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Column Bases with Anchor Bolts

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Abstract - *The vast majority of the building columns are designed for axial compression only with little or no uplift. For such columns, the simple column base plate connection is sufficient. If necessary, the column base plate connections can additionally transmit uplift pressures as well as shear through the anchor bolts. The unequal distribution of uplift loads on the anchor bolts may cause overloading on some of the anchor bolts, leading to failure. An elastic analysis is used in the traditional design of moment resisting column bases, with the assumption that the sections remain planar. Many researchers have carried out detailing, analysis & design procedures based on international codes except Indian Code. This paper includes the analysis of base plate with anchor bolt by considering the combined effect of moment (M), shear force (V) and Axial compressive force (P) in the column. The analysis and design of model is carried out in ANSYS Workbench software. Using existing specifications of AISC, suitable modifications are made for detailed analysis and design of moment resisting column base plate with anchor bolts. The procedure using a combined loading effect with consideration of high bending moment on column for the prediction of the base plate behavior is more suitable for the practical application compare to the prediction based on the proportional loading. The base plate and anchor bolt modelling provides a powerful tool in the analysis and design of critical steel structures in industries especially in cases where the lateral loads such as wind and earthquake are critical.*

Key Words: **Column base plate, Anchor bolts, High bending moment, Uplift pressure, Moment resisting column, etc.**

1.INTRODUCTION

A column base is made up of a concrete-encased column, a base plate, and an anchoring assembly. Un-stiffened base plates are used in the majority of cases, although stiffened base plates may be used if the connection must transfer large bending moments. The critical connection between the steel structure and the foundation is the column base plate connection. Base plates and anchor bolts are generally the last structural steel items to be developed, but they are the first items needed on the working site. All base plates must have anchor bolts to prevent the column from overturning while construction and in most situations, to resist uplift due to huge moments. Anchor bolts are used to secure a structure.

Material selection and base plate design features can influence the cost of manufacturing and erection of steel structure, as well as their efficiency under load. Not only is it critical to design the column base plate connection for strength, but it's also essential to realize how these connections effect the structure's behaviour. Assumptions are made in structural analysis about the constraints defined by the base plate connections. If a more exact analysis is recommended, the stiffness of the column base plate connection in the elastic and plastic ranges under seismic loading, as well as the cyclic force-deformation relations, may be required. The forces and deformations determined by the structural analysis used to design the column base plate connection which are based on the column base plate connection details specified. The normal column-base-plate connection is enough for these columns. Shear force can be transferred using friction against the grout pad or concrete if the base plate lies in compression; in this situation, the anchor bolts do not need to be designed for shear. Bearing against concrete, is done either by anchoring the column base or by inserting a shear lug under the base plate can resist a significant amount of shear stress.

Wind and seismic loads on the structural system can be resisted by using a column base plate with anchor bolts. The establishment of a force couple between bearing on the concrete and tension in the anchor bolts can resist moment at the column base. Anchor bolt design guidelines are provided, as well as practical suggestions for designing and installing anchor bolt systems, based on the ACI and AISC requirements. The design, installation, inspection, and repair of cast-in-place anchors in column-base-plate connections are the focus of this documentation.

Unfortunately Bureau of Indian Standards has not laid down detailed procedure for this important aspect in existing IS: 800-2007 specifications.

1.1 Objectives

[1] To arrive for the critical factored design actions at the base of a typical column i.e. bending moment, axial force and shear force.
[2] To analyze the base plate and to formulate the design guidelines.
[3] To analyze the interaction between base plate and anchor bolt.

[4] To analyze the anchor bolt by considering the combined effect of M-V-P in the column.
[5] To suggest guidelines to Bureau of Indian Standards, for detailed design procedure to be adopted for base plate with anchor bolts resisting large moment.

2. LITERATURE SURVEY

Many researchers have carried out detailing, analysis & design procedures based on international codes except Indian Code. Few important journal papers are reviewed as under.

Mahmoud and Ali Shams [1] The pullout behaviour of embedded steel sections with end plates is quantitatively investigated in this article under various situations. Two I-sections with end plates are analyzed under pullout forces to validate the statistical solution. Rafael and Francisco [2] This paper analyses through finite element several different wide-flange column base elements, with varying plate thicknesses and geometry. The conclusion summarize that the distribution of the loads on the anchor bolts mainly depend on the typology of the base plate and suggest a revision of the codes to be more defined on when unequal axial tensile loads may arise on the anchor bolts and recommend more advanced methods for the estimation of those unequally distributed loads. Jayarajan [3] This paper presents a detailed step-by step procedure for the evaluation of resistance and stiffness of various elements of base plate connection by using the "component approach" given in EC3, that are then assembled to obtain the resistance and rotational stiffness of base plate connection required for their classification. James and Lawrence [4] The purpose of this document is to assist engineers and fabricators with instructions for designing, detailing, and specifying column base plate and anchor bolt connections in a way that eliminates typical fabrication and erection issues. This guide is based on the AISC Specification for Structural Steel Buildings (AISC, 2005). William and Derek [5] The objective of this Steel Tips issue is to assist engineers, fabricators, and contractors with realistic instructions for designing and detailing steel column base plates. Frantisek and Zdenek [6] The behaviour of the base plate and anchor bolts, that are the major elements of a base plate connection, is described in this study. Mohamad and Salman [7] The goal of this research is to establish anchor bolt with improved tensile load performance. The design concept uses a T form, which is equivalent to a headed anchor bolt design and is widely utilized in industry. Konstantinos and Emad [8] The outputs of a finite element analysis of single-headed anchors under tension are addressed in this research, which leads to the development of such a simple equation that characterizes the stiffness of a headed anchor bolt buried in concrete. Picard and Beaulieu [9] This paper presents the results of an experimental investigation on the behavior of steel column base connections. The results prove that the method of analysis used to determine the ultimate moment capacity of the base connection is conservative. Stamatopoulos and Ermopoulos [10] The ultimate behaviour of column base plate connections is investigated in this study, and the related M-P curves are calculated using the problem's major parameters.

3. SYSTEM MODELLING

In the analysis, design and detailing of the steel structure, the latest editions of following Indian Standards as well as American Standards will be referred.

Geometrical Properties:

1. Concrete pedestal size - 720x720x200 mm
2. Base plate size – 360x360x40 mm
3. Column – ISHB200
   From IS 808 : 1989
   Mass – 37.3 kg/m, 365.9 N/m
   Sectional Area (a) – 47.54 cm^2
   Depth of Section (h) – 200 mm
   Width of Flange (b) – 200 mm
   Thickness of Flange (t_f) – 9 mm
   Thickness of Web (t_w) – 6.1 mm
   Modulus of Elasticity (z_p) – $397.23x10^3$
4. Diameter of Anchor bolt -16 mm
5. Length of bolt – 120 mm

Loads:

1. Moment - 52 kN.m
2. Axial force - 200 kN
3. Shear force - 50 kN

The engineering data application is very confined control for all material properties of ANSYS Workbench. Graphical user interface has five specific regions. In sketching mode first we have to select a plane to sketch model by using line, rectangle, polyline, circle and many more. In order to create 3D solid from sketching we have to switch over modeling mode. Material assignment for base plate, concrete pedestal and I- Section has to be done and the global coordinate system is present where X=0, Y=0, Z=0. For meshing physics preference is given to mechanical. Initially the generate mesh for model using surface meshing through preview mode. After that for fine meshing we go to sizing and also multizone method. Analysis is carried out in two steps. In this module we apply the fix support and loading conditions like axial load P, bending moment M & shear force F.

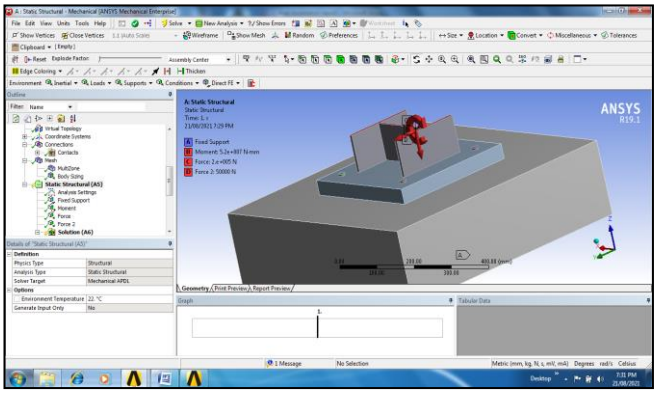

Fig -1: Load Application

3.1 Design of column base plate connections

In column base plate connections, three alternative design load conditions are examined.
- Axial Concentric Compressive Loads
- Large Moments on the Base Plates
- Shear resistant design

When a column base resists only compressive column axial loads, the base plate must be large enough to counter the bearing forces transmitted from the base plate, which is known as the concrete bearing limit, and the base plate must be thick enough to resist the bearing forces transmitted from the base plate, which is known as the base plate yielding limit.

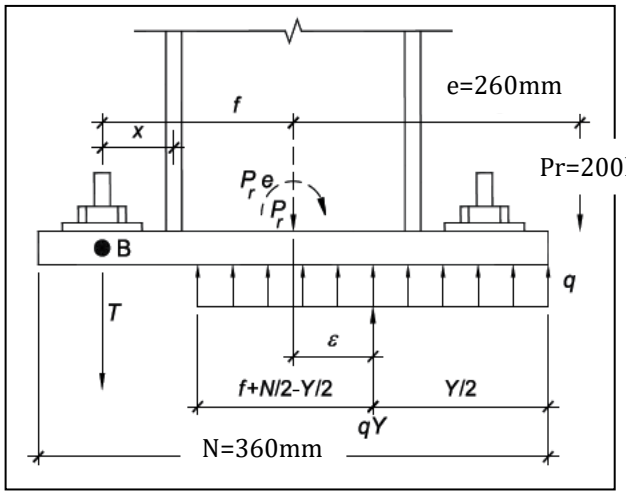

Fig -2: Base plate with large moment

Large moment conditions exist when,

$$e > e_{crit} = \frac{N}{2} - \frac{P_r}{2q_{max}}$$

General Design Procedure

1. Determine the axial load and moment acting on the top of the column.
2. Take a trial base plate size, N × B.
3. Then determine the equivalent eccentricity, $e = M_r / P_r$ and the critical eccentricity,

$$e_{crit} = \frac{N}{2} - \frac{P_r}{2q_{max}}$$

If e > e_{crit}, then go with below mentioned steps (design of the base plate with large moment). Otherwise, go for design of the base plate with small moment.

Check the inequality of equation and if it is not satisfied then choose larger plate dimensions.

4. Calculate the bearing length Y and tensile force in the anchor bolt T_u.
5. At the end evaluate required minimum base plate thickness $t_{p(req)}$ at bearing and at the tension interfaces. Choose the larger value,
6. Determine the anchor required bolt size.

4. RESULTS AND DISCUSSION

4.1 Calculation for design of column base plate with large moments

Determine the critical eccentricity

$$q_{p\,(max)} = f_{pmax} \times B$$

$$f_{p(max)} = \phi\left(0.85 f_C'\right)\sqrt{\frac{A_2}{A_1}}$$

$f_{p(max)}$ = 33.15 N/mm q_{max} = 11934 N

e_{crit} = 171.6206 mm

Here $e > e_{crit}$, so this is the case of base plate with large moment.

Check the inequality for below equation, if it is not satisfied then chooses larger plate dimensions.

$$\left(f + \frac{N}{2}\right)^2 \geq \frac{2P_r(e+f)}{q_{max}}$$

Since 96100 mm² >13071 mm² the inequality is satisfied and real solution for Y exist.

$$Y = \left(f + \frac{N}{2}\right) \pm \sqrt{\left(f + \frac{N}{2}\right)^2 - \frac{2P_r(e+f)}{q_{max}}}$$

Y = 200 mm

$T_u = q_{max}Y - P_r$ = 2186800 N

Determine the minimum plate thickness

At bearing interface:

$$m = \frac{N - 0.95d}{2}$$

m = 85mm

The required plate thickness may be determined from

Because $Y \geq m$:

$$t_{p(req)} = 1.49m\sqrt{\frac{f_{p(max)}}{f_y}}$$

$t_{p(req)}$=46.11828 mm

At the tension interface:

$$tp\ (req) = 2.11\sqrt{\frac{Tu.x}{B.fy}}$$

$$tp\ (req) = 52.5213mm$$

The bearing interfaces influence the design of the base plate thickness.

4.2 Results obtain from ANSYS Workbench

The equivalent stresses are found maximum at the flange to web connection which are in compression causing some amount of deformation of web portion. Bending of base plate has been seen due to high bending moment.

Table -1: Equivalent stresses in structure

Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1.	6.1218e-004	521.57	9.5736
2.			

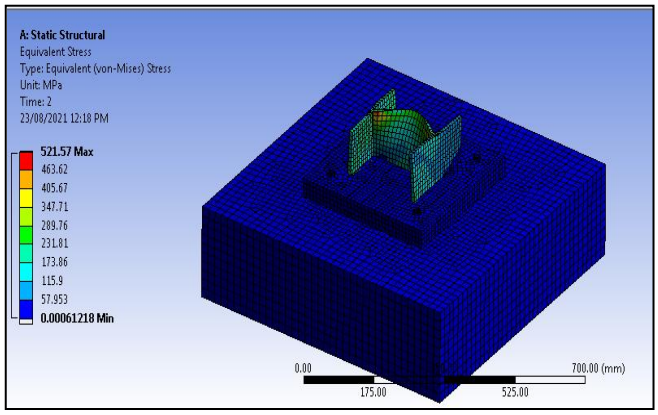

Fig -3: Equivalent stresses in structure

The stresses in anchor bolts are as follows, 35.367 MPa, 52.50 MPa, 29.802 MPa and 13.179 MPa.

Table -2: Total deformation of base plate with anchor bolts

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.	2.2288e-003	5.4162e-002	1.5581e-002
2.			

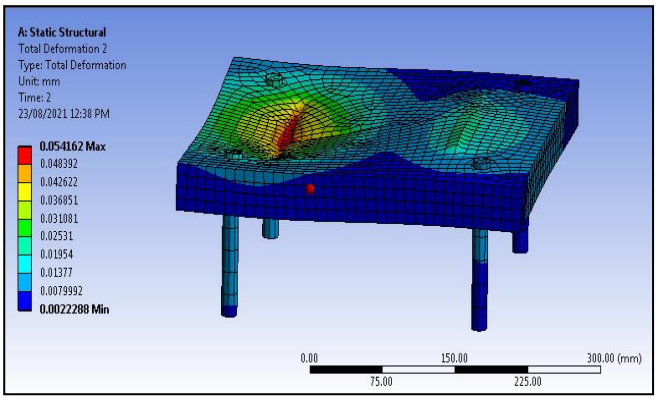

Fig -4: Total deformation of base plate with anchor bolts

5. CONCLUSIONS

Conclusions that can be drawn from study are as follows:

[1] Anchor bolts play an important role to resist the high bending moment by developing force couple between bearing on the concrete and tension in anchor bolts.
[2] Under the combined action of axial force, moment and shear the base plate stresses found higher than expected in the vicinity of the stress concentration areas causes bending of the base plate.
[3] When a compression force was applied to the top of column, a significant increase in the flexural stiffness of the base connections was observed. Based on the analysis, no more damage was reported for the embedded part column bases.
[4] The procedure using a combined loading effect with consideration of high bending moment on column for the prediction of the base plate behavior is more suitable for the practical application compare to the prediction based on the proportional loading.
[5] The base plate and anchor bolt modelling provides a powerful tool in the analysis and design of critical steel structures in industries especially in cases where the lateral loads such as wind and earthquake are critical.

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