimental data and the corresponding bar graph that this type of strengthening leads to increase in the ultimate

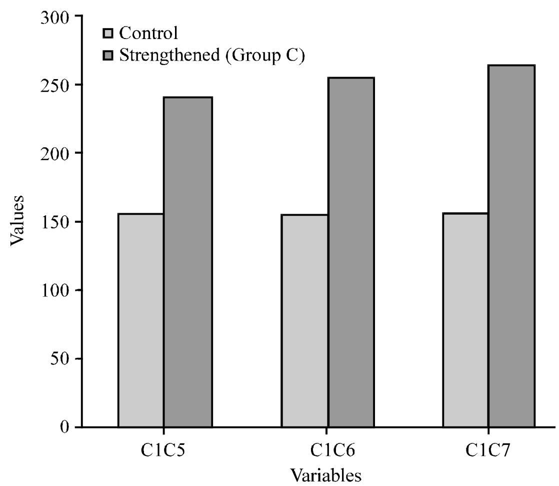

Fig. 5: Ultimate load capacity of strengthened columns (category C)

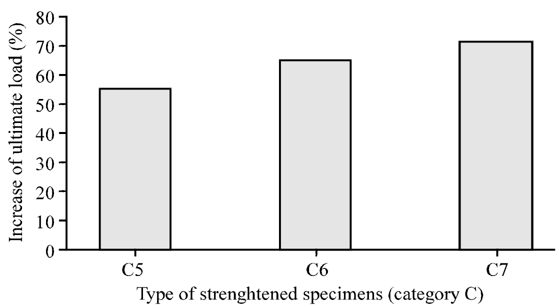

Fig. 6: Increase of ultimate load capacity for strengthened columns (category C)

load carrying capacity from 155 kN for the control Column (C1) to 240, 255 and 265 kN for second category of strengthened columns C5-C7, respectively as shown in Fig. 5. Therefore, there is an increase in ultimate loads as (54.8%) for (C5), (64.5%) for (C6) and (70.9%) for (C7) comparing with control Column (C1), respectively, as shown in Fig. 6. This noticeable increase can be attributed to the significant increase in stiffness due to the strengthening method by four steel angles. This remarkable increase in the ultimate capacity can be explained due to the considerable increase in stiffness and the huge role of the strengthening method by four steel angles have the constant size beside to the main role of tying steel plates in strengthening.

The effect of strengthening the column specimens by the third pattern of strengthening (category D) which comprises of two columns by constant sizes of four vertical steel angles at column corners (all angles of constant size L (20×20×2.5 mm) linked by horizontal battens of constant size and different in spacing is shown

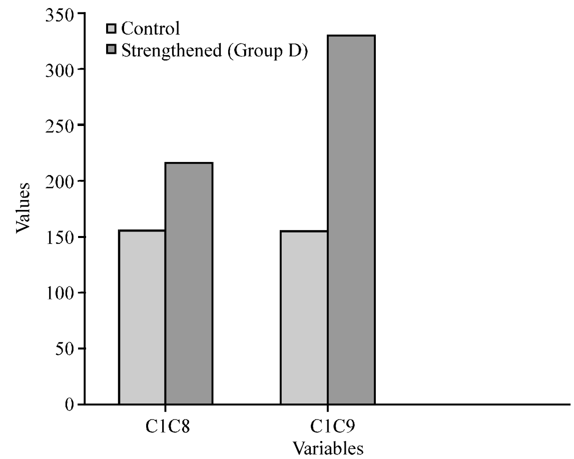

Fig. 7: Ultimate load capacity of strengthened columns (category D)

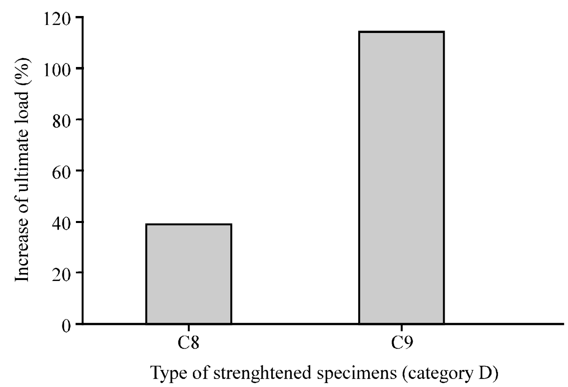

Fig. 8: Increase of ultimate load capacity for strengthened columns (category D)

in Fig. 7. The experimental data and the corresponding bar graph stated that strengthening leads to increase in the ultimate load carrying capacity from 155 kN for the control Column (C1), to 215 and 330 kN for third category of strengthened Columns (C8) and (C9), respectively. There is an increase in ultimate loads as 38.7% for (C8) and 112.9% for (C9) comparing with control Column (C1), respectively, as shown in Fig. 8. This remarkable increase in the ultimate capacity can be discussed as the considerable increase in stiffness and the huge role of the strengthening method by four steel angles have the constant size beside to the excellent distribution and closely spacing of tying horizontal battens in strengthening.

CONCLUSION

This study can be reached according to the test results that obtained in this study: the strengthening technique of timber columns adopting in this research by using external steel jacket performed by using steel angles and (battens or steel plates) is applicable and can significantly increase the ultimate load for all cases of strengthening by 38.7-112.9% compared with the unstrengthened (control) columns. For the first case of strengthening (category B) when timber columns externally strengthening by different sizes of four vertical steel angles at column corners fastened by horizontal battens of the constant size and spacing, the ultimate capacity is significantly increased by 67.7-96.8% compared with the unstrengthened (control) column.

For the second case of strengthening (category C) when timber columns externally strengthening by constant sizes of four vertical steel angles at column corners fastened by different sizes of steel plates at top and bottom of columns, the ultimate capacity is significantly increased by 54.8-70.9% compared with the unstrengthened (control) column.

For the third case of strengthening (category D) when timber columns externally strengthening by constant sizes of four vertical steel angles at column corners fastened by (horizontal battens of constant sizes but different in spacing, the ultimate capacity is significantly increased by 38.7-112.9% compared with the unstrengthened (control) column. The using of steel jacket carried out by using steel angles and (battens or steel plates) as external strengthening to timber columns leads to significant rise in stiffness, toughness and robustness causing in improving the mode of failure from the short-term ductile mode for unstrengthened timber columns to long-term ductile mode for strengthened columns.

REFERENCES

Ahmad, Y., 2010. Bending behavior of timber beams strengthened using fiber reinforced polymer bars and plates. Ph.D Thesis, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.

Areemit, N., N. Faeksin, P. Niyom and P. Phonsak, 2013. Strengthening of deficient RC columns by steel angles and battens under axial load. Proceedings of the 13th International Conference on East Asia Pacific Structural Engineering and Construction (EASEC-13), September 11-13, 2013, Hokkaido University, Sapporo, Hokkaido, Japan, pp: I-7.

Cai, Y.J., W. Zhang and W.P. Zhang, 2012. Experimental study on eccentric compression behavior of timber columns with longitudinal cracks strengthened by CFRP sheets. J. Adv. Mater. Res., 446: 3132-3136.

Chang, W.S., 2015. Repair and reinforcement of timber columns and shear walls-A review. Constr. Build. Mater., 97: 14-24.

Dolan, C.W., T.L. Galloway and A. Tsunemori, 1997. Prestressed glued-laminated timber beam-Pilot study. J. Compos. Constr., 1: 10-16.

Gonzalez-Bravo, C., J. Claver, R. Alvarez and R. Domingo, 2012. Improvement of the mechanical properties of formed steel cross section profile for timber upgrading. Adv. Mater. Res., 498: 139-144.

Pinto, L., 2008. Inventory of repair and strengthening methods timber. Master Thesis, Polytechnic University of Catalonia, Barcelona, Spain.