

Numerical Study of the Base Fixity

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Abstract

Details of a numerical model of base column are presented to study the actual behavior. Different configurations of steel column base were investigated. The base fixity was investigated by modeling analysis using software program ANSYS. The rotational stiffness–moment relationships are established for each type of base fixity until failure of base. The investigation of these relations indicates that the behavior of the base column divides to three regions. The first region is elastic, the second is inelastic and the last region is plastic. The analysis of the first zone (elastic zone) is considered sufficient for use of the initial linear response where the design processes is carried out. The relationships between the ratio of the base size and the rotational stiffness of column are established. Using these relationships, elastic prediction stiffness formulae for the base fixity were initiated. The suggested equations were compared with the recent methods. The suggested rules show good accuracy and adequate values with the accurate behavior of the base column connections.

Keywords:

Base Stiffness, Base Fixity, stability.

1. Introduction

The base column connection is an integral element of a steel frame. The fixity of base column connections is assumed in most design either perfectly pinned or fixed. This simplification leads to an incorrect estimation of frame behavior for buckling and straining action. In fact, the connections are between the two extreme assumptions. Both types of connections represent partially restrained. Also, the end conditions represent significant parameters of the stability and stiffness of the steel member.

Also, the fixed bases increases the overall cost of the structure, but the rotational restrained offered by commonly used “pinned” column bases is sufficient to increases the buckling strength of these frames.

Therefore, the column bases are one of the last studied structural elements in European scale, COST C1 (1999). The full scale frame experiments and in situ measurements indicate influence of the column base in the rigidity of the frame behavior, Ermopoulos et al, (1995). The influence of the soil deformation can be neglected in most cases Wald (1995). The recent experimental and theoretical work devoted to Eurocode 3 (1994) gives the answers of how to predict the resistance of base column connection and stiffness of steel members, Wald (1996), COST C1 (1999). Wald (1996) adopted an empirical equation based on large numerical study to predict the stiffness of the base connection arrangements. He suggested that the rotational stiffness of semi rigid column base can be computed by:

$$K_{\text{base}} = \frac{E.t.z^2}{20} \quad (1)$$

Where, t = the plate thickness , Z = the gauge of anchor bolts to the steel member as shown in Figure (2). Now the structural design is depending on software and models. The finite element models are to be able to describe behavior of the structures in more complex way. Hence, the support connection can be described by spring with rotational stiffness values to simulate the accurate behavior of the steel frames.

2. The moment – rotational relationship

Where the stiffness of column base depends on the moment rotational relationship, the determination of this relationship can be carried out by using software program ANSYS. The rotational stiffness of the base column can be calculated by the following equation:

$$K = M / \theta \quad (2)$$

Where, K is stiffness of the base; M is the applied bending moment; and the θ is the rotation of the column at the base plate.

The objective of this study is to establish the rotational stiffness of the base column for different type of base column configurations with various parameters for design proposes. A fitting relationship can be suggested to give a manual calculation of the rotational stiffness of the base fixity at elastic region.

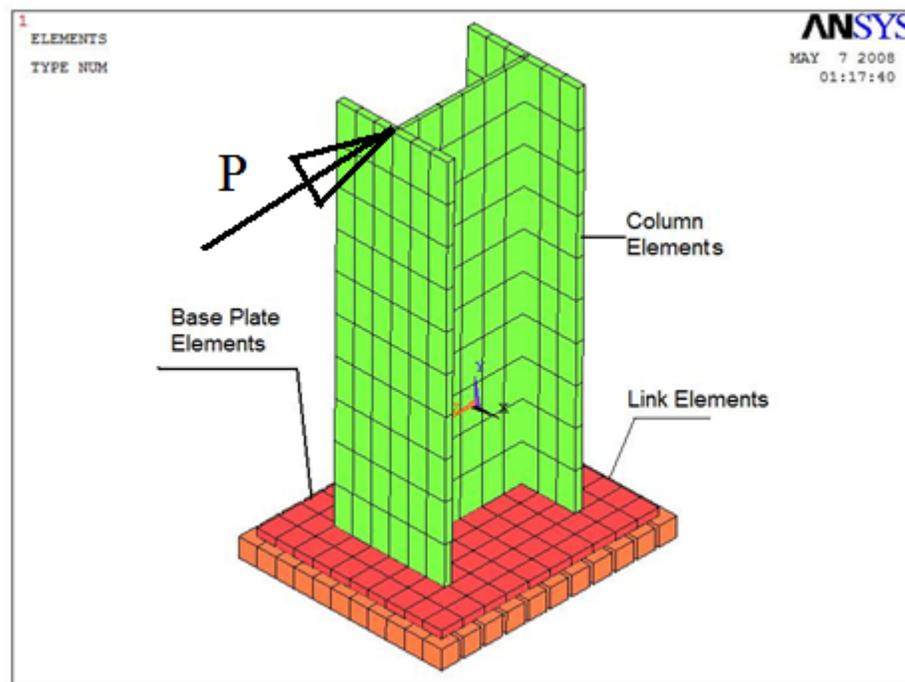


Figure 1: The Modeling system of the case study.

3. The numerical Model

Figure (1) shows numerical model of the Finite Element model of the base column connection. The model consists of steel column with 1.0 meter height, free at the top and fixed at the bottom by the base plate. The ANSYS model was constructed using thin plate bending element “shell 143” for column section. The element has 4 nodes with six degrees of freedom at each node. The base plate elements are represented by solid elements “Solid 185“. Winkler mode was used to substitute the concrete base by springs. The concrete base was represented by link elements which carry compression only “LINK10“. The properties of this element were assumed to be elastic. The anchor bolts were represented by link elements which carry tension only “LINK10“. The properties of the link were assumed as the stress strain curve of concrete.

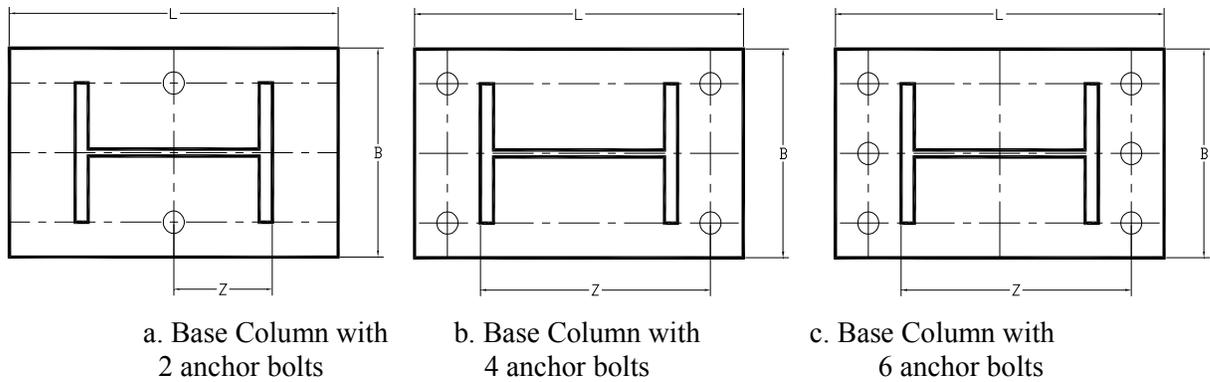


Figure 2: The studied cases of base columns configurations

The rotation of the steel beam was measured and the relationship between the rotation of the steel member and the applied bending moment were established directly by the program. Three types of base configuration as shown in Figure (2) were studied. The steel column was standard HEA 300 and the base plate was 20 mm thickness for the three different type of fixation. The applied moment was carried out by applying lateral load at the top of the steel column at 1.0 meter height from the base connection. This means that the applied moment equals the applied lateral load by the distance 1.0 meter. The rotation of the steel beam was measured and the relationship between the rotation of base of the steel column (θ) and the applied moment (M) are established directly by the program. Figure (3) indicates an example of this relationship.

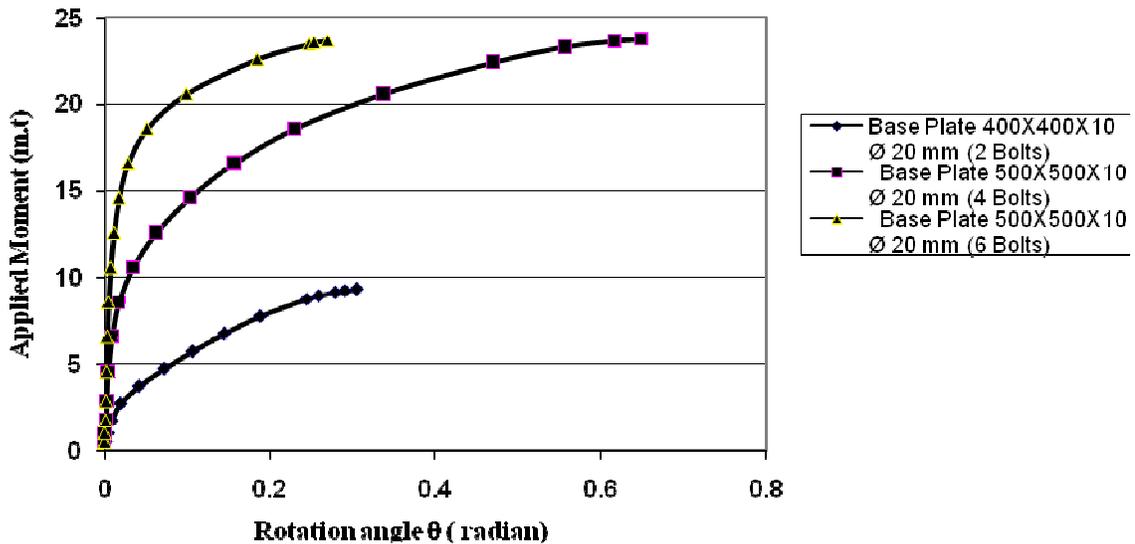


Figure 3: Relationship between applied moment and the rotation of column at base.

The study of Figure (3) indicates that the relationship between the rotation of the steel beam and the applied bending moment consists of three stages. The first stage is linear where the stiffness of the base column connection is elastic region. The second stage is nonlinear and the stiffness is elasto - plastic region. The third stage is the plastic region. The analysis of the first zone (elastic zone) is considered sufficient for use of the initial linear response where the design processes is carried out.

4. Parametric study

The study was carried out for three groups of base connection configurations as shown in Figure (2) : in the first group the base plate is fixed by 2 anchor bolts, in the second group, the base plate is fixed by 4 bolts, and the third group the base plate fixed by 6 anchors.

For each group , the following parameters are investigated; 1- the base plate thickness are changed by 10,20,30 mm; 2- the anchor bolts are taken with diameter 10,20,30 mm and 3- the ratio between length of the base plate and the width are chosen 1,1.25,1.5,2,3. The steel column section is HEA 300.

4.1 Influence of the base plate thickness

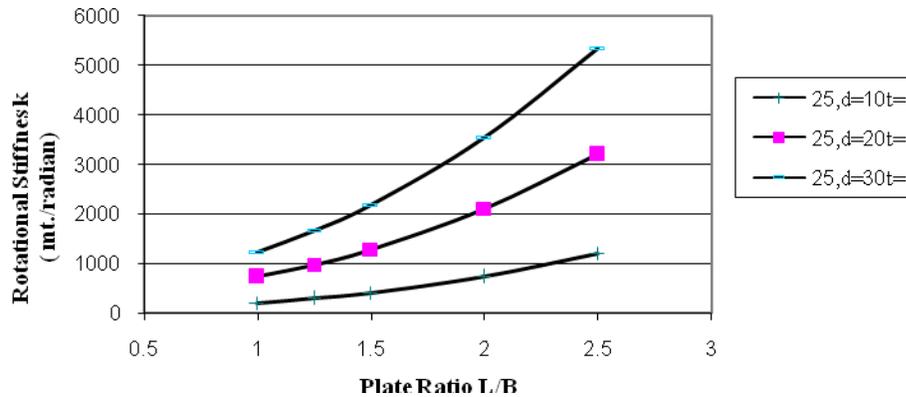


Figure 4: Rotational stiffness of base plate $t=10,20,30$ with two anchor bolts $d=25$ mm.

Figure (4) shows the effect of base plate thickness on the rotational stiffness of the base column. Each line of the chart represents a stiffness for different base thickness. The chart shows that the increasing of the base column thickness from 10 mm to 20 mm increases the rotational stiffness of the base column by 250 % to 317 % for plate ratio L/B various from 1.0 to 2.5 respectively. Where L is the length and B is the width of the base. This means that the plate ratio L/B influences on the stiffness of the base connection.

4.2 Effect of anchor bolts diameter

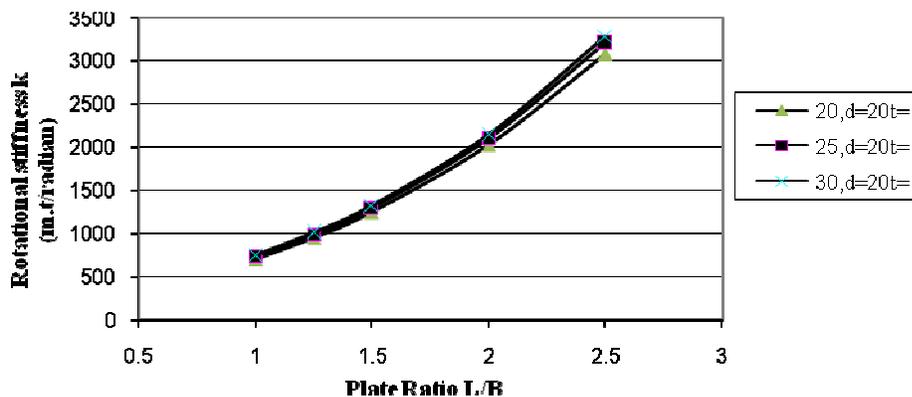


Figure 5: Rotational stiffness of base plate $t=20$ mm with two anchor bolts $d=20,25,30$ mm.

The study of Figure (5) indicates that the effect of the diameter of the anchor bolts is very small in the rotational stiffness of the base column. The changing of diameter of anchor bolts from 20 mm to 30 mm increases the stiffness of the base by 2-3%.

4.2.1 Group 1, two anchor bolts

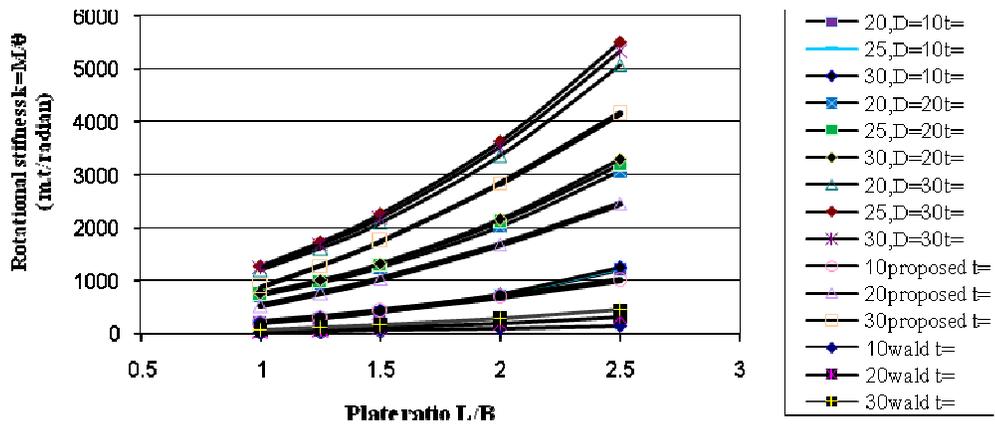


Figure 6: Rotational stiffness of base column with two anchor bolts

Figure (6) indicates three groups of curves for base column which is fixed by two anchor bolts $D=20, 25, 30$ mm as shown in Figure (2a). The first group for base plate thickness $t=10$ mm, the second group for $t=20$ mm, and the third group for $t=30$ mm. The chart also indicates the proposed curve fitting which obtained by using curve fitting software for each group and results of using the equation 1 given by Wald (1996). It is clear to notice from Figure (6) that the equation 1 given by Wald (1996) is very conservative. Using the curve fitting software, an equation can be performed to fit the obtained results. The suggested Equation for this type of base column fixation is:

$$K = E \cdot Z^{1.3} \cdot t^{1.7} \tag{3}$$

Where ;

K is the rotational stiffness of the base column.

E is the modulus of elasticity of concrete base (t/m^2).

Z is the gauge between the anchor bolts and the steel column section as shown in Figure (2a) in meter

t is the plate thickness in meter.

4.2.2 For Group 2, four Anchor Bolts

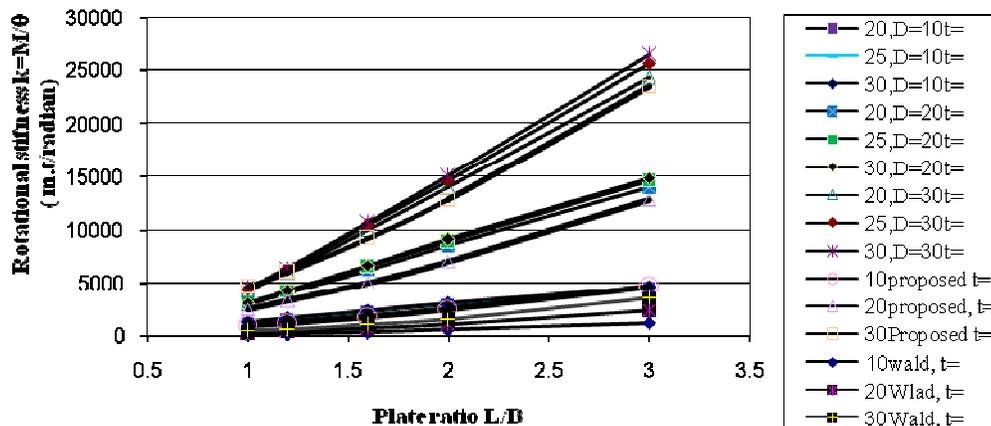


Figure 7: Rotational stiffness of base column with two anchor bolts

Figure (7) indicates three groups of curves for base column which is fixed by two anchor bolts $D=20,25,30\text{mm}$ as shown in Figure (2b). The first group for base plate thickness $t=10\text{ mm}$, the second group for $t=20\text{mm}$, and the third group for $t=30\text{mm}$. The chart also indicates the proposed curve fitting of each group and results of using wald equation (equation 1). It is clear to notice from Figure (7) that the equation 1 given by wald (1996) is very conservative. The using of curve fitting software on the obtained results, an equation can be performed to represent the actual behavior of the base column. The suggested equation for this type of base column fixation is:

$$K = 2. E. Z^{1.5} . t^{1.5} \quad (4)$$

4.2.3 For Group 3, Six Anchor Bolts

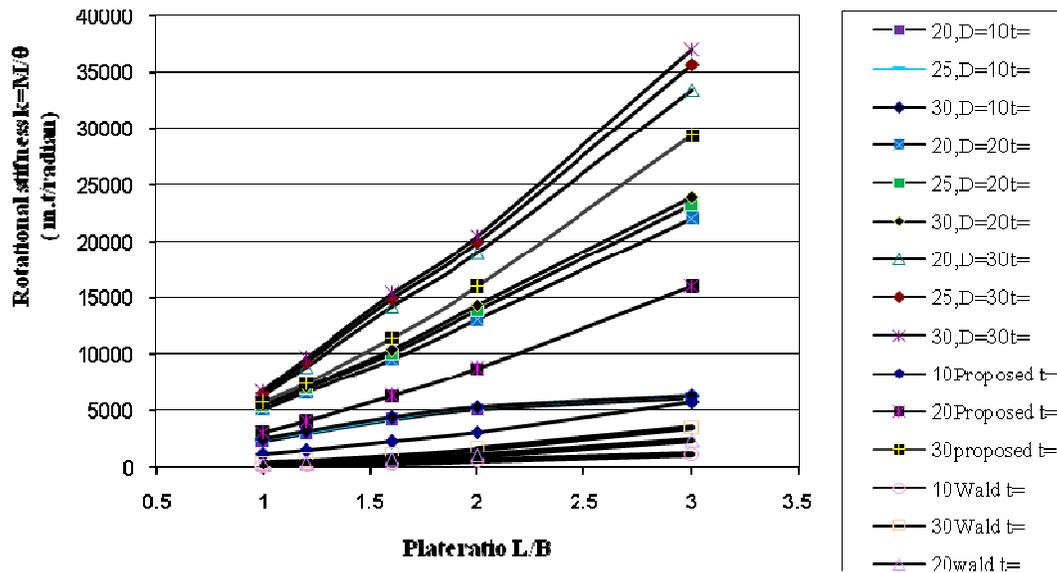


Figure 8: Rotational stiffness of base column with six anchor bolts

Figure (8) indicates three groups of curves for base column which is fixed by two anchor bolts $D=20,25,30\text{mm}$ as shown in Figure (2c). The first group for base plate thickness $t=10\text{ mm}$, the second group for $t=20\text{mm}$, and the third group for $t=30\text{mm}$. The chart also indicates the proposed curve fitting of each group and results of using wald equation (equation 1). It is clear to notice from Figure (8) that the equation of wald (1996) is very conservative. In this case of fixation an equation can be performed by using curve fitting software to represent the actual behavior of the base column. The suggested Equation for this type of base column fixation is:

$$K = 2.5 E. Z^{1.5} . t^{1.5} \quad (5)$$

5. Failure mode

The failure of the base plate in the first group occurred at the toe of the column section as shown in Figures (9,10,11). Figure (12) indicates failure of column beam at point of applied load. This has been occurred when the inertia of the base plate is greater than the inertia of the column section.

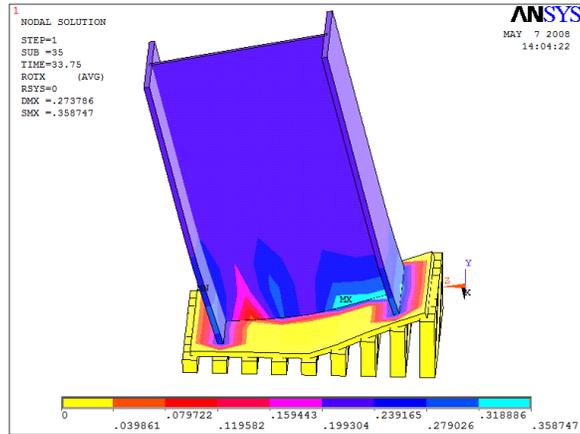


Figure 9: Failure mode of Base plate $t=20$ mm with 2 anchor bolts.

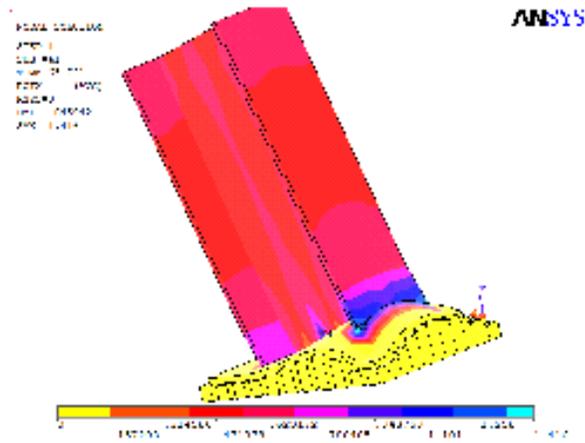


Figure 10: Failure mode of base plate $t=20$ with four anchor bolts

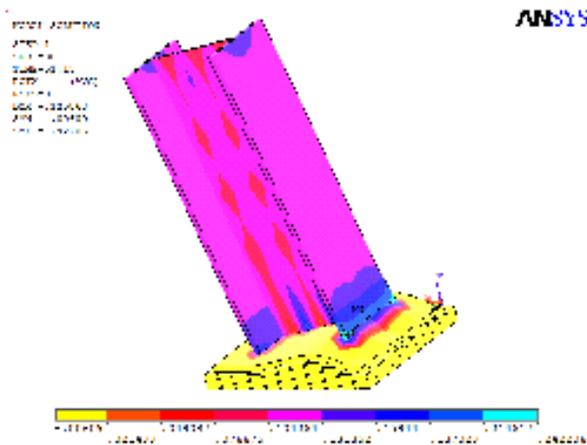


Figure 11: Failure mode of base column $t=20$ with 6 anchor bolts.

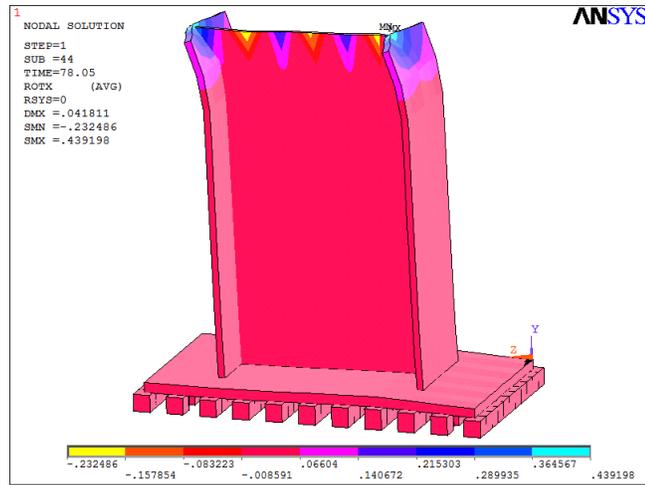


Figure 12: Failure mode shape of base plate $t=30$ mm with 6 anchor bolts.

6. Conclusion

The following conclusion can be obtained from this study:

- Wald equation et al. (1996) for predicting rotational stiffness of the base column is conservative.
- The major factors affecting on the rotational stiffness of the base column are the thickness of the base plate, the ratio of the base dimension which is influenced by the gauge Z between the anchor bolts and the steel column section.
- The inertia of the column base plate should be designed less than the inertia of the column section.
- The proposed equations (Eqs. 3, 4, 5) are adopted the rotational stiffness values for the studied cases.

7. References

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