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Finite Element Analysis of Pressure Stability of Unequal Angle Steel

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Abstract

This paper mainly studies the compressive stability bearing capacity limit of unequal angle steel. Through the gradual analysis of the diagonal steel parameters, the finite element software is used to simulate the bearing capacity of the angle steel, and further analysis is carried out under the data comparison, and then the unequal edge is obtained. The overall floating tendency of angle steel under the change of multi-angle parameters such as compression mode, slenderness ratio, size, plate length and wall thickness. This study aims to provide reference and guidance for increasing the mechanical properties of unequal angle steel and controlling the reasonable economic accuracy of the angle.

Keywords

Unequal angle steel; Finite element analysis; Ultimate bearing capacity; Multi-angle paramate.

1. Introduction

With the rapid development of the economy, walks of life are nurturing innovative forces on the existing basis, increasing the demand for power resources in the whole society is becoming more and more important. Electric power resources are the source of power for the development of various industries in our country. The power generation, transmission, distribution, and use of power resources are related to the value and significance of power resources. Among them, the correct and reasonable transmission process is particularly important in increasing the power transmission rate.

The study of Gu [1] showed that when the slenderness ratio of the equilateral angle steel changes, the deformation of the entire angle steel will also change, and when it is reduced, the angle steel is more likely to show local buckling, and the smaller the slenderness ratio, the width-thickness ratio has an effect on the bearing capacity of the angle steel. Have a significant impact. Song [2] found through the comparison of test and analysis results that when the length of the angle steel is relatively large, the load-bearing capacity of the unequal angle steel mainly affects the stability of the stressed parts, and the small part of the increase in strength may not The bearing capacity is significantly improved. Gu [3] used simple tensile and bending tests to successfully obtain the elastic modulus and Poisson's ratio of the unequal angle steel, and calculated the centroid of the unequal angle steel, which is used in industrial and engineering structures for unequal angle steel. The application provides a theoretical basis. Under the premise of ensuring that the equilateral angle steel connection is not damaged, Li [4] showed through experiments that the failure modes of the specimens are mainly divided into three types: partial, bending and bending torsional buckling. As the slenderness ratio continues to increase, the main forms of buckling follow this to occur local buckling, bending buckling, and bending-torsional buckling. And during the experiment, it was found that when the slenderness ratio of the equilateral angle steel or the unequal angle steel is greater than a certain fixed value, the influence of the eccentricity on the bearing capacity will not have much influence.

Yang[5] in the study of the axial compression bearing capacity of the unequal-leg angle steel with one-sided bolt connection showed that all unequal-leg angle steel members that are relatively long and thin rods did not appear obviously during the process of slowly increasing the load at both ends. The torsional deformation of this type of unequal-sided angle steel members is the main failure mode of bending buckling. Li [6] In the research experiment of cold-formed unequal angle steel shaft compression rod, it is shown that cold-formed unequal angle steel is generally prone to elastic bending and torsion buckling when the slenderness ratio is not less than 90, and it is easy to occur when the slenderness ratio is less than 90. Elastic-plastic bending torsional buckling. Although relevant research has been carried out, there is still little research on the impact of the rational use of 'unequal-leg angles' of transmission poles and towers on the force-bearing capacity of transmission towers in the process of transmitting power resources. Transmission towers with reasonable constructions can not only improve economic benefits, but also Can reduce safety hazards. Among the various towers, the angle steel tower has its own unique advantages over other types of towers. The parts are easy to manufacture, easy to assemble, and easy to purchase, and the angle steel production and processing process is relatively simple.

Therefore, in order to increase the popular use of unequal angle steel in more fields, especially to break through the bottleneck used in the construction of domestic transmission line towers, increase the force study of unequal angle steel, and then analyze the comparison of unequal angle steel. The outstanding advantages of equilateral angle steel are of great significance.

2. Theory

2.1. Nonlinear Buckling Analysis

Unequal angle steel and equilateral angle steel are the same series of components, but unequal angle steel is more specific. Its section type does not belong to the symmetrical section type in the mechanics courses of materials and structure. It is an asymmetric section type member and bears externally. During the load process, such asymmetrical cross-section members will not produce general bending deformation, but will undergo bending torsion buckling deformation, and even reach an unstable state. Chen [7] pointed out in the research that when a member undergoes flexural-torsional buckling deformation under pressure load, an elastic stage will occur first, and the load that causes elastic flexural-torsional buckling deformation at this time has nothing to do with the order of loading, and MATLAB energy can be used The method calculates the ultimate bearing capacity that the angle steel can withstand. Guo [8] According to the principle of the stationary value of potential energy calculated by the MATLAB energy method, the equilibrium differential equation is deduced, and finally the following elastic buckling equation of the bending member under pressure is summarized after simplification and calculation:

$$(N_{E_X}-N)(N_{E_Y}-N)\left[i_0N_W-N({i_0}^2+2\beta_xe_x+2\beta_ye_y)\right]-N^2[(N_{E_X}-N)(y_0-e_y)^2-(N_{E_Y}-N)(x_0-e_x)^2]=0$$

Among them, e_x,e_y are the eccentricity of the external load N, N_{E_X}, N_{E_Y}, N_W are the critical force of elastic bending and the critical force of elastic torsion buckling around the x and y axes, respectively,β_x,β_y are the cross-section asymmetry parameters, calculated according to the following formula :

$$\beta_x=\frac{\int_A x(x^2+y^2)dA}{2I_y}-x_0$$

$$\beta_y=\frac{\int_A y(x^2+y^2)dA}{2I_x}-y_0$$

I_x, I_y are the inertia axes of the angle steel section around the x-axis and the y-axis respectively.

2.2. Design Specifications

According to my country 'Code for Design of Steel Structures' [9] (GB50017-2017) version of the introduction to and unequal angle steel, we can consider the simplified unequal side steel structure as a standard structure first, and regard it as It is carried out by angle steel unilateral axial member, and the strength reduction coefficient is used to consider the influence of load eccentricity caused by unilateral connection. The stability calculation method is as follows:

$$N \leq \varphi_b A \eta_t f$$

φ_b, the stability coefficient of the axial compression member (take the smaller of the stability coefficients of the two main axes of the interface), which is checked and used according to the slenderness ratio and the yield strength of the steel.

It can also be calculated according to the following calculation formula:

$$\lambda_n = \frac{\lambda}{\pi}\sqrt{f_y/E} \leq 0.215:$$

$$\varphi = 1 - a_1\lambda_n^2$$

$$\lambda_n = \frac{\lambda}{\pi}\sqrt{f_y/E} > 0.215:$$

$$\varphi = \frac{1}{2\lambda_n^2}\left[(a_1 + a_2\lambda_n + a_3\lambda_n^2) - \sqrt{(a_2 + a_3\lambda_n + \lambda_n^2)^2 - 4\lambda_n^2}\right]$$

For the cross-section of type b, a_1=0.65, a_2=0.965, a_3=0.3, η_t is the eccentricity influence coefficient when unilateral connection. For equilateral angle steel η_t=0.6+0.0015λ, short side connected unequal angle steel η_t=0.5+0.0025λ, the unequal angle steel with the long sides connected η_t=0.7, and η_t in the above three cases is not greater than 1.0.

3. Research Content

In this study, the ANSYS finite element software was used for calculation, and the change trend of different angles was analyzed by changing the parameters of different angles.

3.1. Angle Steel Size and Thickness [10]

Currently there are hundreds of unequal angle steel sizes that can be produced, but relatively few angle steel sizes can be applied and used in the construction of transmission line towers, some of which are as follows:

Table 1. Dimensions of unequal angle steel in common tower lines

Long limb width	Short limb width	Leg thickness	Fillet radius
……			
90	56	5/6/7/8	9
100	80	6/7/8/10	10
125	80	7/8/10/12	11
140	90	8/10/12/14	12
160	10	10/12/14/16	13
……			

3.2. Slenderness Ratio [11]

Table 2. Modification coefficient K of slenderness ratio of compression member

No.	Force at the end of the rod	Slenderness ratio λ	Slenderness ratio correction coefficient K	Examples of applicable members
1	Compression at the centers of both ends	$0<\lambda<120$	1	Components connected by two limbs
2	One end is centered and one end is eccentrically compressed	$0<\lambda<120$	$0.75+30/\lambda$	One end has two limbs, one end is short; crossed oblique material
3	Eccentric compression at both ends	$0<\lambda<120$	$0.5+60/\lambda$	Single limb connecting member at both ends
4	Unconstrained at both ends	$120<\lambda<220$	1	Cross-inclined material and single-inclined material connected by a single bolt
5	There is a constraint at one end	$120<\lambda<231$	$0.9+11.98/\lambda$	Crossing oblique material connected by more than two bolts
6	There are constraints at both ends	$120<\lambda<242$	$0.82+21.64/\lambda$	There are two or more bolted components at both ends

3.3. Arrangement and Quantity of Bolts

Table 3. Arrangement and quantity of angle steel

Limb Width	Baseline	First-row guideline	Second-row guideline	Maximum useable aperture of angle steel
......				
<56	28 (32)			17.5
<75	38 (40)			
<90	45			
<125	60	50	80	21.5
<140	70	55	90	25.5
......				

Table 4. Bolt spacing and edge distance are as follows [12]

Bolt diameter	Component aperture	Bolt spacing			Margin	
		single row	Double row	End distance	Rolling margin	Chamfer margin
M12	Φ13.5	40	60	20	≥17	≥18
M16	Φ17.5	50	80	25	≥21	≥23
M20	Φ21.5	60	100	30	≥26	≥28
M24	Φ25.5	80	120	40	≥31	≥33

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3.4. Angle Steel Material

Choose to use two kinds of materials, Q235 and Q345, which are relatively widely used.

Table 5. Mechanical properties of Q235 and Q345 steel

Steel grade	Yield Strength		tensile strength		Elongation
	MPa	Kg/mm^2	MPa	Kg/mm^2	No more greater
Q235A	235	24	375-460	38-47	26
Q235B					
Q235C					
Q235D					
Q345A	345	/	470-630	/	21
Q345B	345		470-630		21
Q345C	≥ 325		470-630		22
Q345D	≥ 295		470-630		22

4. Result Analysis

4.1. Load-displacement Diagram

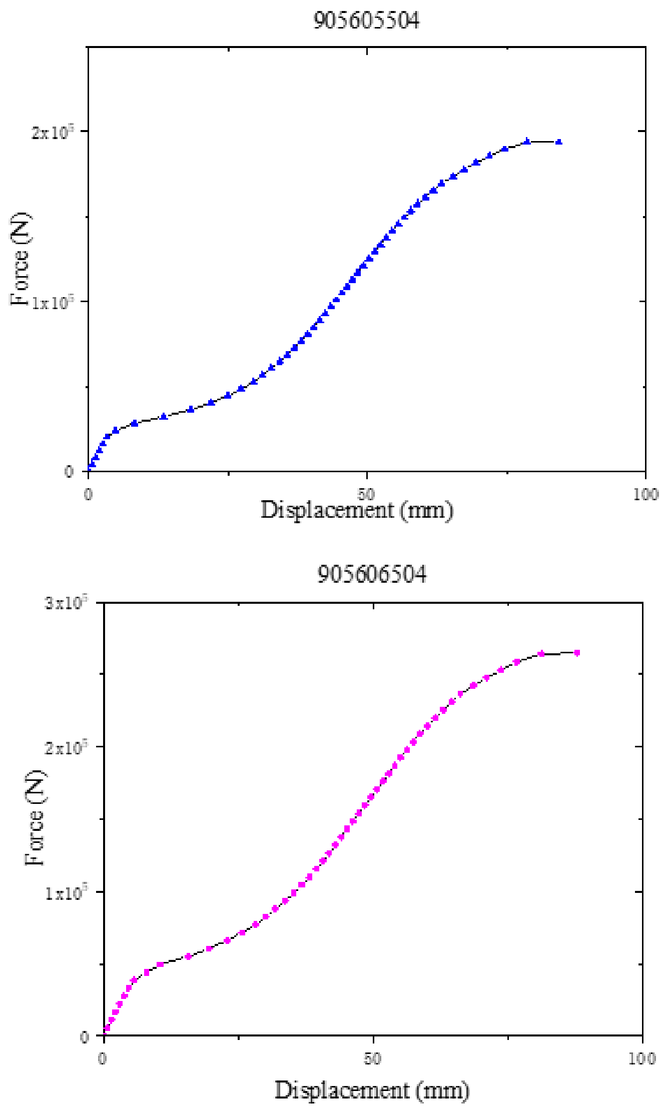

Figure 1. Load-displacement curve

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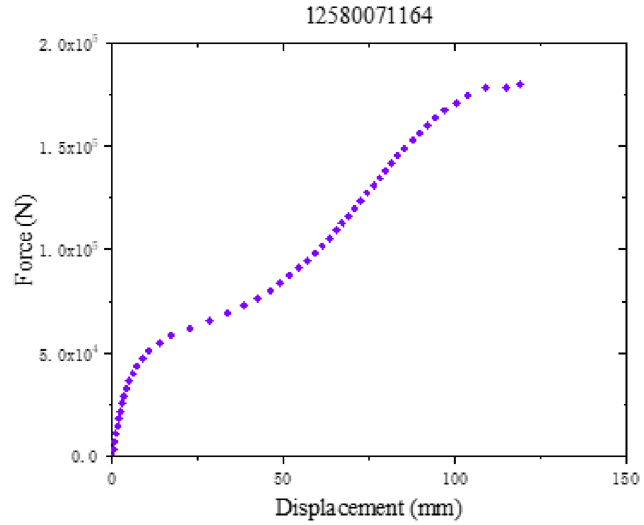
This research mainly uses ANSYS finite element software for analysis and simulation. Various load-displacement curves can be obtained by post-processing of the simulation, including load-axial displacement curve, load-transverse displacement curve, etc. There are many types of angles in the simulation. Through processing, it is found that the load-axis displacement curves of different angles have similar trends. The figure shows the axial displacement curves of some angles, and the material is all Q235. The name of the curve is "long leg width + short leg width + wall thickness + length". For example, 905605504 is an L90×5 unequal angle steel with a length of 504 and a leg thickness of 5. It can be seen from the figure 1 that in the initial stage of loading, the angle steel is in the elastic deformation stage, and the curve changes linearly. As the pressure increases and approaches the ultimate bearing capacity, the angle steel undergoes plastic deformation and enters the elastoplastic stage. The displacement will suddenly increase, and there will be a non-linear change. It is mentioned in the parameter setting that the angle steel material is regarded as an ideal elastic plastic body, the tangent modulus is 0, and the strengthened part after yielding is not considered. When the finite element software calculation does not converge, the load increment will be small and the deformation displacement will be large. At this time, the load has reached the ultimate bearing capacity.

4.2. The Effect of Slenderness Ratio

The first type of simulation experiment was carried out on the three angle steel sizes of L90*56, L125*80, L140*90 respectively, and some of the load-displacement diagrams are like figure 2:



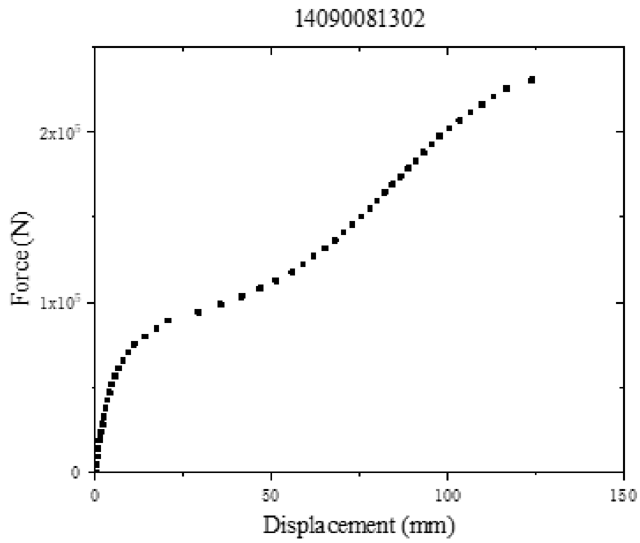


Figure 2. Load-displacement curve

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The ultimate bearing capacity under various parameter conditions is as shown in Table 6:

Table 6. Simulation results of bilateral compression angle steel

Material	Slenderness ratio λ	Angle Steel Length (mm)	Long limbs (mm)	Short limbs (mm)	Thick limbs (mm)	Ultimate bearing capacity (KN)
Q235	30	504	90	56	6	265
Q235	40	672	90	56	6	172
Q235	50	840	90	56	6	131
Q235	60	1008	90	56	6	105
Q235	80	1344	90	56	6	75.6
Q235	30	1164	125	80	8	222
Q235	40	1552	125	80	8	156
Q235	50	1940	125	80	8	123
Q235	60	2328	125	80	8	97.8
Q235	30	1302	140	90	8	210
Q235	40	1736	140	90	8	126
Q235	50	2170	140	90	8	121
Q235	60	2604	140	90	8	98.5

The deformation trend chart is as figure 3

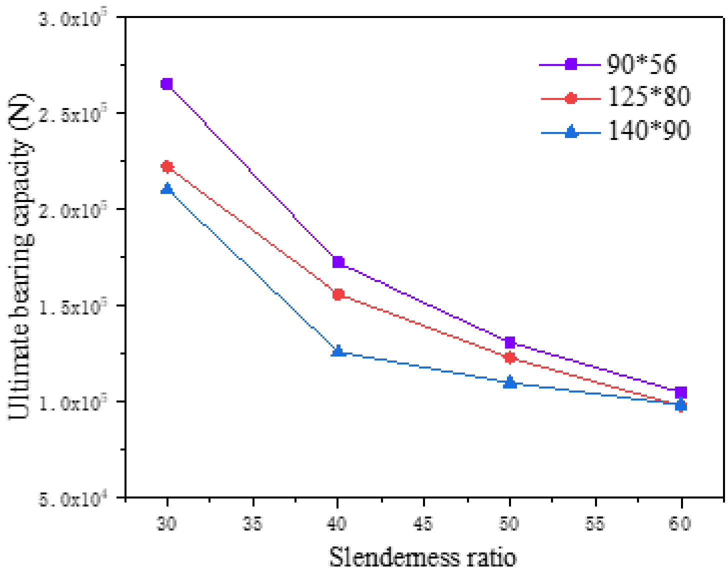

Figure 3. Slenderness ratio-bearing capacity summary chart

According to the figure 3, we know that in the three size angle steels L90*56, L125*80, and L140*90, the overall change trend is roughly the same, and the ultimate bearing capacity increases with the length of the angle steel. The ratio increases and decreases gradually, and it gradually tends to be easy to lose stability. Among them, according to image a, it can be seen that in the process of increasing the slenderness ratio of the angle steel with the size of L90*56, the value of the ultimate bearing capacity decreases more prominently, while the angle steel

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with the size of L140*90 is increasing with the length. As the fineness ratio gradually increases, the decrease is slightly relieved. The middle size angle steel L125*80 is in the middle range.

From the changing trends of the above three curves, we can conclude that the larger the overall size of the angle steel, the smaller the ultimate bearing capacity will increase with the increase in the slenderness ratio. On the contrary, the smaller the overall size of the angle steel, the ultimate bearing capacity will increase with the length. The finer ratio increases with the increase. It also verified everyone's default idea that no matter the size of the angle steel, as the slenderness ratio increases, the overall ultimate bearing capacity will decrease.

4.3. The Effect of Limb Thickness

In order to understand the influence of angle steel limb thickness on its compression stability, three types of angle steels of L90*56, L125*80, and L140*90 are selected for calculation. First, change the thickness of the angle steel, and the slenderness ratio is 30. Different specifications of unequal-sided angle steel have different cross-section radius of gyration. It is found that the radii of gyration of these types of specifications are different. Therefore, the length of the angle steel will be different when the slenderness ratio is the same. The following mainly analyzes the influence of limb thickness from two aspects of its ultimate bearing capacity and load-axial displacement curve. The ultimate bearing capacity under various parameter conditions is summarized in Table 7:

Table 7. Simulation results of variable angle steel limb thickness under bilateral compression

Material	Slenderness ratio λ	Angle Steel Length (mm)	Long limbs (mm)	Short limbs (mm)	Thick limbs (mm)	Ultimate bearing capacity (KN)
Q235	30	504	90	56	6	265
Q235	30	504	90	56	5	194
Q235	30	504	90	56	7	346
Q235	30	504	90	56	8	426
Q235	30	1164	125	80	8	222
Q235	30	1164	125	80	7	179.8
Q235	30	1164	125	80	10	335
Q235	30	1164	125	80	12	471
Q235	30	1302	140	90	8	210
Q235	30	1302	140	90	10	328
Q235	30	1302	140	90	12	471
Q235	30	1302	140	90	14	629

The change trend chart is as figure 4:

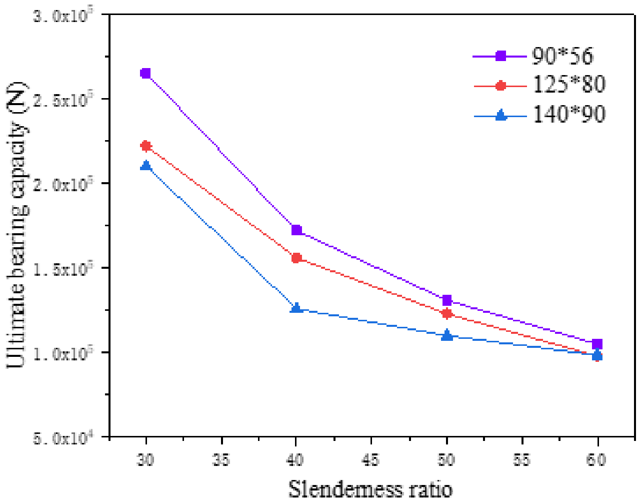

Figure 4. Wall thickness-bearing capacity summary chart

Through Figure 4, we know that the ultimate bearing capacity of these three sizes of angle steel is gradually increasing as the wall thickness increases. Analyzing the trend of the graph shows that the three sizes of angle steel, L90*56, L125*80, and L140*90, as the wall thickness continues to increase, the overall change trend and the upward trend of angle steel are basically the same, but the angle steel The larger the size, the higher the ultimate bearing capacity of the foundation will be. After the corresponding wall thickness is increased, the overall ultimate bearing capacity will increase more. Similarly, the smaller the overall angle steel size increases, the smaller the increase.

From the above analysis, we can conclude that as the wall thickness increases, regardless of the size of the angle steel, the increase in the ultimate bearing capacity is basically the same, and there will be no large gap due to the difference in the size of the angle steel.

4.4. The Influence of Material

In addition to simulating the compression of Q235 material, this simulation changed the material properties. The angle steel gave Q345 material characteristics. The unequal-leg angle steel of L125*80 specification was simulated, and the slenderness ratio was 30, 40, 50, and 60. Comparing the two materials Q235 and Q345, the comparison is mainly made from three aspects: failure form, ultimate bearing capacity, and the trend of ultimate bearing capacity with slenderness ratio. The change trend chart is as figure 5:

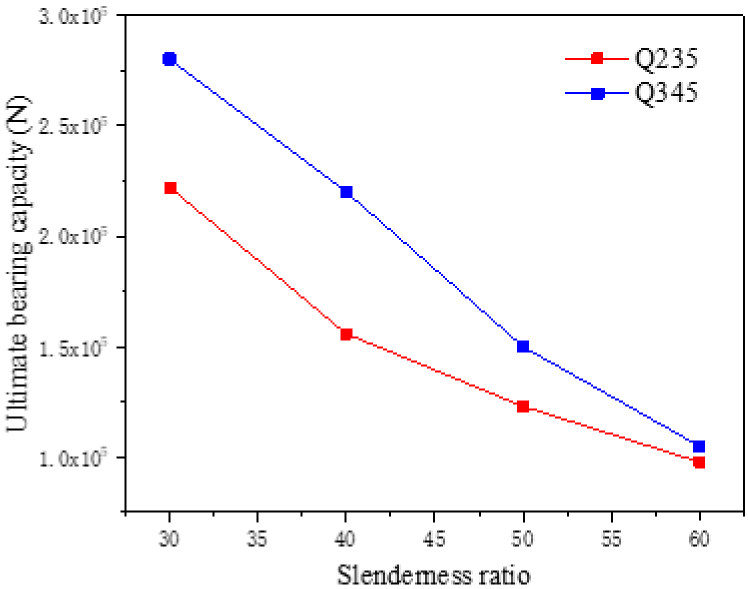

Figure 5. Different material steel slenderness ratio-bearing capacity summary chart

From the Figure 5, we know that both Q235 and Q345 material, the ultimate bearing capacity of angle steel will gradually decrease with the increase of slenderness ratio, but the overall change trend of angle steel with Q345 material is more rapid , And relatively speaking, the change trend of angle steel made of Q235 is slightly weaker.

Based on the above analysis, we can see that the material properties of angle steels are relatively better. As the slenderness ratio changes, the ultimate load-bearing capacity changes more. However, the relative material performance is weaker, and the overall slenderness ratio changes. The bearing capacity changes slightly.

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5. Future

This article mainly discusses the 'Finite Element Analysis of the Stability of Unequal Angle Steel under Compression', so the focus of the research is on the changes in the stability of the unequal angle angle due to changes in its own indexes under various compression conditions. That is, the changing trend of the ultimate bearing capacity that can be withstood. Therefore, the finite element simulation results of this time did not take into account the initial defects of the angle steel, such as the initial curvature of the angle steel, manufacturing errors, etc. and this test is an analysis simulation under an ideal state, and the ultimate bearing capacity value will be somewhat different from the real one. The value has a certain error, but the error range belongs to the normal range.

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