

# Study on the mechanical properties of inclined rod steel canopies

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**Abstract.** A tilt-tie steel structure canopy is used as the research object, and the structural mechanics solver is used to focus on the calculation and analysis of the different connection methods between the various parts of the structure and the force situation of the canopy under different angles of the tilt-tie, to analyze the important mechanical performance indexes, to arrive at the best connection method and angle of the tilt-tie, and to optimize the design of the tilt-tie canopy system according to the conclusions drawn from the above analysis.

**Keywords:** Steel canopy; Diagonal ties; Mechanical properties.

## 1. Introduction

Canopy is a kind of building assembly installed at the entrance or top of the building to block the wind and rain, and is widely used in urban buildings, stations, airports and other places. The forms of rain shed are classified according to the materials used, there are mainly concrete structure rain shed and steel structure rain shed, steel structure rain shed is more used because of stronger, lower construction cost and higher construction efficiency, among which the steel structure tilt rain shed is more typical, at present, the research and analysis about the steel structure tilt rain shed mainly focus on the design and construction methods, etc., about the analysis and optimization of the mechanical properties of this kind of rain shed The research on the analysis and optimization of the mechanical properties of this type of canopy is still blank, and the analysis and research on its mechanical properties can improve the stability of the overall structure and optimize the structural design of the canopy.

## 2. Features and uses of canopies

### 2.1 Applicability and characteristics of concrete structural canopies

Concrete structure canopy is a more traditional style of canopy, generally in the design of canopy structure with small span or small load. Concrete structures are more durable and fire resistant, generally do not require regular maintenance and repair under normal conditions of use and are not flammable [1]; good integrity and moldability, can be made into various shapes and sizes of components and structures according to the needs of the design, and are less difficult to produce. But the disadvantages and limitations of concrete canopies are more prominent. [2]

(1) Concrete canopies are self-reliant and their self-weight is much greater than the weight of a steel structure of the same height or span.

(2) Concrete has a low tensile strength and is susceptible to cracking when used as a tensile component, and although the presence of cracks does not necessarily mean that structural damage occurs, it can have an impact on the durability and aesthetics of the structure.

(3) The parts are not easy to replace after damage, and it is difficult to repair the reinforcement, but once there is damage can only be replaced.

(4) Concrete structures generally need to be poured on site, and there are many cross-operations between the site pouring concrete structure canopy and other building construction, large amount of scaffolding for single-storey structures, and high site road requirements for concrete tanker trucks to enter the site, resulting in high manpower costs and high overall construction costs.

## 2.2 Applicability and characteristics of steel canopies

Compared with concrete canopies, steel canopies are more widely used. Steel canopies take steel frame as the main structure and steel as the main force-bearing parts, steel has high strength and light weight compared with other building materials, and the nature of steel material is uniform and isotropic, which is an ideal elastic material and meets the requirements of mechanical properties of materials in engineering. It is conducive to simplifying the design. Steel canopies have the following advantages. [3]

(1) compared with the concrete structure canopy need to be poured on site, long construction period, noise, serious pollution and other shortcomings, steel structure canopy inherit the light self-weight of steel, high strength and other characteristics, generally using factory prefabricated, standardized production makes the overall quality control easily, high degree of on-site assembly, disassembly and maintenance convenient, reduce the construction and operation time, shorten the construction period, comprehensive construction costs are low, can Effectively reduce the use of materials, high cost performance.

(2) Steel structures are recyclable, and steel can be reused, reducing construction waste and saving construction costs.

(3) Concrete structure canopy because of its own self-weight is difficult to cover a large area, steel structure canopy through reasonable structural design, can ensure the safety of the structure at the same time to cover a large area of canopy can be achieved, more typical is the large cantilevered steel structure canopy and station platform canopy.

(4) The seismic performance, overturning resistance and durability of the steel structure canopy system are significantly better than that of the traditional concrete structure canopy, and the scope of application is wider.

(5) Steel structure canopy can be matched with different building materials according to the different scenes of use. For example, in the low temperature areas can be used with heat insulation materials to ensure the indoor temperature; aisle corridor can be used with light-transmitting materials to ensure the indoor light area. The diversity of materials used in the steel structure makes it more adaptable to the environment.

## 3. Forms and characteristics of tilt-tie steel structures

In many forms of steel rain shed tilt rod steel rain shed advantages are more prominent, simple and clear force transmission route, tilt rod production and installation is convenient, the popularity is high, the use of a wide range, the mechanical properties of the tilt rod steel structure rain shed analysis, the structure of the rain shed can be optimized, improve the safety and stability of the structure, improve the utilization of materials, to obtain higher economic benefits. [4]

The diagonal tie steel structure canopy is mainly composed of diagonal tie bar, cross beam, sub beam, diagonal tie bar, cover plate and other parts, as shown in Figure 1. In this paper, the structure form of the selected diagonal tie bar steel structure canopy is cantilevered with a total length of 6m and a width of 6m, with one diagonal tie bar on each side coupled to the cantilevered beam, and two cantilevered beams connected by a cross beam at the far end of the cantilevered beam. The diagonal ties are the main axially stressed components, which will exist in tension or compression depending on the loading conditions, and the cantilever beam is the main bending component.



Figure 1. Diagram of steel structure tilt-rod canopy

### 3.1 Influence of different connection methods on the forcibility and static characterization of diagonal tie steel canopies

In this paper, it is assumed that the distance between the diagonal tie rod tie point and the proximal end of the cantilever beam is 4 m. According to the actual situation, it is assumed that the load is a uniform load of 0.5 KN/m<sup>2</sup> on the cantilever beam and a concentrated load of 1 KN at the distal end of the cantilever beam, as shown in Figure 2. [5] Now the best combination of connections is selected by varying the connections (rigid, articulated) between the diagonal tie and cantilever beam (connection point 1), diagonal tie and support (connection point 2) and cantilever beam and support (connection point 3) on the force situation of the structure. As shown in Table 1, there are eight connection combinations. The main mechanical properties of the structure for the eight cases in Table 1 are shown in Table 2.

Inclined tie in the structure is a tensile component, generally a small diameter hollow circular section rod, axially stressed components, cannot withstand a high bending moment, and the stability of the inclined tie on the overall stability of the structure, the use of connection combination 1 2 3 5 6 7 will produce a bending moment on the inclined tie to make the overall stability of the structure worse, so should not be used in the project, in 4 8 two sets of connection combination on the inclined tie does not exist bending moment, the overall stability of the structure and the mechanical properties are relatively good; the axial force of the diagonal tie in connection method 4 is 3.255KN smaller than that of the diagonal tie in combination 8, which is 6.25KN. The smaller axial force is conducive to reducing the cross-sectional area of the diagonal tie on the premise of ensuring structural safety and reasonably reducing the amount of material used to reduce costs. From the above analysis, the best connection combination is rigid connection between the cantilever beam and the building, hinged connection between the diagonal tie and the building, and hinged connection between the diagonal tie and the cantilever beam.

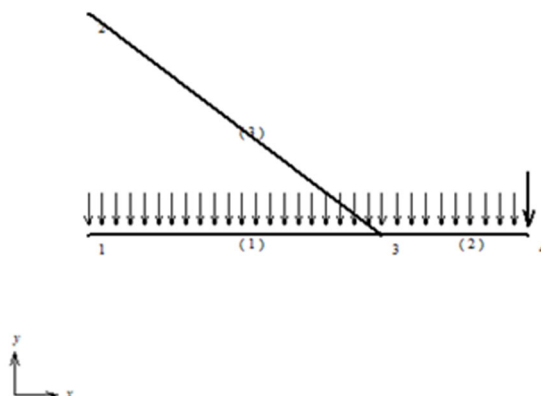


Figure 2. Diagram of the load on the canopy

**Table 1.** Connection between bars

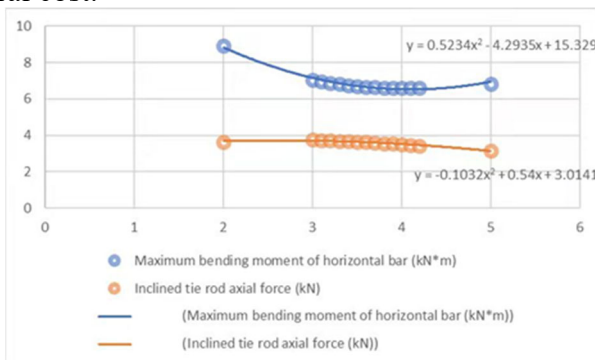
number	Connection point 1	Connection point 2	Connection point 3
1	rigid connection	rigid connection	rigid connection
2	rigid connection	rigid connection	hinge
3	rigid connection	hinge	rigid connection
4	rigid connection	hinge	hinge
5	hinge	rigid connection	rigid connection
6	hinge	rigid connection	hinge
7	hinge	hinge	rigid connection
8	hinge	hinge	hinge

**Table 2.** Mechanical performance indexes

number	Inclined tie rod axial force (kN)	Maximum bending moment of horizontal bar (kN*m)	Maximum bending moment of inclined ties (kN*m)
1	2.889	5.604	2.953
2	3.065	5.505	3.378
3	3.206	6.552	3.000
4	3.499	6.603	0
5	5.916	5.000	2.224
6	4.827	3.000	5.337
7	5.916	3.000	2.224
8	6.250	3.000	0

**3.2 Influence of angle of ties on the force performance of diagonal canopy and static property analysis**

In addition to the connection between the bars, changing the angle of the diagonal tie will also cause the force state of the structure to change significantly. By changing the position of the pulling point of the diagonal tie on the cantilever beam to change the angle of the diagonal tie, the force state of the structure under different angles of the diagonal tie can be analyzed, and the position of the pulling point with the best mechanical properties can be derived. In the structure, the cantilever beam is the main bending member, the design mainly considers the maximum bending moment; the diagonal rod is the main axial force member, the design mainly considers the magnitude of the axial force, in the above state of force when the diagonal rod point in different positions of the two mechanical performance indicators are shown in Table 4 and Figure 3. The maximum bending moment of the cantilever beam has a minimum value when the pulling point is at 4m from the near end of the cantilever beam, i.e. when the angle between the diagonal tie rod and the cantilever beam is 45°, so when the pulling point of the diagonal tie rod is located here, the net cross-sectional area of the cantilever beam required by using the same material is relatively small, thus ensuring The net cross-sectional area of the cantilever beam required for the same material is relatively small when the tension point is located here, thus ensuring the safety of the structure with a reasonable reduction in material usage and structural cost.



**Figure 3.** Fitting curves of the main mechanical property indexes

**Table 4.** Mechanical performance indexes

Distance of pull point from left end (m)	Maximum bending moment of cantilever beam (kN*m)	Inclined tie rod axial force (kN)
2	8.930	3.648
3	7.050	3.748
3.1	6.957	3.731
3.2	6.876	3.712
3.3	6.808	3.690
3.4	6.751	3.667
3.5	6.704	3.642
3.6	6.668	3.615
3.7	6.640	3.588
3.8	6.620	3.559
3.9	6.608	3.529
4	6.603	3.499
4.1	3.305	3.468
4.2	6.612	3.436
5	6.829	3.176

#### 4. Conclusion

This paper analyses and calculates the stresses of steel tilt-tie canopies under various conditions, including the stresses of tilt-tie steel canopies under different connection methods and the stresses under different angles of tilt-ties, and draws the following conclusions from the calculation results.

(1) From the point of view of mechanical properties, the mechanically best connection between the parts of the diagonal tie steel canopy is a rigid connection between the cantilever beam and the building, a hinged connection between the diagonal tie and the building, and a hinged connection between the diagonal tie and the cantilever beam.

(2) in the selection of the angle of the tie mainly consider the value of the cantilever beam maximum bending moment, such as in the above analysis when the angle between the tie and the cantilever beam is 45 °, when the cantilever beam maximum bending moment has a minimum value. In the design selection of other load conditions or other similar dimensions of the angle of the steel structure canopy diagonal tie can be calculated in the same way to optimize.

#### References

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