Indian Journal of Science and Technology, *Vol 8(28), DOI: 10.17485/ijst/2015/v8i28/81825, October 2015*

*ISSN (Print) : 0974-6846*
*ISSN (Online) : 0974-5645*

# An Overview on Effects of Geometric Parameters in Column Connection Behavior via Finite Element Method

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## Abstract

**Background/Objectives:** In this research, behavior of column base with box-shaped column under static loads has been examined via finite element method. **Methods/Statistical Analysis:** Column connection to column base and column base connection to foundation have been modeled with details, and the behavior of connection in form of moment-curvature diagram has been displayed by changing the parameters including column base plate thickness, diameter of anchor rod, axial load, distance between anchor rods, eccentricity of the column in the direction y, x, connection behavior in form of moment-curvature diagram. **Results:** The results indicate that the more column base plate thickness increases, in addition to increasing ultimate resisting moment, joint stiffness in the elastic curve will increase. Further, by decreasing diameter of anchor rod, rigidity of connection will increases and the connection behavior will get close to the state of changing the rigid forms. By decreasing the distance between anchor rods, joint stiffness and ultimate moment resistance will increase and formation will decrease.

**Keywords:** Anchor Rod, Column Base Plate, Finite Element Method, Moment-Curvature Diagram, Parametric Study

## 1. Introduction

Column base plate has been regarded as one of the major elements in steel structures which must transfer the force from column to foundation and avoid emergence of stress concentration at the location of the column on the foundation. In[1] indicated that critical section of column base is the horizontal section under the column at the loading part[1].

In[2] a test was conducted to examine the effect of various factors including anchor rod, plate thickness and eccentricity via 19 laboratory samples. A two-dimensional model was selected for analysis by means of finite elements so as to acquire the parametric analysis on the steel column base plate connections. Parametric analysis of model indicates that the stiffness at column base plate for a parameter is so important, under which lift forces at active connection points in the plate can develop. These forces raise plastic points at the interface in the connections, that these points cannot be considered via design method and classic calculations.

In[3] examined how the stress distributed in column base connection at various states. In addition, this study has addressed finding the moment-rotation curve at this connection by considering the specific procedure and building the relations based on static rules. Results indicated that the moment-rotation curves have been specified based on the change in different parameters, and finally an approximate formula has been proposed to calculate moment-rotation curve, that the results compared to the results from threshold tests represent a suitable accuracy at the method and formula proposed for moment-rotation equation. this study represents a better explanation for connection behavior and rigidity degree or rotational stiffness of connection instead of considering the thorough rigidity of connection[3].

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In[4] two types of connections with two anchor rods were used. The results indicate that increasing force at column causes increasing resistant moment, and this is thoroughly specified in rotation-moment curves. By increasing the compressive forces due to decrease in the existing stress in concrete and its density, the deficiency in concrete reduces and the slope at rotation-moment curve which refers to stiffness gets sharper[4].

In[5] analyzed behavior of two different types of experimental specimen. The specimens were specifically designed so that the bond and punching resistances of the steel column bases could be quantified. Numerical modeling by the Finite Element Method (FEM) has been conducted to investigate the stress distributions in column bases. The numerical results have been calibrated against the test results. The resting and numerical modeling described provide a basis for establishing a design model.

In[6] analyzed and designed column base plates on the assumptions that the plate is rigid and that the plate thickness can be determined from the cantilever action of the plate projections beyond the column face. The work describes the salient features of the two-dimensional finite element analysis of certain base plates which had been tested in the laboratory, and presents the significant findings. The computer results confirm the observed behavior of the test specimens to a reasonable extent.

In[7] examined column base connection behavior under the loading and effect of various components. With regard to importance of connections at recent seismic areas, overview of the factors such as rigidity, formation and extent of energy absorption which have been accepted in laboratory have been considered. The results indicate that the deformations in column and plastic joint raise absorption of a large amount of energy at connection.

In present research, behavior of column base with box-shaped column under static loads has been examined via finite element method. For this, to assume behavior of column base under a variety of loadings including axial load, lateral and seismic load close to reality, all the constituents including column, column base plate, foundation, anchor rod and interaction between elements have been considered. Column connection to column base and column base connection to foundation have been modeled with details, and the behavior of connection in form of moment-curvature diagram has been displayed by changing the parameters including column base plate thickness, diameter of anchor rod, axial load, distance between anchor rods, eccentricity of the column in the direction y, x, connection behavior in form of moment-curvature diagram.

## 2. Modeling and Calibration of Results

### 2.1 Meshing

Element C3D8R has been used to mesh the elements, that there are 8 nodes and 6 freedom degrees at each node at the element C3D8R. Use of this type of element in meshing the model is due to this fact that the actual thickness of elements was considered[8]. To trust on accuracy at the results and acquire the distribution of stress close to reality at the column base plate, more accurate meshing has been used at susceptible points. To increase the speed at calculations at the sections with lower susceptibility such as column and at the sections of the foundation, coarser meshing has been used[9]. The details on meshing various components at connection have been represented in Figures 1 and 2.

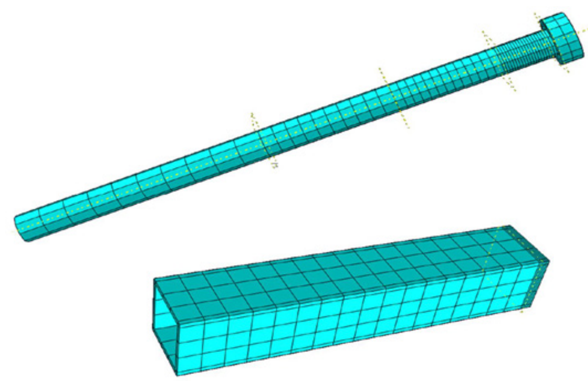

**Figure 1.** The details on meshing column and anchor rod.

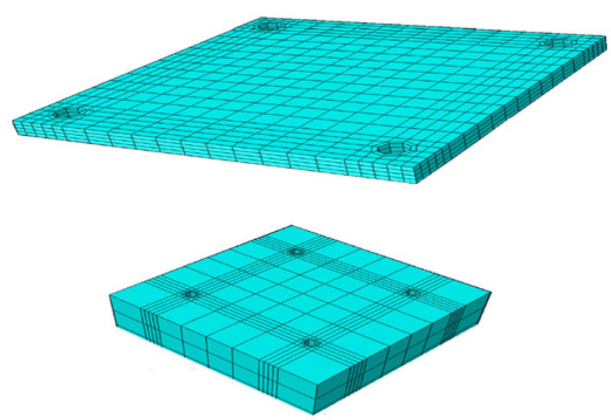

**Figure 2.** The details on meshing column base and foundation.

## 2.2 Calibration of Results

To trust on accuracy of modeling and proposed results, Picard and Beaulieu's laboratory work has been used[10]. Model 12F has been selected from the study by Picard and Beaulieu and the results of moment-curvature curve at this model have been compared with the computer model.

In this model, dimensions of column base, dimensions of box-shaped column, thickness, height, and diameter of anchor rod have been considered equal to 190-300300 mm, 152.5 mm, 12.7 mm, 1 meter and 220 millimeter, 24 millimeter, respectively. To connect column base to the foundation, four anchor rods at two sides have been used, that the distance at the center of each bolt from the next bolt is 70 mm, and the lowest distance of bolts from the next edge at the column base is 30 mm. Figure 3 represents the comparison of the moment-curvature curve at the laboratory model and three-dimensional finite elements model. According to the diagrams, it can observe that the three-dimensional finite elements model at the range of elastic behavior and initial stiffness at the connection gives us reliable results. Nonetheless, a negligent error percent exists at the range of plastic behavior that the reason for it can be sought in the idealization of stress-strain behavior in steel St-37.

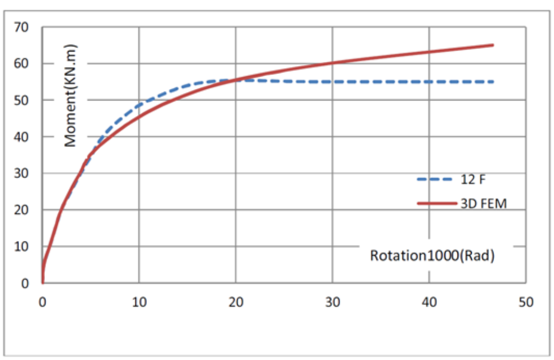


**Figure 3.** Comparison of three-dimensional finite elements model and Picard & Beaulieu's model[10].

Ultimately, three-dimensional modeling for column base, column, foundation and anchor rod has been represented. Figure 4 represents a general schematic for the modeled connection.

## 3. Results

In this article, dimensions of column base plate, dimensions of column, thickness of column, height of column, and dimensions of foundation have been considered equal to 350×350 mm, 10×150×150 mm, 15 mm, 800 mm, 60 × 50 ×50 mm, respectively.

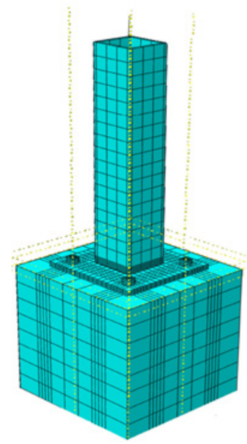

**Figure 4.** A general schematic for column base, column, foundation and anchor rod.

### 3.1 Effect of Thickness of Column Base Plate on Moment-Curvature Diagram

In this section, thickness of column base and diameter of anchor rod have been considered equal to 10×20×30 mm and 28 mm, respectively. Figure 5 represents the moment-curvature curve in connection of column base concerning different thicknesses. The analysis is fulfilled at three stages by thicknesses 10, 20 and 30 mm. As expected, by changing the thickness, stiffness at system's responses will be different. With regard to moment-curvature diagram in connection, it can perceive that in addition to increasing the ultimate moment, stiffness at the elastic point of curve increases by increasing thickness[11–13].

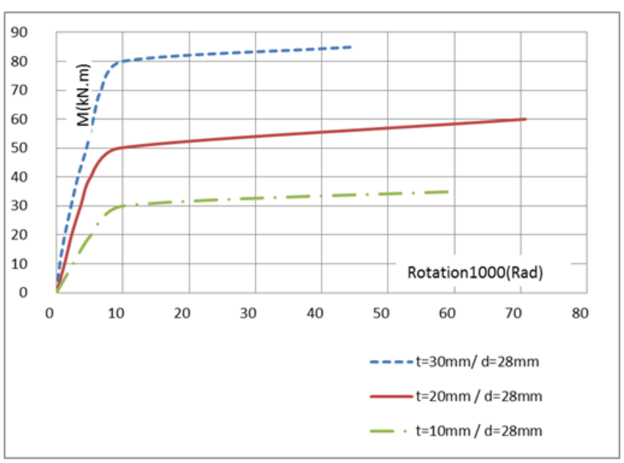


**Figure 5.** Moment-curvature diagram at various thicknesses.

#### 3.1.1 Thickness 30 mm

Concerning thickness 30 mm, deformation has been rigid in connection and the connection at the edge rotates as rigid as possible. Hence, bending deformations have occurred under the yield level at the column base plate and the rotation has occurred as rigid as possible.

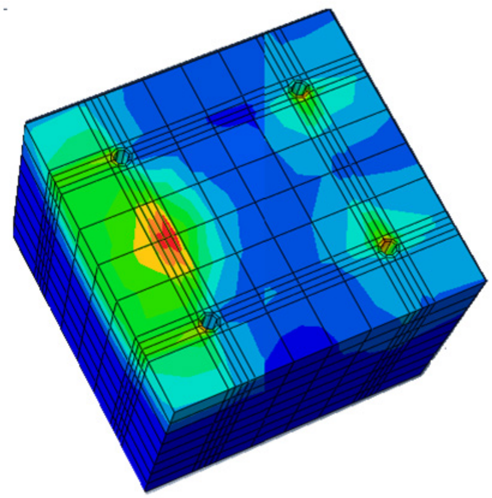

**Figure 6.** Maximum stresses at the foundation due to finite elements analysis for the sample with plat thickness 30 mm.

The yield due to comminuted concrete as the result of compression is the prevailing yield occurred in this sample, shown in Figure 6. With regard to few deformations at the plate as well as the yield at the considered sample based on brittle measure of yield in the concrete, such case will have no good function in the seismic applications that is why it is not recommended despite high resistance.

#### 3.1.2 Thickness (20 mm)

The best connection behavior can be witnessed in case connection is enough resistant and the behavior is enough deformable. Under such conditions, the amount of energy absorption in connection will increase. At high thicknesses, connection behavior despite sufficient resistance has not been enough deformable, and yield modes have been in form of yield at anchor rod and yield due to comminuted concrete that are mentioned as brittle yields. Yet, concerning average thicknesses of plate, in addition to deformation at connection, sufficient resistance will be acquired with the thorough conditions at a suitable connection for the behavior in cyclic loading. Hence, the model with thickness of plate (20 mm) has been suitable.

#### 3.1.3 Thickness (10 mm)

Concerning thickness 10 mm at column base plate, as expected, the yield mode is so deformable and stable. In this case, the bending yield at column base plate does not represent any sign for yield. At this case, the yield lines on the column base plate represent the net yield on column base plate without yield at column and anchor rod and/or comminution in concrete.

### 3.2 Effect of Diameter of Anchor Rod on Moment-Curvature Diagram

Diameter of anchor rod is another effective parameter in connection behavior. Effect of this parameter is greater in the samples with the yield mode as the yield at anchor rod. Moment-curvature diagrams for column base plate at thickness (20 mm) and diameters of 20, 24 and 28 mm have been represented in Figure 7. Effects of diameter of anchor rod at the state with yield mode can be observed in Figure 8.

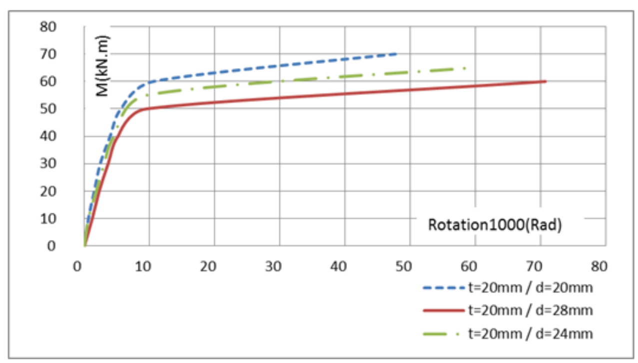


**Figure 7.** Moment-curvature diagram at for column base plate at thickness (20 mm) and diameters of 20, 24 and 28 mm.

Interpretation of the results from moment-curvature diagram indicates that yield mode from the yield mode at the column base plate and yield at anchor rod transforms to the mode of tensile yield at anchor rod and yield due to comminuted concrete or brittle yield by decreasing the diameter of anchor rod from 28 to 24 and 20 mm at the thickness of column base plate (20 mm). As the result, the rigidity at connection increases by decreasing the diameter of anchor rod, whereby the connection behavior gets closer to the mode of rigid deformation. Hence, with regard to formation of brittle yield modes in connection with decreasing the section level at the anchor rod, it can deduce that decreasing the section level at anchor rod is not suggested due to the aforementioned reasons at seismic cases. Nonetheless, in case the thickness of column base plate is in a large extent, the results can be interpreted in another way. At this mode, decreasing the diameter of anchor rod can induce the connection behavior to the deformation behavior. This reality can be witnessed at moment-curvature diagram for the thickness of column base plate at 30 mm and various diameters, as shown in Figure 8.

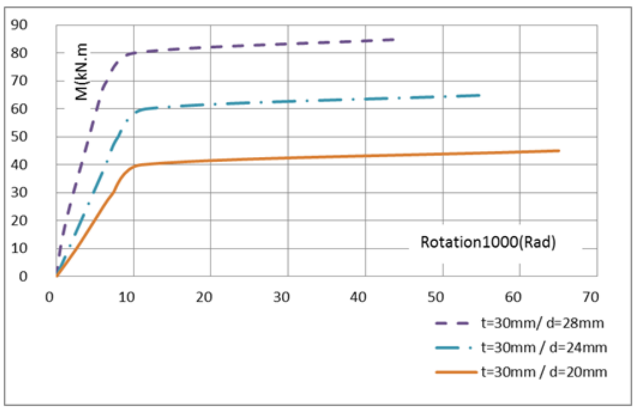


**Figure 8.** Moment-curvature diagram for the thickness of column base plate at 30 mm and various diameters.

As expected, decreasing diameter of anchor rod at high thicknesses will result in decreasing stiffness at anchor rod. With regard to the reduction of stiffness and absorption of lower force, the resisting moment at the connection reduces and the deformations due to anchor rod increase.

## 3.3 Effect of the Distance between Anchor Rods at Moment-Curvature Diagram

In this section, the distance at the center of anchor rods changes from the lateral edge at the column base, under which the effect of this change at behavior of column base is examined via finite elements analysis. Figure 9 represents the models under analysis in this section. In this mode, the thickness of column base plate, diameter of anchor rod, and distance of anchor rods have been considered equal to 20 mm, 28 mm, 50, 100 and 120 mm.

The results from three-dimensional finite elements analysis indicate that decreasing distance between the anchor rods causes increasing stress among them. In other words, the more distance between the anchors rods is greater, stress at the column base increases. Nonetheless, the most effect of distance between the anchor rods can be witnessed at the deformation in column base plate. Figure 10 represents the moment for the yield at column base plate at thickness of 20 mm at two various modes from the starting time for setting the anchor rods. The ultimate status for the deformation at column base plates represents this fact that the more distance between the anchor rods increases, deformations increase in a large extent. Figure 11 represents moment-curvature diagram at three various modes for the distance at the center of anchor rod from the lateral edge (n). The more distance of anchor rods from the edge increases, the stiffness at the column base increases.

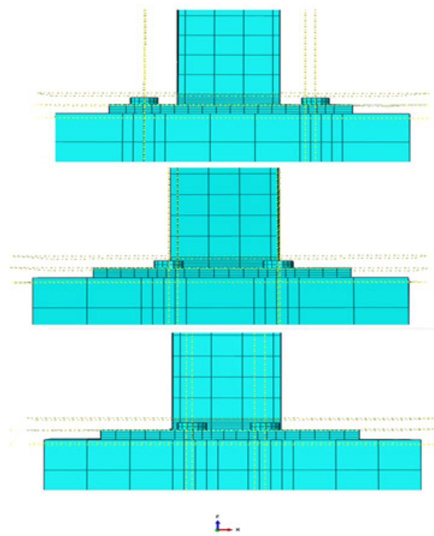

**Figure 9.** Various positions of anchor rod at the three-dimensional finite elements model.

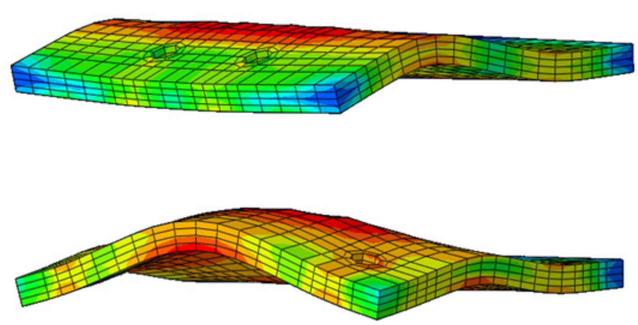

**Figure 10.** Deformations at the plate at various positions in anchor rod due to the three-dimensional finite elements analysis.

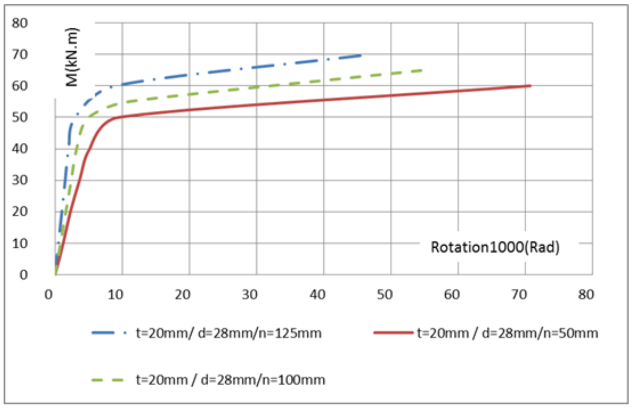


**Figure 11.** Moment-curvature diagram at various positions for setting the anchor rod.

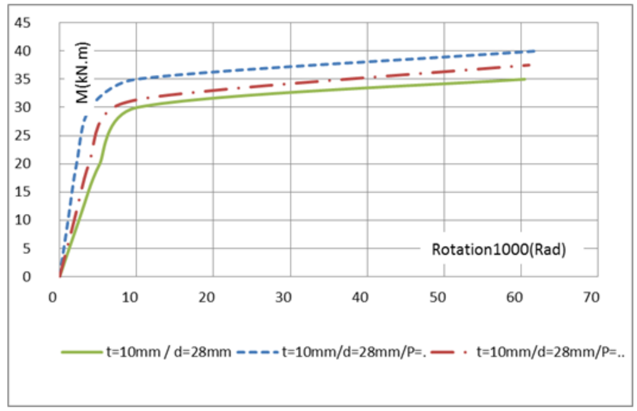


**Figure 12.** Moment-curvature diagram for the plate at thickness 10 mm and axial loads P, 0.5P and 0.

## 3.4 Effect of Axial Force at Moment-Curvature Diagram

In this section, diameter of anchor rod has been considered equal to 28 mm and the diameter of axial load has been considered P and 0.5P. Effect of increasing the axial force to the permitted amount in moment-curvature diagram causes increasing stiffness at elastic area and increasing resisting moment in connection. In addition, by increasing the axial force, amount of energy absorption regarding an increase in moment-curvature curves increases, and this increase has been witnessed at high thicknesses. Figures 12-14 represent moment-curvature diagrams for the ultimate axial loads, half of this amount and without axial load at the thicknesses 10, 20 and 30 mm. Figure 12 indicates that increasing the axial force at low thicknesses of column base plate does not affect the resisting moment and the connection formation. The highest effect of axial force in connection occurs in the column base plates with high thickness, and this can be witnessed at moment-curvature diagram in Figure 14. As specified in this figure, increasing the axial force in addition to the aforementioned factors causes increasing deformation in connection at higher thickness of column base plate. Therefore, it can perceive that increasing the axial force will decrease amount of deformation at connection at the same moments in connection.

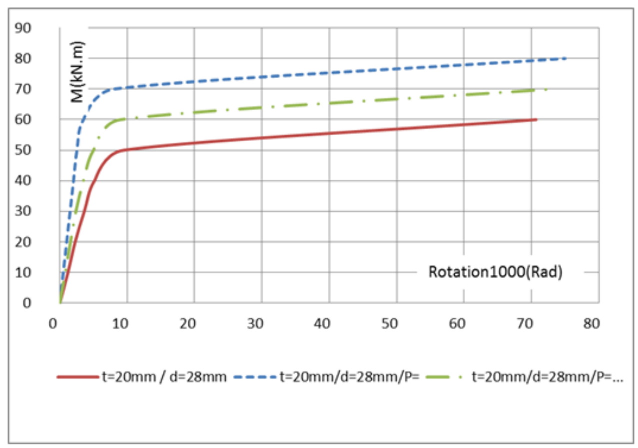


**Figure 13.** Moment-curvature diagram for the plate at thickness 20 mm and axial loads P, 0.5P and 0.

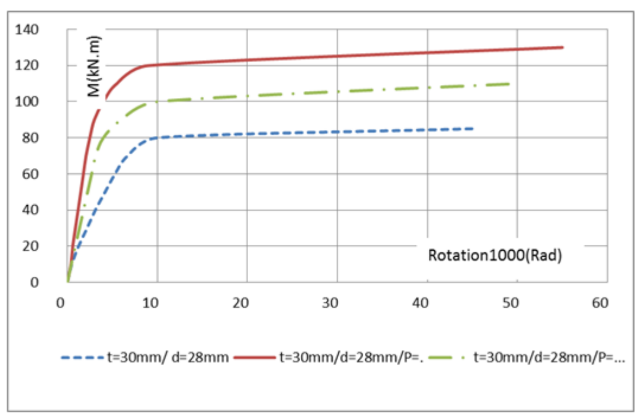


**Figure 14.** Moment-curvature diagram for the plate at thickness 30 mm and axial loads P, 0.5P and 0.

## 4. Conclusion

In this research, behavior of column base with box-shaped column under static loads has been examined via finite element method. Column base connection as an important element in transferring various loads to the foundation represents an effective efficiency in case of having suitable resistance and deformation. This status occurs in connection under the conditions that the selection of effective parameters in behavior accomplishes with sufficient accuracy. Hence, the present research aimed to examine effect of effective parameters in behavior of connection as much as possible. The parameters affecting moment-curvature diagram include column base plate thickness, diameter of anchor rod, axial load, distance between anchor rods, eccentricity of the column in the direction y, x. to sum up, the results below have been characterized:

It must take sufficient accuracy in determining the amounts for thickness especially at seismic problems so as to have the best behavior in connection in sake of formation and resistance.

By increasing the thickness at column base plate, in addition to increasing the ultimate resisting moment, the stiffness at connection at the elastic point at the curve will increase.

Deformation in connection has been rigid at the high thickness at column base that the connection rotates at the edge of connection in a rigid state. Hence, bending deformations occur less than the yield limit at the column base plate.

By decreasing the diameter of anchor rod, the rigidity at connection increases and connection behavior gets close to the deformation at rigid forms.

By decreasing the section level at anchor rod, the probability for formation of brittle yields especially at higher thicknesses comes to realize. Hence, decreasing the section level at anchor rod in seismic cases is not suggested.

By decreasing the distance between anchor rods, stiffness in connection and ultimate moment increases and formation decreases.

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