# TRANSVERSE STRESS DISTRIBUTION IN CONCRETE COLUMNS EXTERNALLY CONFINED BY STEEL ANGLE COLLARS

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## ABSTRACT

Transverse confining stress in concrete columns has been known to enhance the strength and ductility. Recently, external confinement techniques have been widely developed due to the high demand of columns retrofits. For square or rectangular columns, providing effective confining stress by external retrofit is not an easy task. The stress concentration at corners causes highly non-uniform confining stress distribution. One approach of external retrofit for rectangular concrete column is by using steel collars. Simple collars consist of steel angles connected by bolts in their corners can be a promising retrofit method.

In this study, the proposed retrofit method is simulated by Finite Element approach using the ABAQUS software. Steel Collars consisting of four steel angles installed with uniform spacing are used to confine the columns externally. The model is subjected to uniform unit compressive pressure on top, and restraint by vertical rollers on the bottom. An important assumption is made by making perfect bond between concrete column and the steel collars. The connections at four corners of each collar are also assumed to be perfect. The main objective of the study is to observe if 3D Finite Element modeling by using ABAQUS can simulate the confining effect of the steel collars.

Results show that the steel collars suffer both axial and bending action in order to confine the concrete lateral expansion. Consequently, the concrete experiences transverse stress distributions from the confinement effect. However, relatively uniform transverse stress distribution due to strong contact between concrete and steel collars may not be achieved easily in actual practice. But the results indicate that if the steel collars are strong enough, more uniform transverse stress distribution can be expected. In conclusion, the Finite Element modeling by ABAQUS software in this study, can predict the behavior of the idealized retrofit approach.

**Keywords:** ABAQUS, finite element, steel collars, confining stress distribution, RC columns.

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## 1. INTRODUCTION

Transverse confining stress in concrete columns has been known to enhance the strength and ductility (Mander et.al. 1988, Saatcioglu and Razvi 1992, Sheikh and Uzumeri 1980). Such stress can be provided by internal confinement (conventional stirrups) or external confinement. Recently, external confinement techniques have been widely developed due to the high demand of columns retrofits (Chai et.al. 1994, Priestley et.al. 1994, Wu et.al. 2003). Many techniques have been proven to be successful in retrofitting circular columns. However, for square or rectangular columns, providing effective confining stress by external retrofit is not an easy task. The stress concentration at corners causes highly non-uniform confining stress distribution (Choi et.al. 2010, Guo et.al. 2006, Nesheli and Meguro 1992, Priestly et.al. 1994, Saatcioglu and Razvi 1992, Saatcioglu and Yalcin 2003, Xiao et.al. 2003). One new approach of external retrofit for rectangular concrete columns is by using steel collars (Hussain and Driver 2005, Liu et.al. 2008). This approach has advantage of being easy to use in practice. Simple collars consist of steel angles connected by bolts in their corners can be a promising retrofit method. Aside of non-uniform confining stress, the behavior of such approach is still not known well due to highly uncertainties in contact between steel collars and the rectangular concrete column. It is natural to conduct computer simulation before conducting experiment on new method with many specimens. This study, with some idealized assumptions, aims to observe the potential of the external retrofit method.

## 2. SPECIMEN CONSIDERED

In this study, a simple specimen of externally confined reinforced concrete column is considered. Steel Collars consisting of four steel angles installed with uniform spacing are used to confine the columns externally. The specimen considered can be seen in Figure 1.

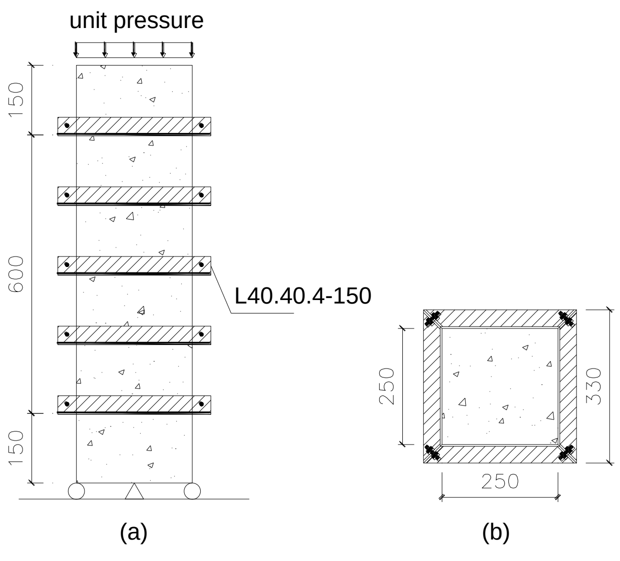



**Figure 1: The Specimen Considered.**

The concrete column model (250×250×900) is confined by steel angle collars (L40.40.4) equally spaced at 150 mm. The model is subjected to uniform unit compressive pressure on top, and restraint by vertical rollers on the bottom. The compressive strength of the concrete, $f_c$' is taken as 20 MPa (corresponding elastic modulus is determined by current Indonesian Concrete Code, the SNI 03-2847-1992). Steel elastic modulus, $E_s$ is taken equal to 20000 MPa.

## 3. FINITE ELEMENT MODELING IN ABAQUS SOFTWARE

In this study, an important assumption is made by making perfect bond between concrete column and the steel collars. This assumption is modeled by giving "tie" constraint for contact surface between steel angle collars and concrete. The connections at four corners of each collar are also assumed to be perfect. This is modeled by blending the four steel angles into one monolithic steel angle collar, without connection in its corners (Figure 2).

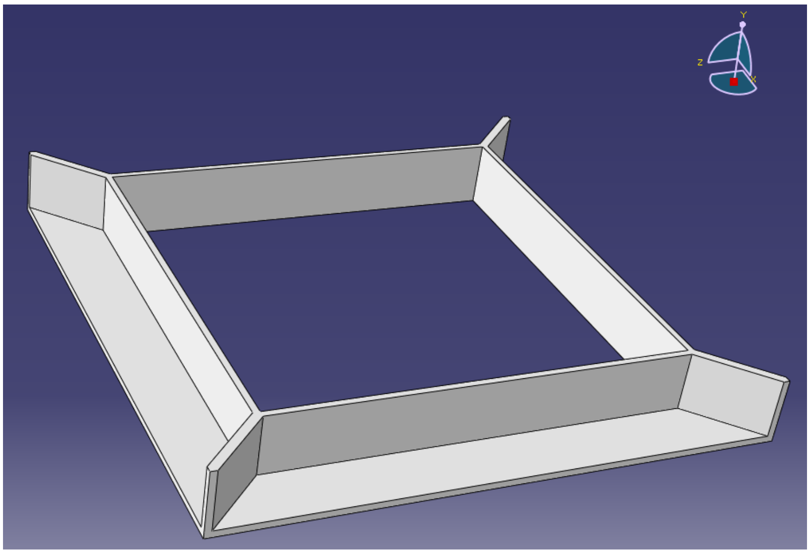


**Figure 2: Monolithic Model of Steel Collar Used in the Study.**

Standard homogenous elastic materials are used for both concrete and steel. The restraints are modeled to allow the bottom of specimen to move freely in lateral direction, thus eliminating confinement effect of boundary condition. Element type used for both concrete and steel collars is the 8-noded 3D brick element (C3D8) without reduced integration. Under standard mechanical uniform compressive pressure, static linear analysis is performed on the specimen. The main objective of the study is to observe if 3D Finite Element modeling by using ABAQUS can simulate the confining effect of the steel collars. The whole model is meshed with 20 mm characteristic size. Illustration of the meshed specimen in ABAQUS can be seen in Figure 3.

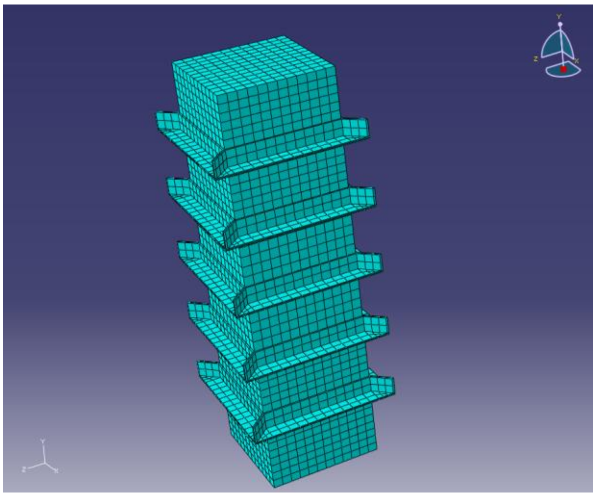
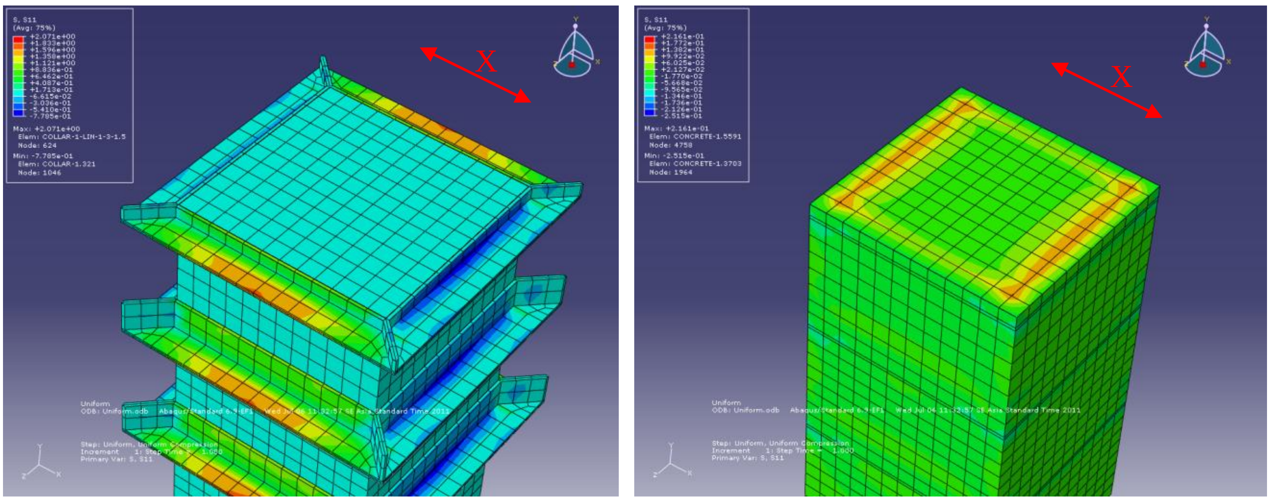


**Figure 3: The Finite Element 3D Model.**

## 4. RESULTS AND DISCUSSION

Figure 4a shows the transverse stress contour on X-direction, sliced in the mid-height of the specimen. It can be seen, that steel collars parallel to X-direction suffer more stress. Further, the outer most parts of the parallel steel angles show maximum tension stress. It verifies that combined axial and bending actions in the steel collars play role in confining the concrete (can be seen by un-uniform axial stress). In Figure 4b, the same transverse stress contour is plotted on the concrete only. It can be seen that, the sides of the concrete experience nearly uniform pressure from the collars. This is due to the assumption of perfectly bond contact between concrete and steel. In reality, the assumption logically is not entirely correct. The transverse stress distribution is not necessarily uniform in real practice.




(a) (b)

**Figure 4: Typical Cross Sectional Transverse Stress Distribution (a) at steel collar, and (b) at concrete column.**

## 5. CONCLUSION

To summarize the study, some points can be concluded:

- The results indicate that if the steel collars are strong enough, near uniform transverse stress distribution can be expected.
- The Finite Element modeling by ABAQUS software in this study, can predict the behavior of the idealized retrofit approach.

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