



PREDICTION METHOD FOR MOMENT-ROTATION BEHAVIOR OF EXPOSED-TYPE STEEL COLUMN BASES UNDER BI-AXIAL BENDING

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ABSTRACT

It has already been proved that assuming them as pinned or fixed supports is not a suitable way to simulate their actual behavior because in most cases, column bases have strong semi-rigid behavior highly affecting the overall behavior of the structure. In order to reflect the column base behavior to the frame design work, the column base can be modeled as a kind of semi-rigid and partial strength connection with plastic rotation capacity. In this paper, standard M- θ skeleton curve of exposed-type column base and estimation method on inelastic behavior under bi-axial bending is proposed. Also, a method to simulate the inelastic behavior of column base in case of biaxial bending by expanding uni-axial restoring force characteristic model to bi-axial model is proposed, anchor bolt yielding type and base plate yielding type respectively.

Keywords: Exposed-type column base, Biaxial bending, Anchor bolt yielding type, Base plate yielding type

INTRODUCTION

Column bases are important parts of a structure, which transfer loads acting on upper structure to the foundation. They deform under shear forces and bending moments, particularly in rotation, when the structure is subjected to lateral forces. Their behavior under such loading strongly affects the overall behavior of the structure. It has already been proved that assuming them as pinned or fixed supports is not a suitable way to simulate their actual behavior because in most cases, column bases have strong semi-rigid behavior highly affecting the overall behavior of the structure. In order to reflect the column base behavior to the frame design work, the column base can be modeled as a kind of semi-rigid and partial strength connection with plastic rotation capacity. In this chapter, standard M- θ skeleton curve of exposed-type column base and estimation method on inelastic behavior under bi-axial bending is proposed. Also, a method to simulate the inelastic behavior of column base in case of biaxial bending by expanding uni-axial restoring force characteristic model to bi-axial model is proposed.

PROPOSAL OF STANDARD M- θ SKELETON

M- θ skeleton curve derived from past test data

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Available four past experimental results on base plate yielding type of column base is obtained from both domestic and oversea sources. The maximum moment, M_u , is standardize at 1/25. Because most of available test results do not reach to the final failure and sometimes, the maximum resistance is not detected. Plots of normalized curves of M/M_u vs. rotation of column base for the present tests and some available past experimental results on exposed-type column base for the base plate yielding is shown in Figure 1.

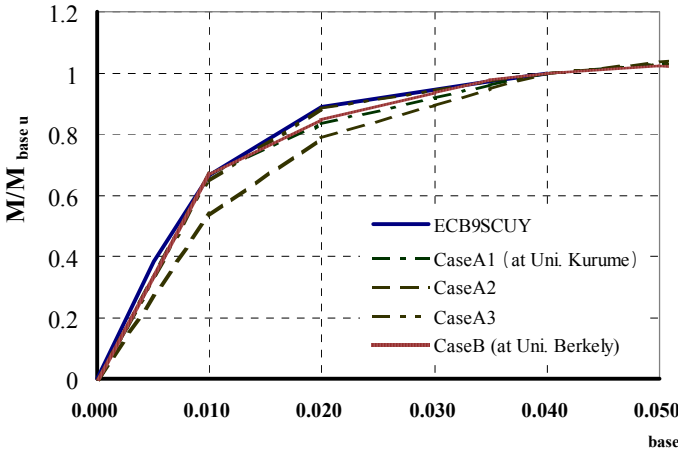


Figure 1. Normalized plots of $M-\theta$ curves for base plate yielding type

Where the maximum moment reached to the maximum rotation, the rotation capacity at maximum resistance should be predicted from the anchor bolt elongation capacity of the predicted final collapse mode. The past experimental data standardized their maximum column base rotation capacity. Figure 1 show normalized plots of moment vs. column base rotation curves for anchor bolt yielding type.

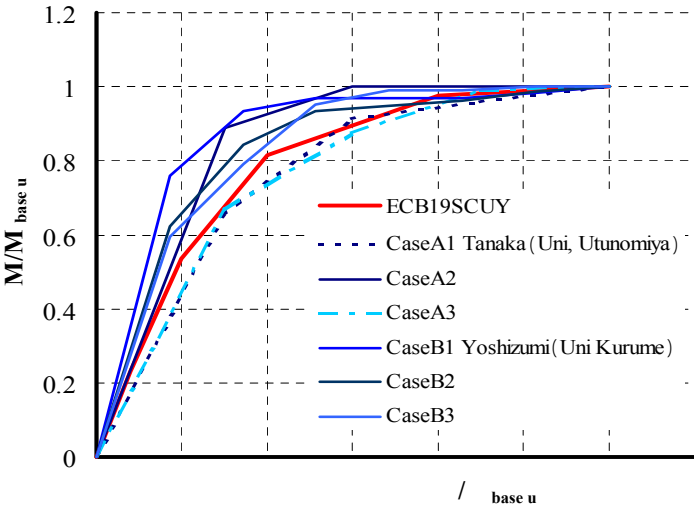


Figure 2. Normalized plots of $M-\theta$ curves for base plate yielding type

Proposal of $M-\theta$ skeleton curve for anchor bolt yielding type

It is difficult to evaluate rotation stiffness and yielding resistance of connection exactly. Since the yielding progress gradually for the plate yielding type, also the deterioration of load-displacement relationship takes place gradually. Moreover, it is more difficult to evaluate the rotation stiffness, which reflected each local deformation of a connection by the simple mechanical model. Normalized plots of moment vs. column base rotation curves derived from past experiment data is proposed in Figure 3. Values of M/M_u for test curves are also read at 1/1000, 1/500, 1/250, and 1/125 in column

base rotation. This kind of technique is an empirical formula obtained merely from experiment results, and also it covers a wide range of connection parameter variation. About the standard M- θ skeleton curve for base plate yield type of exposed type column base, firstly, maximum resistance of column base is calculated by the limit analysis or plastic analysis such a chapter 4. Since the resistance and initial stiffness have usually big correlation, the maximum resistance is standardized at 1/25 rotation angle. The standard M- θ skeleton curve for base plate yielding type proposes ($\theta : M/M_{base\ u}$) = (1/250: 0.3), (1/125: 0.55), and (1/25: 1.0).

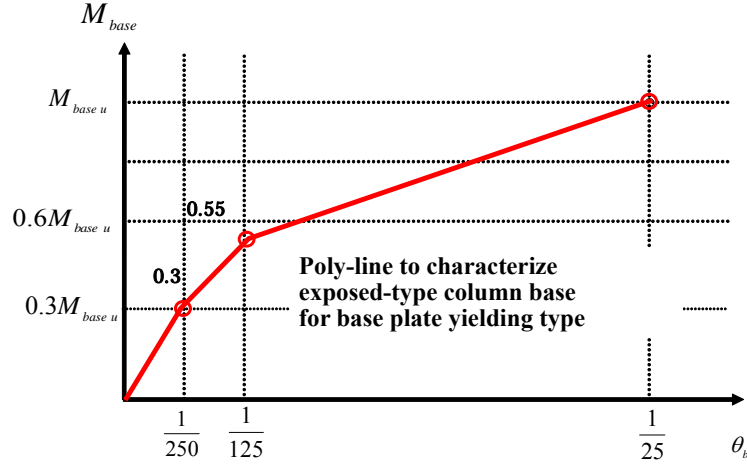


Figure 3. Standard M- θ skeleton curve for base plate yielding type

Both maximum resistance and rotation capacity has to be estimated to determine the last critical point. Rotation stiffness can be derived from the formula of rotation elastic stiffness of exposed-type column base of LSD (AIJ), and the point of intersection with yield resistance ($0.6M_{base}$) is detected.

$$\begin{aligned}
 K_{base} &= \frac{n_t E A_{bolt} (dc + dt)^2}{2l_{bolt}} \\
 &= \frac{\varepsilon_u E M_{bu}}{1.5 \theta_{base\ u} \sigma_{ub}} \\
 &= 340 \left(\frac{dc + dt}{l_{bolt}} \right) M_{bu}
 \end{aligned} \tag{1}$$

$$M_{bu} = n_t A_{eff} \sigma_{ub} (dc + dt), \quad \theta_{base\ u} = \varepsilon_u l_b / (dc + dt)$$

Also, from the past experimental result, the maximum resistance point of a column base, which is also a common point for rotation angle of $2/3\theta_{base\ u}$ can be derived. For the anchor bolt yielding type, it is proposed tri-linear model as the standard skeleton curve with linking the three points. The standard M- θ skeleton curve for anchor bolt yielding type proposes ($\theta : M/M_{base\ u}$) = $(340(dt+dc)/l_{bolt} : 0.6)$, $(2/3 \theta_{base\ u} : 1.0)$, and $(\theta_{base\ u} : 1.0)$

ESTIMATION OF INELASTIC RESPONSE FOR THE BI-AXIAL BENDING

In case of base plate yielding type

According to the proposed standard M- θ model, uni-axial restoring force characteristic model is expanded to bi-axial model, a method to simulate the inelastic behavior in case of bi-axial bending is proposed. In case of base plate yielding type, it is proposed that the independent spring, which has uni-axial hysteresis property, is set up at a right angle along the axis of column base section, according to the limit analysis result shown in figure 5. (Choi & Ohi, 2005)

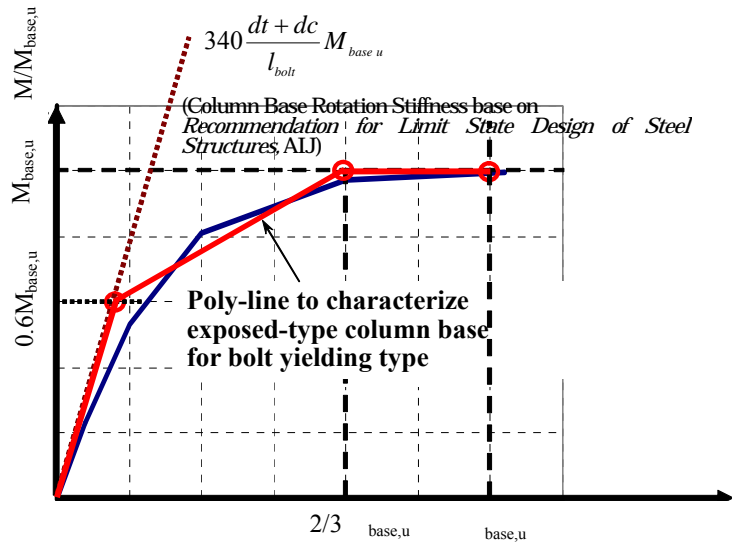


Figure 4. Standard M- θ skeleton curve for anchor bolt yielding type

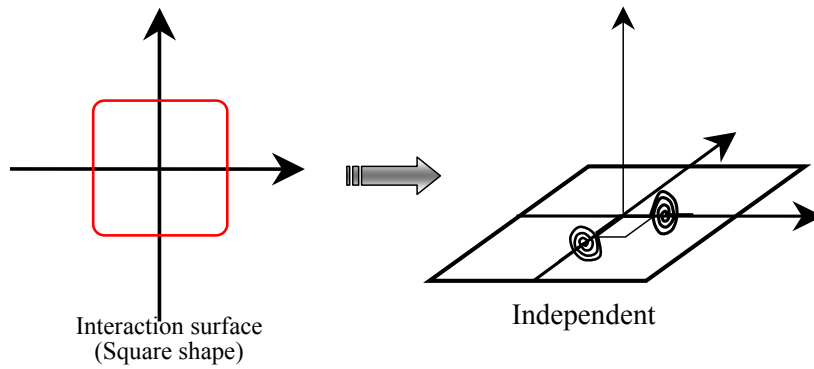


Figure 5. Modeling of bi-axial bending for base plate yielding type

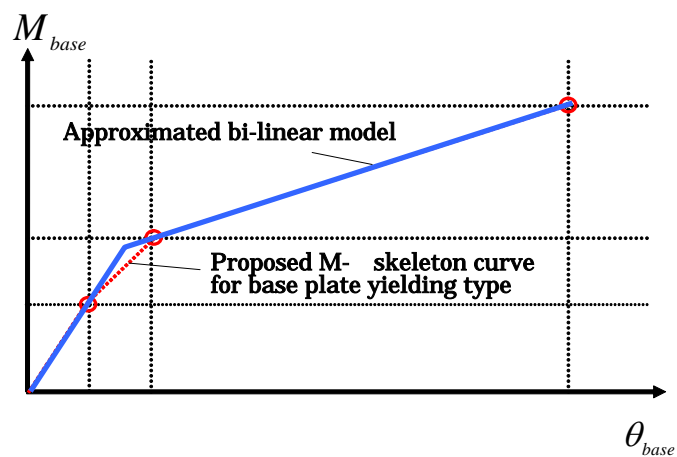


Figure 6. Approximate bi-linear model for base plate yielding type

In case of base plate yielding type

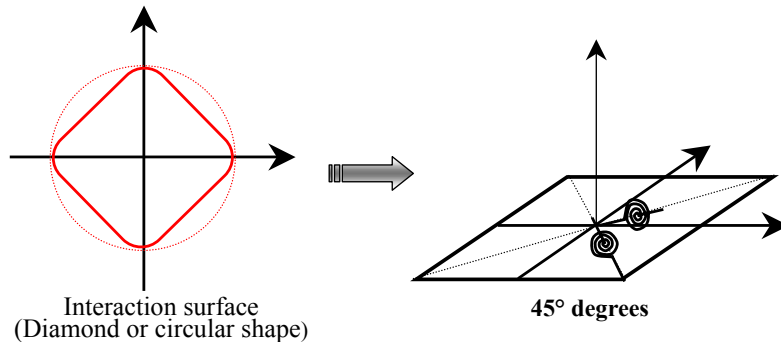


Figure 7. Modeling of bi-axial bending

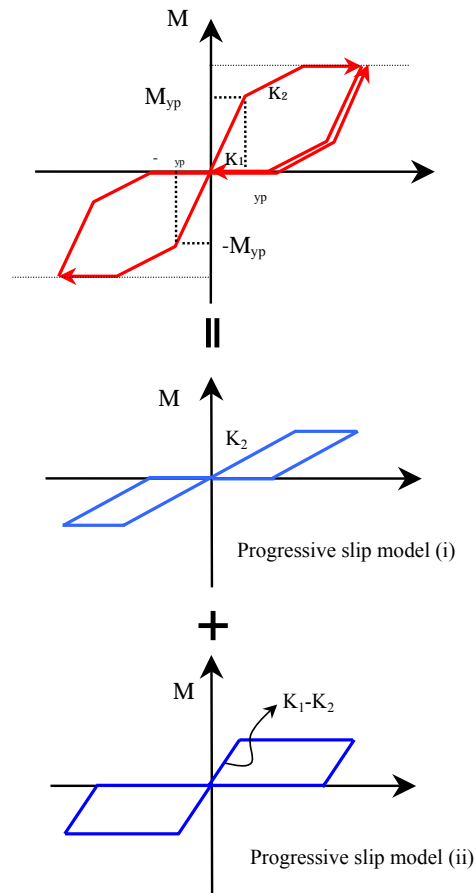


Figure 8. Hysteresis loops (Progressive slip model)

Uni-axial restoring force characteristic model is expanded to bi-axial model, a method to simulate the inelastic behavior in case of biaxial bending is proposed. According to the analysis of the resistance correlation surface obtained from limit analysis, we propose a model turning the independent spring 45 degrees having uni-axial restoring force characteristics. Spring arrangement is presented in Figure 7.

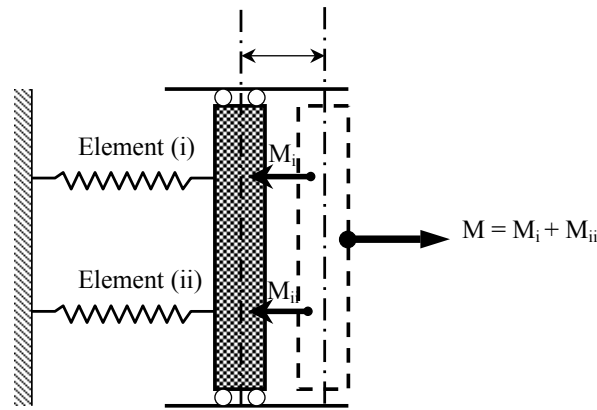


Figure 9. 2-component hysteresis model

Furthermore, since the superposition of the components of the spring arranged to move in the direction of 45 degrees, to have uni-axial stiffness and resistance exceed, the size of spring used in 45 degrees case is $1/\sqrt{2}$ times of the size of the spring used for uni-axial case. The applicability of the proposed method was examined to compare with the past test results of bi-axial circular cyclic loading. (Figure 10 and 11)

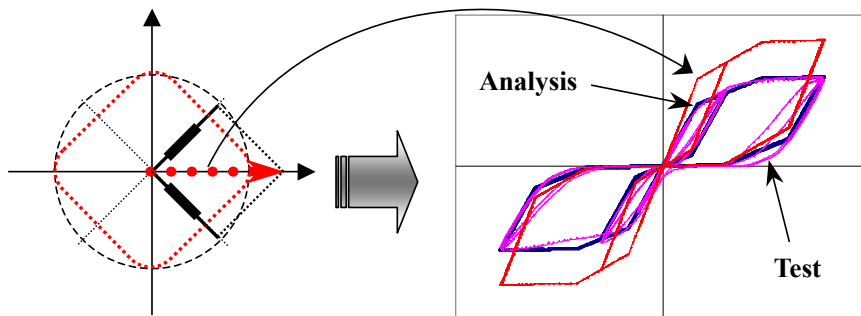


Figure 10. Comparison of inelastic analysis with test result for uni-axis

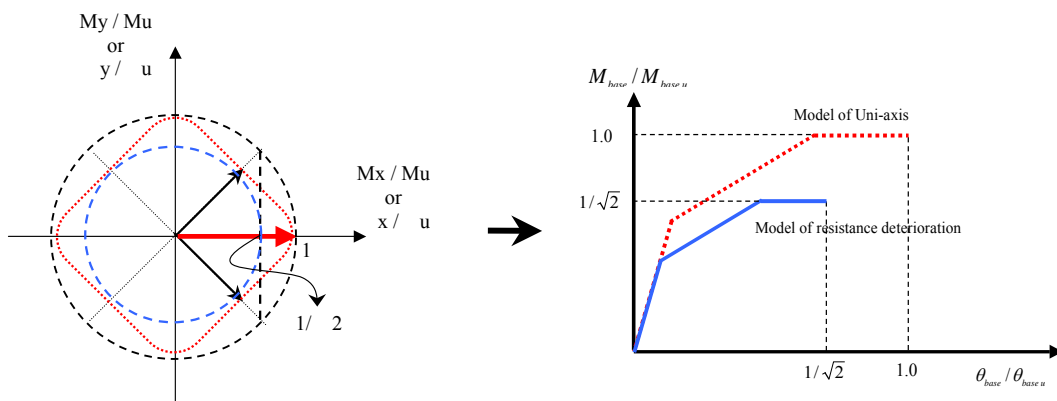


Figure 11. Resistance deterioration model

COMPARISON OF INELASTIC ANALYSIS WITH TEST RESULT

In case of base plate yielding type

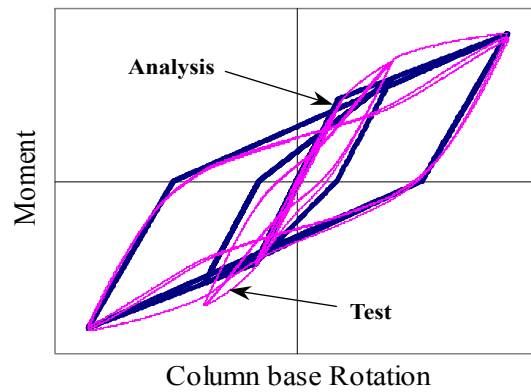


Figure 12. Comparison of analysis with test result for uni-axis of base plate yielding type

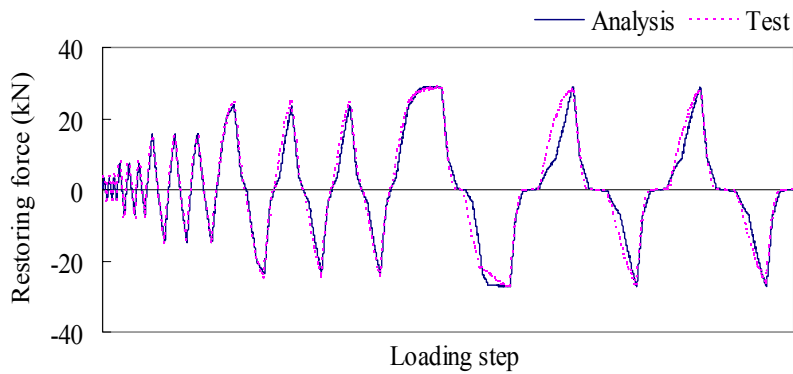


Figure 13. Comparison of restoring force for uni-axial loading

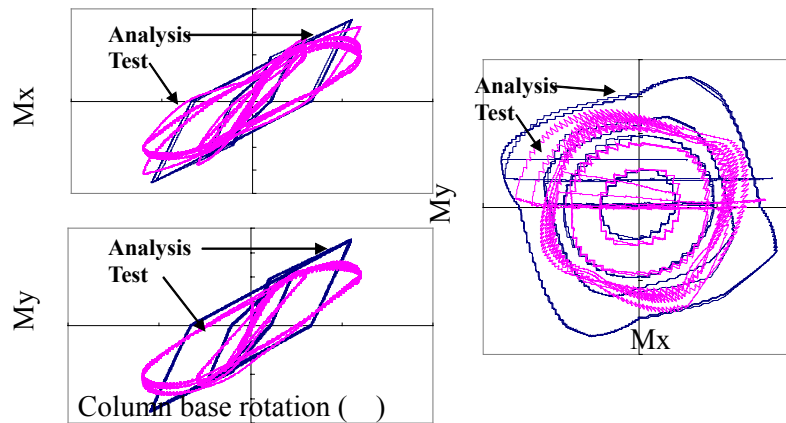


Figure 14. Comparison of inelastic analysis with test result

In case of Anchor bolt yielding type

Analytical results are compared with the experiment result in figure 12-15. Although the experiment result is pursued well for a single axis, in case of bi-axial circular shape type there is a phenomenon with a different inclination of the load route. The model that even the resistance decrease is expressible in detail requires it. However, the tendency to outline shape on a rectangular resistance correlation can be understood.

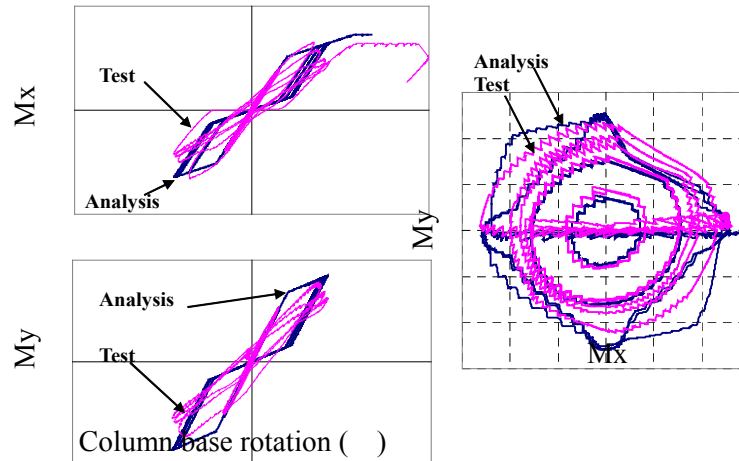


Figure 15. Comparison of inelastic analysis with test result

CONCLUSION

A standard M- skeleton curve of exposed-type column base and estimation method on inelastic behavior under bi-axial bending are proposed. By using the simple analysis model, where the springs are placed on x and y axis of the column base, it is possible to obtain general interaction surface shape under bi-axial bending following inelastic hysteresis loop.

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