Eccentric Interaction between Strong and Weak Axes in the Design of Asymmetric Angle Steel Strength

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Abstract. Steel structural members use many types of material sections and a wide range of sizes. Among them, Angle steel is more economical than I-type due to the use of materials, and is usually used for beam web support and diagonal support. Therefore, this study will analyze the eccentric axis strength change of L-shaped angle steel under the action of biaxial bending moment. The angle steel is divided into equilateral angle steel and unequal angle steel, and the calculation of unequal angle steel is the most complicated. Due to the asymmetry of the axial force, when the angle steel bears an axial force, it will cause eccentric load, which makes it the bending moment caused by the angle steel will change the structure. Therefore, in this study, an unequal-sided angle steel with a length of 10 ft. L8 × 4 × 7/16 was selected as the research object, and the eccentric strength changes of the strong and weak axial forces of the angle steel were analyzed.

1. Introduction
This study is to analyze the eccentric strength of the bending moment on the angle steel when the angle steel is connected to the panel. When the distance between the strong axis (W D) and the weak axis (Z D) changes (refer with Figure 1), the pressure intensity of the eccentric axial that the angle steel can withstand will also change. To analysis the strong and weak axis, the properties of the angle steel need to be obtained first, and then the correct eccentric pressure intensity is calculated using the AISC2017 standard formula, and then the calculated values are compared and analyzed. Because of the asymmetry of the wheelbase of the unequal angle steel and its calculation is more complicated than that of the equilateral angle steel, this study takes the unequal angle steel L8 × 4 × 7/16 as the research object. The eccentric load design of single angle steel mostly adopts the code formula developed by the American Society of Steel Structures [1], and then studies and analyzes. Because of the reliability of the code and the relevant specifications of the current steel structure design in Taiwan are based on the American Steel Structure Society Therefore, this study uses the AISC (2017) specification as the research basis for analysis of subsequent studies.

Liu [2] tested the behavior of single-angle steel beams and columns using unequal-angle angle steels to test eccentric compression with respect to any major or minor principal axis of the angle steel section. Madugula [3,4] studied the design of angle steel and the flexural strength of columns. Bhilawe [5] uses equal angles and a range of maximum principal slenderness ratios to determine elastic and inelastic failure characteristics, including flexural torsional effects. Yuan [6] the basic assumption used in the research is that the angle of the total strain energy is that part of the beam undergoes a uniformly distributed load can be simplified into a two-stage process. In order to verify
the analytical solution developed, non-linear finite element analysis. **Chan** [7] used a simplified formula to calculate the elastic deflection and flexural buckling load of a single-angled member. For single-angled members, a new buckling curve considering the Eurocode 3 design rules was proposed to surround the main and counter-spindles. Withstand eccentric loads. A reliable and effective finite element model is provided to verify the proposed equations and study the different parameters affecting buckling behavior. **Kim** [8] studied the cross-sections of various composite angles to maximize the stress intensity of compression bending under high strength.

**Bradford** [9] are all studying the bending, torsion and buckling behavior of angle steel members, and studying the strength values they bear. The former two use cold-pressed members. Research experiments were conducted, and the last one was studied with high-strength steel plate beams.

**Shi** [10] Experimental studies were performed using the sectioning method. The residual stress magnitude and distribution of 15 sections were obtained, and the influence of the aspect ratio was clarified. Further research on the residual stress and buckling behavior of high-strength steel members provided useful experimental data and calculation methods. **Liu** [11] studied the local buckling behavior of high-strength isometric steel under axial compression, using finite element model to analyze the local buckling behavior of high-strength steel isometric steel under axial compression, and verified by test results.

The analysis of single-angle steel has many conservative and underestimated behaviors. This study analyzes the biaxial eccentric pressure strength analysis of single-angle steel, collects its design formula, and explains the analysis steps. Since the isometric steel differs from the unequal angle steel in that the isometric steel has a symmetry axis and the unequal angle steel has no symmetry axis, the section characteristics of the unequal angle steel are calculated under equal pressure. Complexity. The eccentric load diagram of the angle steel is shown in Figure 1. The D point is the position of the eccentric load, and the ABC three points are the control points of the design strength. According to the recommendations of the AISC specification, the relative position of the load geometry is shown in Figure 1, and analyzed with reference to specific geometries.

![Figure 1. Angle steel point diagram.](image)

**2. Eccentric Load Acting on Single Angle Steel (AISC 2017)**

Mutual Force Bending Moment Mutual Equation of Integral Member. The difference between the integral component equation and the section equation is that the value of \( \frac{P_r}{\phi c P_n} < 0.2 \) must be met after the value is obtained. If the value meets the specification, the component is a large axial force criterion, and otherwise Small axial force criterion.

When \( \frac{P_r}{P_c} \geq 0.2 \) is the large axial force criterion.

\[
\frac{P_r}{P_c} + \frac{8}{9} \left( \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \right) \leq 1.0
\]

(1)
When $\frac{p_r}{P_c} < 0.2$ is a small axial force criterion.

$$\frac{p_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \leq 1.0$$

(2)

formula:

$P_r$ = Considering the axial compressive stress value of LRFD load combination \( \cdot \) kips(N)

$P_c$ = $\phi_c P_n$ = Design axial strength in beam and column \( \cdot \) kips(N)

$M_r$ = Consider the bending stress value of the LRFD load combination \( \cdot \) kip − in(N − mm)

$M_c$ = $\phi_b M_n$ = Design bending moment strength of beam strong shaft \( \cdot \) kip − in(N − mm)

$\chi$ = Subscript related to strong axis bending

$\gamma$ = Subscript is related to weak axis bending

$\phi_c$ = Pressure strength reduction factor \( \cdot \) $\phi_c = 0.90$

$\phi_b$ = Bending load strength reduction factor \( \cdot \) $\phi_b = 0.90$

Calculating the critical setback load of a non-migrating member ($P_{el}$)

$$P_{el} = \frac{\pi^2 E I^*}{(K_1 L)^2}$$

(3)

Calculating the amplification factor ($\beta_1$).

$C_m$ is conservatively take $1.0 \cdot \alpha = 1.0$(LRFD).

$$\beta_1 = \left[\frac{c_m}{1 + \frac{P_r}{P_{el}}}\right] \geq 1$$

(4)

Calculating the bending member without the lateral displacement member.

$$M_u = \beta_1 \times M_{nt}$$

(5)

$M_{nt}$ is the required flexural strength of the component when there is no lateral displacement of the component.

$$M_{ntw} = P_r \times z_D$$

(6)

$$M_{ntz} = P_r \times w_D$$

(7)

In this case, the target search function in the Excel software is used to determine the axial bending strength, and the minimum value of the value is obtained. The value is the eccentric axial pressure strength ($P_r$) that the section can withstand. The value obtained in the equation of the force bending moment and the integral moment of the axial force of the integral member are compared with each other to determine the section control of the angle.
3. Example of Biaxial Eccentricity Strength Calculation

The angle steel is an L8×4×7/16 unequal angle steel with a length of 10 ft. After a series of complicated calculation processes, the length (ft) of the angle steel and the obtained eccentric shaft pressure intensity value are graphically presented.

Figure 2 shows the eccentric axial pressure intensity values of the strong axial distance when the fixed distance of the weak axis is 5 (in). The values presented in the Figure are the values of the double eccentric pressure generated by the biaxial eccentricity. The curve change is different from the common round curve, but has different curve representations. It can be seen from Figure 2 that when the weak axis distance is 5 (in), when the strong axis distance is 0 (in), the intensity curve changes to a smooth curve with a maximum value of 39.15 kips, and if the strong axis distance moves to 0.2 (in), 0.4 (in), and 0.6 (in), The intensity change curve is the same as the round curve, but the intensity value is higher according to the distance. The higher the intensity value, the greater the eccentric shaft strength value is 43.48 kips and the distance is 0.4 (in) when the strong axis distance is 0.2 (in). The maximum intensity value is 48.92 kips, and the maximum eccentric axial pressure intensity value of the strong axis distance of 0.6 (in) is 52.96 kips, which is also the maximum value of the biaxial eccentric pressure intensity value in the study.

In the study, the farther the distance is 0.6 (in), the distance will be a limit. If the distance continues to increase, the resulting eccentric axial pressure intensity will gradually become smaller, which can be 0.8 (in), 1 (in), 2 (in), the curve change is known, and the changes of the three intensity curves are different from the other curves. The three curves are different when the length of the angle is 5 (ft) and the other intensity curves in the study. When the distance is 0.8 (in), when the angle is 11 ft, the eccentric axial pressure intensity value will be higher than the 0.6 (in) eccentric axial pressure intensity value. At this time, the eccentric shaft pressure intensity value is 34.80 kips, and when the strong axis The distance is 0.8 (in), and the length of the 13 (ft) is higher than the 0.6 (in) eccentric axial pressure intensity value, and the eccentric axial pressure intensity value is 28.50 kips.

4. Conclusion

When calculating the pressure strength of the eccentric shaft, the angle steel needs to first determine which kind of limb it belongs to, considering whether it is necessary to correct the formula, to avoid the local frustration of the component, or to be destroyed when the state is not reached, when using the shaft When the force bending moment interaction equation is complicated, it is complicated and requires multiple calculations and corrections, so that the obtained value is the final accurate value. This study takes L8×4×7/16 length 10 ft unequal angle steel as Calculation basis and analysis.
It can be seen from the calculation of the example that the calculation formula is very complicated. Therefore, when analyzing the eccentric axial pressure intensity value of the angle steel, a series of analysis and planning have been done, and the analysis steps are summarized step by step to facilitate subsequent calculation. Actions, and use the Excel target search table to analyze the calculated values.

The research results are as follows:

1. Analysis of the properties of angle steel, the various properties and parameters required for angle steel are obtained, and the calculation of the eccentric strength is started.

2. Use the calculation formula of AISC2017 specification to find the value, use Excel's target search function to bring in the formula, find the eccentric axial pressure intensity of each point, compare it with the standard value, and repeat the correction to get the exact value.

3. Use the modified formula to analyze and find the distance between the angled steel core and the strong and weak axes at each point in the study. When the value is larger, the distance is farther. After obtaining the distance parameter, the points can be calculated. The value of the eccentric shaft pressure strength.

4. When the uniaxial eccentricity, the resulting eccentric axial pressure intensity value will show a smooth curve, and the farther the distance, the lower the eccentric axial pressure strength will be; the two-axis eccentric curve will grow in the opposite direction, first by the distance 0 (in) The starting strength value is increased more, but when the distance is 0.6 (in), it is the limit, and then it will gradually decrease.

5. When the weak axis of the biaxial eccentricity is fixed at 5 (in) and the strong axis distance is 0.8 (in), the eccentric pressure strength value will be higher than the 0.6 (in) eccentric axis pressure strength when the angle is 11 ft. Value, the eccentric axis pressure intensity value is 34.80 kips at this time, and when the strong axis distance is 0.8 (in), the length is 13 (ft), which is higher than the eccentric axis pressure intensity value of 0.6 (in), and the eccentricity at this time The axial pressure strength value is 28.50 kips.

5. Reference

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