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Study on the Calculation Method of Honeycomb Steel Structure

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Abstract

Honeycomb beam is I-steel or hot rolled H steel. Steel beam with web holes after cutting, assembled and welded. Its advantages of light weight, high bearing capacity, beauty and economy make it more and more widely used in practical engineering. This paper is the basis of previous studies. Above, the structure form and design method of honeycomb steel beam are summarized and a brief economic evaluation is conducted, which provides convenience for future engineering designers and researchers. Its main features are: High flexural stiffness, material saving, good economy. Due to the honeycomb steel beam dislocation welding makes the height of the finished component is greater than the parent component, makes the honeycomb steel beam bending stiffness increased significantly, like the bending stiffness of honeycomb steel beam can reach 1.5 times of the prototype steel, and the production process does not increase the material dosage and component surface area, so as to save steel, save material cost and fire prevention, rust coating cost, at the same time the honeycomb combination beam can also reduce the total weight of the structure, and save the structural system resistance to vertical force and horizontal force of required materials, also reduce the materials required for basic design.

Keywords

Honeycomb Steel Structure; Bending Shear Performance; Bending Stiffness.

1. Introduction

Honeycomb beam is a new type of steel structure member, through the opening in the web, save the material, reduce the dead weight of the structure, facilitate the layout of pipes and other equipment, make full use of the building space, in the large span, high-rise and other buildings. However, due to the influence of the hole, the study of the honeycomb beams is very necessary. Because this member increases the section height than the original industrial shape member, it increases the section stiffness and bearing capacity without increasing the amount of steel, which is especially suitable for the components designed by stiffness control design, such as roof purlin, floor beam with human span and light load.

1.1 The Purpose and Significance of the Project

At the present stage, honeycomb components have been used in many buildings in China, but the research on honeycomb steel beam and honeycomb combination beam in China is not deep enough, and a mature design system has not been formed and the complete technical specifications are lacking. A large number of studies at home and abroad also focus on the bending resistance, shear bearing capacity and stability of honeycomb beam and honeycomb beam, while the research on the negative

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bending moment area of honeycomb beam beam is very limited. The honeycomb composite beam can significantly reduce the height of the beam when applied in the form of continuous beam, and the secondary beam can be designed as a continuous beam when applied in the frame structure, while the frame main beam needs to consider the interaction between the beam and column nodes. Although the internal force distribution of the main beam is different from that of the continuous beam, the design method and calculation criteria of the negative bending moment area are similar to those of the continuous beam. The cracking of the concrete slab in the negative bending moment area of the composite beam will reduce the stiffness of the guide beam, rust the steel bar and steel beam, affect the normal use of the structure and reduce the durability of the structure. Compared with the solid belly beam, the honeycomb beam with the same section height has a lower stiffness, and the negative bending moment has more significant effects on the honeycomb combination beam. Therefore, it is of great theoretical and practical value to study the bearing capacity and bearing characteristics of honeycomb beam. In view of this, the bearing capacity, the destruction pattern, and the stress distribution rules of the honeycomb composite beam are tested. According to the test results, a reliable numerical simulation model is established to explore the development law of the negative bending moment zone of the honeycomb combined beam. The effects of the thickness, the strength ratio of reinforcement, the thickness ratio and the opening ratio of the wing edge of the steel beam were studied. Based on the test and numerical simulation results, the bearing capacity of the negative moment area of honeycomb combined beam is given, and the calculation formula of bearing capacity is established.

1.2 Research Status, Both at Home and Abroad

It has been a hundred years since the concept of honeycomb beam in the early 20th century, and the concept of honeycomb beam was put forward by Harton. In the early years. Subsequently, Amin.Mohbekhah[1] corrected the calculation formula of the bending moment gradient in AISC-LRFD combined with the inelastic torsion of the honeycomb beam. Zhou Chaoyang gave the analysis method of the overall stability and deflection of the honeycomb steel beam considering the hole reduction, and Benediktas Dervinis proposed the method of determining the section size of the honeycomb beam. In 2011, Konstantinos Daniel Tsavdaridis conducted tests and finite element analysis of honeycomb beams with round and non-standard web openings, and studied the failure pattern and ultimate strength of the pier between two adjacent web openings, as well as the effects of web opening spacing, web opening depth and web thickness on the flexion and stability of the pier. It shows that the vertical shear resistance of the honeycomb beam increases with the increase of the pier width, and when the pier bears a large fasting bending force, the vertical shear resistance decreases slightly; and the maximum shear stress increases from the middle height of the pier to the center of the axial force, closer to the bottom surface of the beam[3][6]. In 2012, Jia Lianguang [1] analyzed the shear bearing formula of the honeycomb beam considering the hole type, opening rate and flange thickness, the results showed that the hole type had great influence on the stress concentration of the hole angle of the honeycomb hole, and the ratio increased by 20% to 40%. In 2012, Ehab Ellobody proposed a nonlinear finite element model of simple supported honeycomb steel beam considering the initial geometric defects of steel beam, residual stress and the nonlinear behavior of flange and web materials, and studied and discussed the nonlinear behavior of normal and high strength honeycomb steel beams under the combined flexion mode. The results show that the failure load of the honeycomb steel beam destroyed due to the combined mode of the web distortion and the pier flexion is significantly reduced, and the use of high strength steel greatly increases the failure load of the elongated honeycomb steel beam. In 2015, wang peijun put forward on the basis of the hexagonal hole honeycomb beam to reduce the hole Angle stress concentration of honeycomb beam, the finite element analysis, using ANYSY analysis shows that the circular Angle polygonal hole honeycomb beam performance and characteristics are close to the circular hole honeycomb beam, gives the honeycomb beam bending capacity calculation of oblique column theory and the calculation method of oblique column parameters. In 2016, Delphine Sonck and Jan Belis[2] studied the flexion performance of weak axis bending resistance of honeycomb beam by considering

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the influence of modified residual stress pattern and modified geometry, and proposed the calculation method of critical buckling load of honeycomb beam.

2. The Design of the Honeycomb Beam

2.1 Section of the Honeycomb Beam

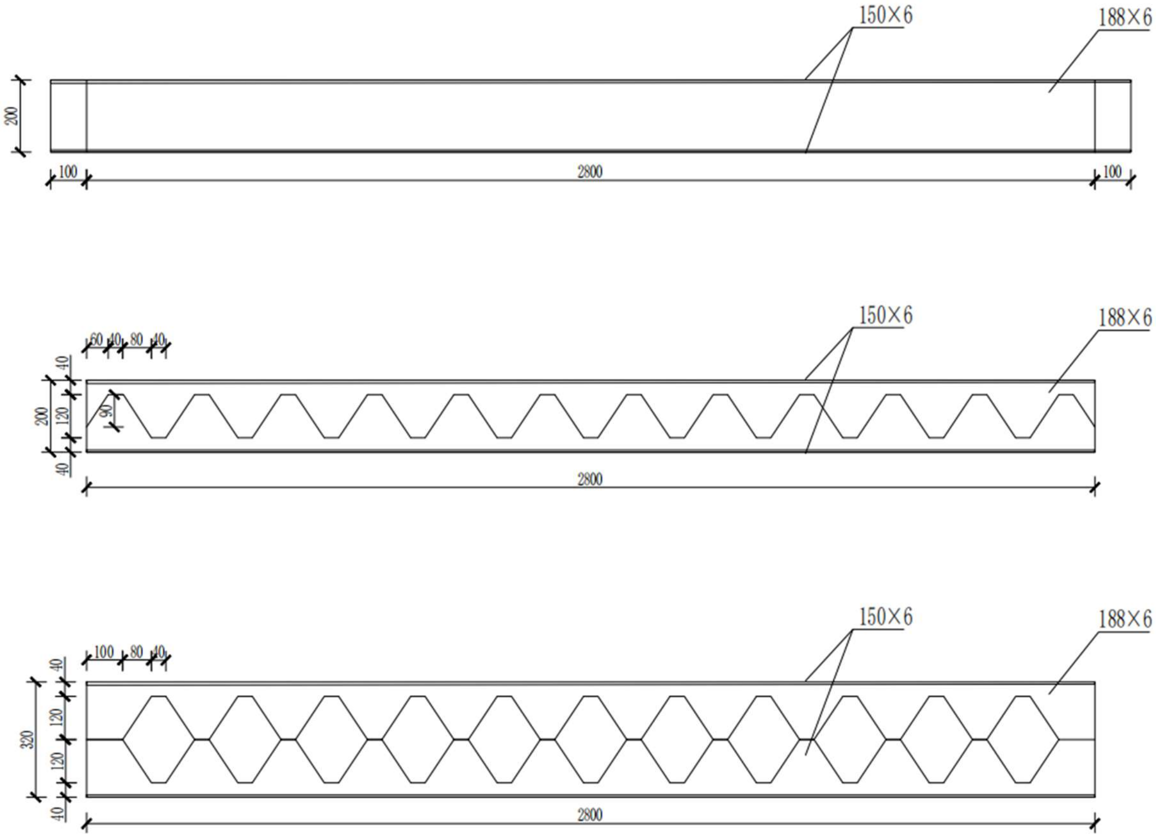

Fig. 1 Section of the Honeycomb Beam

Honeycomb beam, because of its light weight, large bending stiffness and easy holes to lay pipes and cables, is a suitable form of building cover beam with large span and small shear. Schematic diagram of the honeycomb beam with H-shaped steel. The H-shaped steel is divided into two sections along the section line on the web, and then the lower section is turned horizontally, and then the weld is welded with the upper section. At the same time, the shadow of the web is welded between the two sections. Finally, the H-shaped steel beam with the original section height of h1 is made into the peak socket beam with a height of h2

2.2 The Design of Honeycomb Beam Can be based by the Following Practical Calculation Methods

1) When calculating the bending strength of the bent member, it is necessary to select the section plastic development coefficient from the ratio of the free extension length of the flange to the thickness of the flange. In this experiment, we deepen the understanding of the plastic development coefficient of the section by setting the different thickness ratio of the flange[4].

$$\frac{1.1M\max}{\gamma_x W\alpha} \leq f \quad \text{(The section was not weakened)} \tag{1}$$

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$$\frac{M_\beta}{h_T A_T} + \frac{V_\beta a}{4\gamma_{x2} W_{T\min}} \le f \text{ (weakens the maximum cross section)} \tag{2}$$

$M\max$ ----------The maximum bending moment of the beam;

W_α ----------The beam does not weaken the section modulus of the section;

M_β ,V_β --------The unfavorable combination of bending moment and force at the maximum section;

h_T ---------The beam weakens the distance between the upper and lower T-shaped sections at the maximum section;

A_T ----The beam weakens the area of a single T-section at the maximum section;

$W_{T\min}$ -----The beam weakens the minimum section modulus of a single T-section at the maximum section;

a -----Horizontal geometry dimensions of the honeycomb aperture;

γ_x γ_{x2} ------Coefficient of plastic development, taking 1.05 and 1.2, respectively.

Replacement value:

(1.1×31.60×1000×2.8)/(2×1.05×0.220×0.33)=63.838 (N/mm2) < 215

(15.8×1000×2.8)/(0.18×0.90024)+(15.8×0.17)/(4×1.2×3310.2)=60.131 (N/mm2) < 215

2) Scratch check:

The opening of the web will weaken the stiffness of the beam. When the degree of weakening is large, in addition to the influence of bending stiffness weakening on the deflection, the influence of shear stiffness weakening must also be considered. If the weakening degree is small (h2 / h1≤1.5), it can be calculated according to the following simplified formula[5]:

$$\eta \frac{M_{k\max} l^2}{10EI} \le [\upsilon] \tag{3}$$

$M_{k\max}$ ----------Standard of the maximum bending moment in the beam span;

----- Moment of inertia calculated from the section;

l------span of beam;

η -----Consider the deflection amplification factor of the section weakening;

$[\upsilon]$----The deflection allows the value.

Table 1. Toughing magnification coefficient

Depth-span ratio(h_2/l)	1/40	1/32	1/27	1/23	1/20	1/18
η	1.1	1.15	1.2	1.25	1.35	1.4

Mkmax=1×[1.3×(32.11+7.605)+1.5×27.0492.1895]=92.1895 kN.m

(1.4×92.1895×2.8×2.8)÷10EI=0.07345 ≤ 1.15

I=b*h^3/12=(0.2×0.333)/12=5.9895×10-4

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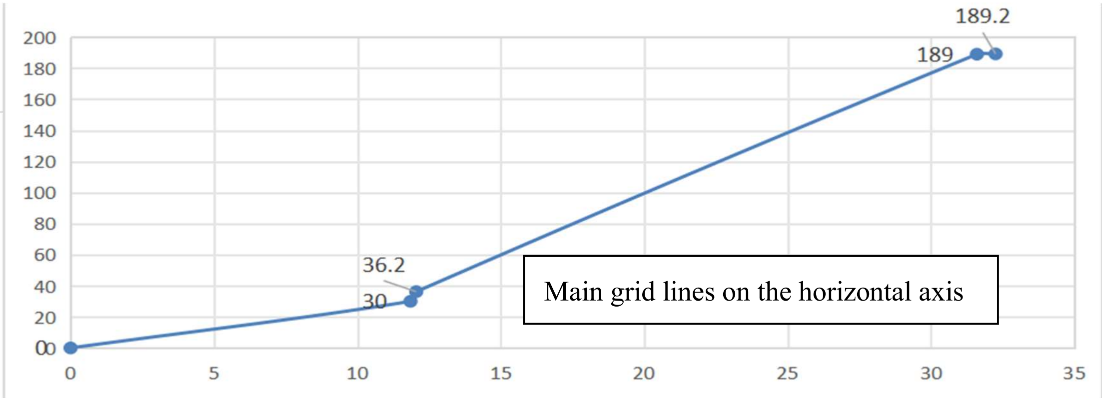

Fig. 2 Record of loading conditions and results

3. Conclusion

The force applied at the first moment is zero, and the steel beam has no bending degree. The second and third moments, the steel beam bends slightly with the increase of the force. The fourth and fifth moments reach the limit state with the increase of the force, and the bending degree of the steel beam reaches the maximum.

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