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Study on the calculation method of critical wind velocity for failure of roof slab connectors of light steel building

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Abstract: The light steel buildings along the high-speed railway are the key content of the environmental remediation of the high-speed railway. At present, it is urgent to carry out systematic research on the rapid quantitative evaluation of its safety, and the critical wind speed is one of its main indicators. From the perspective of the safety critical wind speed of light steel buildings, this paper proposes a calculation method for the critical wind speed of light steel buildings along the high-speed rail line through theoretical derivation research, and conducts regularity research. Under the condition of , the critical wind speed of the roof panel structure gradually decreases with the increase of the span and tends to be stable; under the conditions of the same site and the same design span, the critical wind speed of the roof panel structure increases gradually with the increase of the screw spacing and tends to be stable; when the structural design span is the same as the number of screws, the critical wind speed of the simply supported beam is greater than the critical wind speed of the continuous beam; the critical wind speed of the two-span continuous beam structure is the smallest, and when the continuous beam is greater than or equal to five spans, its critical wind speed tends to a fixed value, and then provides technical support for ensuring the safety of the environment outside the high-speed railway along the line.

1. Introduction

The light steel building is a typical wind-damaged structure, and the damage and loss caused by strong wind have been reported at home and abroad. In order to reduce wind disaster losses, domestic and foreign scholars have conducted a large number of studies on the wind disaster vulnerability assessment of light steel structures, and proposed a variety of analytical models to calculate the change curve of damage and damage degree of light steel building components along with wind speed and direction, so as to estimate the possible wind-induced damage probability and loss probability, and make great contributions to the disaster prevention and reduction of light steel buildings [7-13]. However, the invasion of light steel building envelope and other hard floating objects along the high-speed railway line is more destructive, and the risk is too high, and the wind induced invasion probability can not be analyzed by mathematical statistical probability method to evaluate the strength of light steel building. Based on this, this paper will start from the Angle of safety critical wind speed of light steel buildings, and put forward the calculation method of critical wind speed of light steel buildings along the high-speed railway through theoretical deduction, so as to provide technical support for guaranteeing the environmental safety along the high-speed railway.[3-4]

2. Component Failure Mode

The research results of a large number of scholars show that the screw connected roof panels mainly have the following two failure modes under the action of wind suction load[7-13]:

(1)Drawing failure: the failure of the connection screw pulled out from the substrate;

(2)Pull-out failure: tearing failure of roof panels at screw holes.

3. Component Resistance Model

In order to calculate the reasonable design value of resistance corresponding to the failure mode of the screw connection of the compression steel plate, many scholars have carried out a large number of pull-out and pull-out model tests and finite element numerical simulation analysis, and obtained the calculation formulas of the pull-out and pull-out bearing capacity of different types of screw connection roofing panels [5-10]. Zhang Wenying [8] et al. conducted statistical analysis on various test data. An appropriate correction factor is proposed for the tensile and tensile tensile capacity of screws in the cold-formed thin-wall steel specification.

In this paper, it is suggested that the screw tensile capacity should be calculated using the formula of the Chinese standard "Cold-formed Thin-wall Steel Structure Technical Specification Draft" (GB50018-2017) and multiplied by 0.8 correction factor, that is, the screw tensile capacity is

$$R_t = 0.8N_t^f = 0.6t_c df \tag{1}$$

In this paper, the calculation formula of China Standard Draft is multiplied by 0.25 correction factor, that is, the calculation formula of screw tensile capacity is as follows:

$$R_{ov} = 0.25N_{tov}^f = 0.15d_w tf \tag{2}$$

Based on the above two resistance models, this paper suggests that the minimum of formula (1) and (2) is the resistance of the roof panel connecting screw, that is, the resistance of the screw connecting roof panel is:

$$R = min(R_t, R_{ov}) \tag{3}$$

4. Wind Load Model

According to the Load Code for Building Structures (GB50009-2012) [2], the design value of wind load perpendicular to the surface of the building is as follows:

$$q = \gamma_{Q1}\gamma_L\omega_k b = 1.4 \times 1.0 \times \omega_k b = 0.7\beta_{gz}\mu_{s1,max}\mu_z\rho bv_0^2 \tag{4}$$

Where: q- Design value of wind load (kN/m);γ_{Q1} - The partial coefficient of the dominant variable load is 1.4; γ_L- The adjustment factor of leading variable load considering the design service life is 1.0; ω_k- Standard value of wind load (kN/m2); β_{gz}- Gust coefficient at height z; $\mu_{s1,max}$- Maximum local shape coefficient of wind load; μ_z- wind pressure height variation coefficient; v_0- Basic wind speed (m/s); b- Width of roof panels (m).

5. Internal Force Calculation Model of Member

According to the provisions of Technical Specification for Cold-formed Thin-walled Steel Structures (GB50018-2002) [1], roof panels are calculated as flexural members under wind load, and the roof panels can be simplified into beam unit models, as shown in Figure 1.

The load distribution of the continuous beam structure larger than two spans is shown in Figure 1. This kind of structure has more freedom, and the matrix displacement method [14] is used to calculate the internal force of the structure.

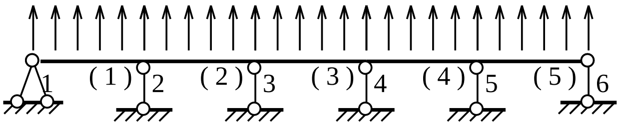

Figure 1: Schematic diagram of wind load on multi-span continuous beams

Number nodes and cells:

The whole coordinate system and unit coordinate system of the structure are established, and the node displacement is numbered. The structure consists of nodes, which are numbered 1,2 from left to right... i... ; Unit numbers from left to right are 1,2...... i... .

The element stiffness matrix of each bar is calculated k^e:

$$k^e = \frac{EI}{l}\begin{bmatrix}4 & 2\\2 & 4\end{bmatrix} k^e = \frac{EI}{l}\begin{bmatrix}4 & 2\\2 & 4\end{bmatrix} \tag{5}$$

Where:k^e - element stiffness matrix; EI- Structural stiffness; l- Structure span.

Original stiffness matrix of composite structure$K$:

$$K_{n\times n} = \frac{EI}{l}\begin{bmatrix}4 & 2 & 0 & 0 & \cdots & 0\\2 & 8 & 2 & 0 & \cdots & 0\\0 & 2 & 8 & 2 & \ddots & \vdots\\0 & 0 & \ddots & \ddots & \ddots & 0\\\vdots & \vdots & \ddots & 2 & 8 & 2\\0 & 0 & \cdots & 0 & 2 & 4\end{bmatrix} \tag{6}$$

Where: $K_{n\times n}$-(n-1) the n×n order stiffness matrix across a continuous beam structure, where$n \geq$ 4.

The unit solid end force F_F^e, equivalent node load F_E and comprehensive node load Fare calculated.The fixed end force of each unit is:

$$F_F^1 = \begin{bmatrix}0\\-\frac{1}{8}ql^2\end{bmatrix} \tag{7}$$

$$F_F^2 = \begin{bmatrix}\frac{1}{12}ql^2\\-\frac{1}{12}ql^2\end{bmatrix} = F_F^3 = \cdots = F_F^i = \cdots = F_F^{n-2} \tag{8}$$

$$F_F^{n-1} = \begin{bmatrix}\frac{1}{8}ql^2\\0\end{bmatrix} \tag{9}$$

Since the equivalent node load and the solid end force are inverse to each other, the equivalent node load of each element is:

$$F_E^1 = \begin{bmatrix}0\\\frac{1}{8}ql^2\end{bmatrix} \tag{10}$$

$$F_E^2 = \begin{bmatrix} -\frac{1}{12}ql^2 \\ \frac{1}{12}ql^2 \end{bmatrix} = F_E^3 = \cdots = F_E^i = \cdots = F_E^{n-2} \tag{11}$$

$$F_E^{n-1} = \begin{bmatrix} -\frac{1}{8}ql^2 \\ 0 \end{bmatrix} \tag{12}$$

The comprehensive node load F of the structure is composed of the aggregate of the unit equivalent node load, and F is obtained as follows:

$$F = \begin{bmatrix} 0 & \frac{1}{24}ql^2 & 0 & \cdots & 0 & -\frac{1}{24}ql^2 & 0 \end{bmatrix}^T \tag{13}$$

Where: F_F^i- Unit i fixed end force matrix; F_E^i- Unit i equivalent node load matrix; F- Integrated node load matrix of the structure.

Solve the equation and obtain the unknown node displacement:

$$\Delta = K_{n\times n}^{-1}F \tag{14}$$

Where, $K_{n\times n}^{-1}$- inverse matrix of structural stiffness matrix, which is symmetric matrix with respect to the principal axis and the auxiliary axis.

Bring$K_{n\times n}^{-1}$ and$F$ into the above formula to get

$$\Delta = K_{n\times n}^{-1}F = \frac{ql^3}{48EI(2a_{n-1}-a_{n-2})} \times \begin{bmatrix} -a_0a_{n-2} - (-1)^n a_0a_1 \\ a_0a_{n-2} - (-1)^{n+1}a_1a_1 \\ \vdots \\ (-1)^{n+1}a_1a_1 - a_0a_{n-2} \\ (-1)^n a_0a_1 - a_0a_{n-2} \end{bmatrix} \tag{15}$$

Make,

$$c_1 = -a_0a_{n-2} - (-1)^n a_0a_1 = -c_n \tag{16}$$

$$c_i = (-1)^{i+2}a_1a_{n-i} - (-1)^{i+n-1}a_1a_{i-1} \tag{17}$$

Obtain,

$$\Delta = \frac{ql^3}{48EI(2a_{n-1}-a_{n-2})}\begin{bmatrix} c_1 & c_2 & \cdots & c_{n-1} & c_n \end{bmatrix}^T \tag{18}$$

$$\delta^i = \frac{ql^3}{48EI(2a_{n-1}-a_{n-2})}\begin{bmatrix} c_i \\ c_{i+1} \end{bmatrix} \tag{19}$$

Where: Δ- Node displacement matrix; δ^i- element rod end node displacement matrix; a_i- Calculation coefficients of the elements in$K_{n\times n}^{-1}$,$a_i = \frac{1}{2}\left[\left(2-\sqrt{3}\right)^i + \left(2+\sqrt{3}\right)^i\right]$,$(i = 0,1,2,\dots\dots,n)$.

The end bending moment of each element is calculated:

By matrix displacement method, the bending moment of element rod end is calculated as follows:

$$M^i = k^e\delta^i + F_F^i \tag{20}$$

When you put in δ^i and F_F^i, you get

$$M^1 = \frac{ql^2}{48EI(2a_{n-1}-a_{n-2})}\begin{bmatrix} 4b_1 + 2b_2 \\ 2b_1 + 4b_2 \end{bmatrix} + \begin{bmatrix} 0 \\ -\frac{1}{8}ql^2 \end{bmatrix} \tag{21}$$

$$M^{n-1} = \frac{ql^2}{48(2a_{n-1}-a_{n-2})}\begin{bmatrix}4b_{n-1}+2b_n\\2b_{n-1}+4b_n\end{bmatrix}+\begin{bmatrix}\frac{1}{8}ql^2\\0\end{bmatrix} \tag{22}$$

When $2\leq i\leq n-2$,

$$M^i = \frac{ql^2}{48EI(2a_{n-1}-a_{n-2})}\begin{bmatrix}4b_i+2b_{i+1}\\2b_i+4b_{i+1}\end{bmatrix}+\begin{bmatrix}-\frac{1}{12}ql^2\\\frac{1}{12}ql^2\end{bmatrix} \tag{23}$$

Where: M^1 -- the pole end moment of unit 1; M^i-- rod end moment of unit i, $2\leq i\leq n-2$;M^{n-1} -- Rod end moment of unit n-1.

Calculate the bar end shear of each element:

$$V_1 = \left[\frac{3}{8}+\frac{b_2-b_1}{24(2a_{n-1}-a_{n-2})}\right]\times ql \tag{24}$$

$$V_{2,left} = \left[\frac{5}{8}-\frac{b_2-b_1}{24(2a_{n-1}-a_{n-2})}\right]\times ql \tag{25}$$

When $2\leq i\leq n-2$,

$$V_{i,right} = \left[\frac{1}{2}+\frac{b_i+b_{i+1}}{8(2a_{n-1}-a_{n-2})}\right]\times ql \tag{26}$$

When $3\leq i\leq n-1$,

$$V_{i,right} = \left[\frac{1}{2}-\frac{b_{i-1}+b_i}{8(2a_{n-1}-a_{n-2})}\right]\times ql \tag{27}$$

$$V_{n-1,right} = \left[\frac{5}{8}-\frac{b_n-b_{n-1}}{24(2a_{n-1}-a_{n-2})}\right]\times ql \tag{28}$$

$$V_n = \left[\frac{3}{8}+\frac{b_n-b_{n-1}}{24(2a_{n-1}-a_{n-2})}\right]\times ql \tag{29}$$

Where: V_1- the shear force of no1; $V_{2,left}$- Shear force on the left side of no2; $V_{i,right}$- Shear force on the right side of node i; $V_{i,left}$- Shear force on the left side of node i; $V_{n-1,right}$- Shear force on the right side of node-N-1; V_n- Shear force on node n.

Calculate the support reaction of each node:

$$R_1 = V_1 = \left[\frac{3}{8}+\frac{b_2-b_1}{24(2a_{n-1}-a_{n-2})}\right]\times ql = \alpha_1 ql \tag{30}$$

$$R_n = V_n = \left[\frac{3}{8}+\frac{b_n-b_{n-1}}{24(2a_{n-1}-a_{n-2})}\right]\times ql = \alpha_n ql \tag{31}$$

When $3\leq i\leq n-2$ time,

$$R_i = V_{i,left}+V_{i,right} = \left[1+\frac{b_{i+1}-b_{i-1}}{8(2a_{n-1}-a_{n-2})}\right]\times ql = \alpha_i ql \tag{32}$$

$$R_2 = V_{2,left}+V_{2,right} = \left[\frac{9}{8}+\frac{b_1+2b_2+3b_3}{24(2a_{n-1}-a_{n-2})}\right]\times ql = \alpha_2 ql \tag{33}$$

Where: R_1- the support reaction force of node 1; R_2- the support reaction force of node 2; R_i- Support reaction of node i; R_n- The support reaction of node n;α_i - Calculated coefficient of the branch reaction force of node i,$i = 1,2,\dots\dots,n$.

Maximum support reaction N_{max}:

The supporting reaction force of a continuous beam with different span numbers is numerically calculated, and $R_{max}=R_2$ is obtained, and the calculation coefficient α_2 of R_2 is statistically calculated as shown in Table 1 below:

Table 1: Calculation coefficient of maximum flexural support reaction of roof panel structure.

Number of structure nodes N	α_2
2	0.5
3	1.25
4	1.100
5	1.143
6	1.132
7	1.135
8	1.134

6. Calculation of Critical Wind Speed

The critical state of the structure is defined when the maximum resistance R is equal to the maximum support reaction Rmax, and the natural wind speed corresponding to this state is the critical wind speed [v].

According to the internal force calculation results, the maximum support reaction force of roof slab under wind load is:

$$N_2 = \alpha_2 ql \tag{34}$$

The basic equation corresponding to the critical state of the structure is:

$$mR = N_2 = \alpha_2 ql = 0.7\alpha_2\beta_{gz}\mu_{z1}\mu_z\rho blv_0^2 \tag{35}$$

The critical wind speed is obtained [v]:

$$[v] = \sqrt{\frac{mR}{0.7\alpha_2\beta_{gz}\mu_{z1}\mu_z\rho bl}} \tag{36}$$

By bringing the calculation coefficient of R2 into the above equation, the calculation formula of critical wind speed of roof panel structure can be obtained as shown in Table 2.

Table 2: Formula of critical wind speed of roof panel

Structural span n	Critical wind speed [v](m/s)
1	$\sqrt{\frac{mR}{0.35\beta_{gz}\mu_{s1}\mu_z\rho bl}}$
2	$\sqrt{\frac{mR}{0.875\beta_{gz}\mu_{s1}\mu_z\rho bl}}$
3	$\sqrt{\frac{mR}{0.77\beta_{gz}\mu_{s1}\mu_z\rho bl}}$
4	$\sqrt{\frac{mR}{0.8\beta_{gz}\mu_{s1}\mu_z\rho bl}}$
5	$\sqrt{\frac{mR}{0.792\beta_{gz}\mu_{s1}\mu_z\rho bl}}$
6	$\sqrt{\frac{mR}{0.794\beta_{gz}\mu_{s1}\mu_z\rho bl}}$
≥7	$\sqrt{\frac{mR}{0.794\beta_{gz}\mu_{s1}\mu_z\rho bl}}$

7. Study on the Regularity of Critical Wind Velocity Parameters

Based on the calculation formula of critical wind speed, it can be seen that under the condition of the same site and the same design screw spacing, the critical wind speed of roof panel structure gradually decreases and tends to be stable with the increase of span. Taking 3-span, 4-span and 5-span continuous beams as an example, the variation law of critical wind speed with span is calculated as shown in FIG. 2-Fig. 4.

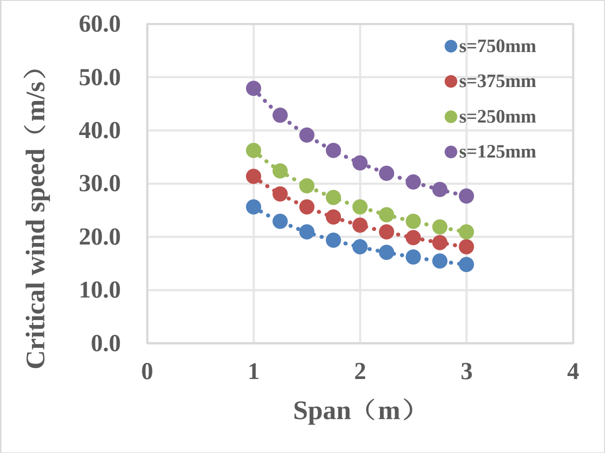

Figure 2: Curve of critical wind speed with span of 3-span continuous beam structure

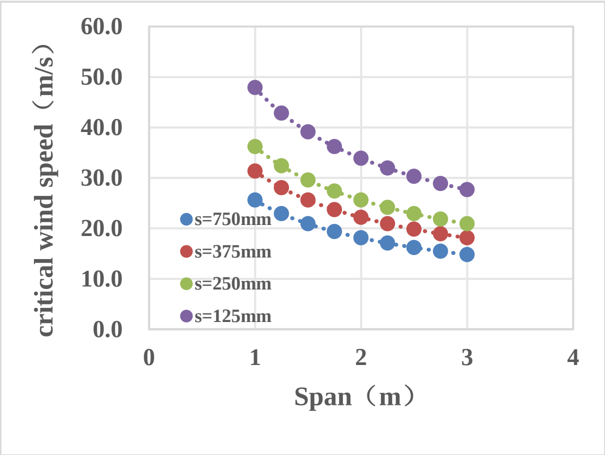

Figure 3: Curve of critical wind speed with span of 4-span continuous beam structure

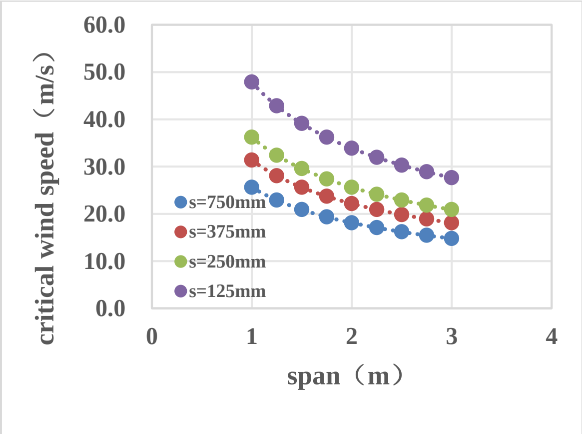

Figure 4: Curve of critical wind speed of 5-span continuous beam structure with span

Based on the calculation formula of critical wind speed, it can be seen that under the same site and the same design span, the critical wind speed of roof panel structure gradually increases and tends to be stable with the increase of screw spacing. Taking 3-span, 4-span and 5-span continuous beams as an example, the variation of critical wind speed of continuous beams with the number of screws is calculated as shown in FIG. 5-7 below.

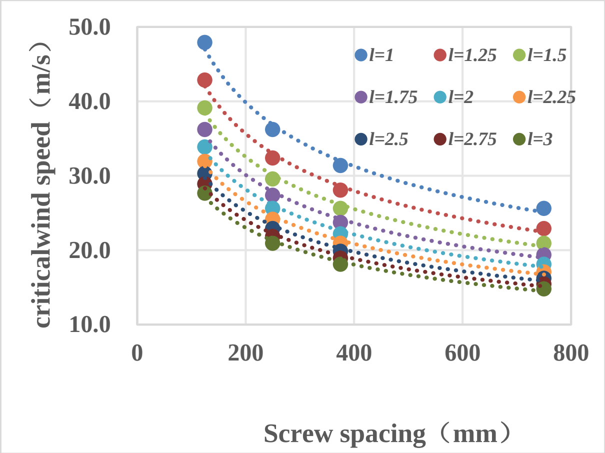

Figure 5: Curve of critical wind speed of 3-span continuous structure with the number of screws

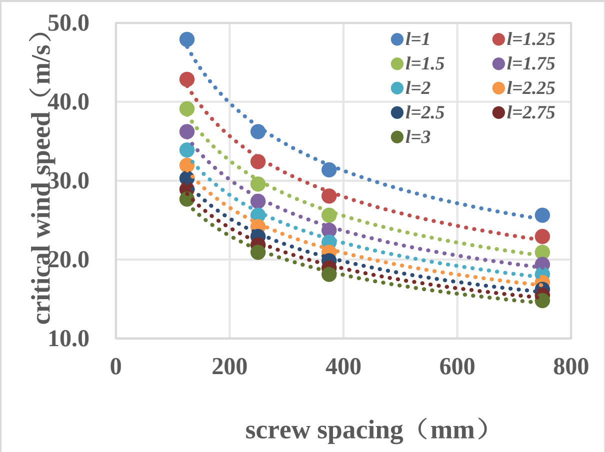

Figure 6: The critical wind speed of a 4-span continuous structure varies with the number of screws

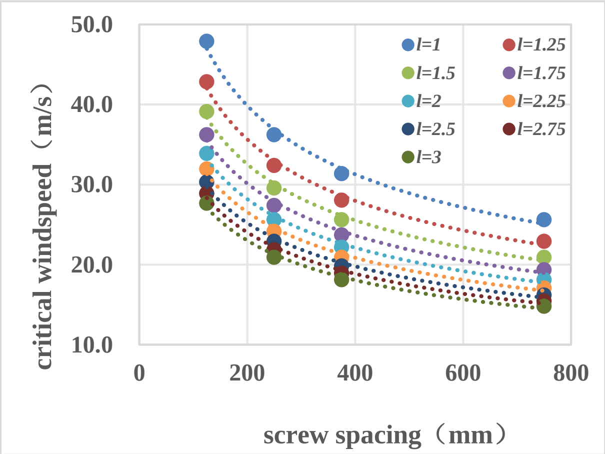

Figure 7: The critical wind speed of a 5-span continuous structure varies with the number of screws

In the same site, the critical wind speed of the simple supported beam is greater than that of the continuous beam when the design span and the number of screws are the same. The critical wind speed of the two-span continuous beam structure is the smallest, and when the continuous beam is greater than or equal to five spans, its critical wind speed tends to a constant value. The critical wind speed of different design screw spacing varies with the number of spans, as shown in FIG. 8-11.

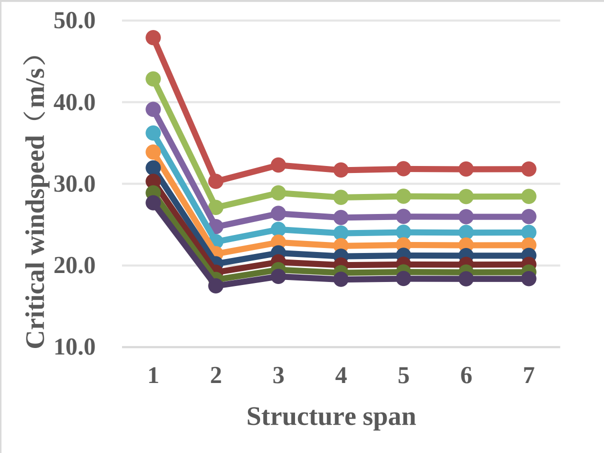

Figure 8: Curve of critical wind speed with the number of spans when the screw spacing is 125mm

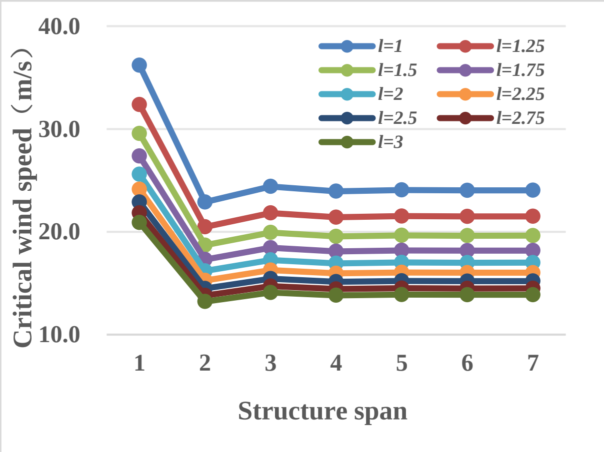

Figure 9: Change curve of critical wind speed with the number of spans when screw spacing is 250mm

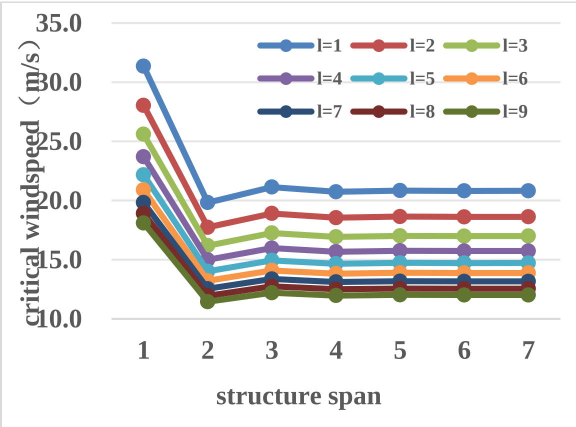

Figure 10: Curve of critical wind speed with the number of spans when the screw spacing is 375mm

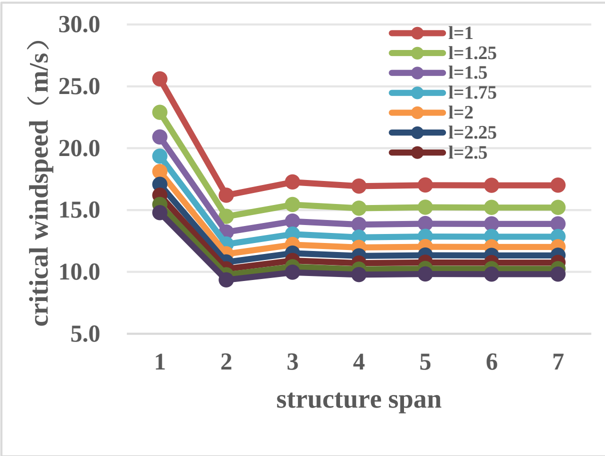

Figure 11: Change curve of critical wind speed with the number of spans when screw spacing is 750mm

8. Critical Wind Speed Application Case

Table 3: Comparison table of critical wind speed [v] of roofing panels in Guangdong.

Number of spans n	Screw spacing (*mm*)	Span *l*(*m*)								
		1	1.25	1.5	1.75	2	2.25	2.5	2.75	3
1	750	25.6	22.9	20.9	19.3	18.1	17.0	16.2	15.4	14.8
	375	31.3	28.0	25.6	23.7	22.1	20.9	19.8	18.9	18.1
	250	36.1	32.3	29.5	27.3	25.6	24.1	22.9	21.8	20.9
	125	47.8	42.8	39.0	36.1	33.8	31.9	30.2	28.8	27.6
2	750	16.2	14.5	13.2	12.2	11.4	10.8	10.2	9.7	9.3
	375	19.8	17.7	16.2	15.0	14.0	13.2	12.5	11.9	11.4
	250	22.9	20.4	18.7	17.3	16.2	15.2	14.5	13.8	13.2
	125	30.2	27.0	24.7	22.9	21.4	20.2	19.1	18.2	17.5
3	750	17.2	15.4	14.1	13.0	12.2	11.5	10.9	10.4	9.9
	375	21.1	18.9	17.2	16.0	14.9	14.1	13.3	12.7	12.2
	250	24.4	21.8	19.9	18.4	17.2	16.2	15.4	14.7	14.1
	125	32.2	28.8	26.3	24.4	22.8	21.5	20.4	19.4	18.6
4	750	16.9	15.1	13.8	12.8	12.0	11.3	10.7	10.2	9.8
	375	20.7	18.5	16.9	15.6	14.6	13.8	13.1	12.5	12.0
	250	23.9	21.4	19.5	18.1	16.9	15.9	15.1	14.4	13.8
	125	31.6	28.3	25.8	23.9	22.4	21.1	20.0	19.1	18.3
5	750	17.0	15.2	13.9	12.8	12.0	11.3	10.7	10.2	9.8
	375	20.8	18.6	17.0	15.7	14.7	13.9	13.2	12.5	12.0
	250	24.0	21.5	19.6	18.2	17.0	16.0	15.2	14.5	13.9
	125	31.8	28.4	25.9	24.0	22.5	21.2	20.1	19.2	18.3
6	750	17.0	15.2	13.8	12.8	12.0	11.3	10.7	10.2	9.8
	375	20.8	18.6	17.0	15.7	14.7	13.8	13.1	12.5	12.0
	250	24.0	21.5	19.6	18.1	17.0	16.0	15.2	14.5	13.8
	125	31.7	28.4	25.9	24.0	22.4	21.2	20.1	19.1	18.3
7	750	17.0	15.2	13.9	12.8	12.0	11.3	10.7	10.2	9.8
	375	20.8	18.6	17.0	15.7	14.7	13.9	13.1	12.5	12.0
	250	24.0	21.5	19.6	18.1	17.0	16.0	15.2	14.5	13.9
	125	31.7	28.4	25.9	24.0	22.4	21.2	20.1	19.1	18.3

According to the preliminary investigation results, the most frequent occurrence of wind-induced floating matter encroachment occurred in Guangzhou Bureau, which is taken as an example to illustrate. The selected B-class sites in Guangdong are connected with ST5.5-12#-75 self-drilling screw single-row crest with equal spacing. The roof plate structure with a height of less than or equal to 10m from the ground and a thickness of 0.5mm and an effective thickness of 750mm is a single-layer laminated steel plate structure. According to equation (7), the critical wind speed of roof panel in the above areas with the same parameters as the test model can be calculated, as shown in Table 3.

9. Conclusion

Through this study, the following conclusions are drawn:

(1) From the perspective of the safety critical wind speed of light steel buildings, this paper proposes the calculation method of critical wind speed of light steel buildings along the high-speed railway through theoretical derivation and research, carries out regular research, and takes Guangdong as an example to carry out application case analysis, so as to provide technical support for ensuring the safety of off-road environment along the high-speed railway.

(2) Under the condition of the same site and the same design screw spacing, the critical wind speed of the roof panel structure gradually decreases and tends to be stable with the increase of the span; Under the same site and the same design span, the critical wind speed of roof panel structure gradually increases and tends to be stable with the increase of screw spacing. When the design span and the number of screws are the same, the critical wind speed of the simply supported beam is greater than that of the continuous beam. The critical wind speed of the two-span continuous beam structure is the smallest, and when the continuous beam is greater than or equal to five spans, the critical wind speed tends to a constant value.

References

[1] GB 50018-2002, Technical specification for cold-formed thin-walled steel structures[S].
[2] GB 50009-2012, Code for load on building structures[S].
[3] ANSI/AISI S100-2016, North American Code for the design of cold formed steel structures[S].
[4] BS5950-5-1998, Structural use of steel structures in buildings in the United Kingdom - Part 5: Code of practice for the design of cold formed thin gauge profiles[S].
[5] AS/NZS4600-2018, Australian standard for cold-formed steel structures[S].
[6] EN199313-2006, Euro Specification 3- Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheets[S].
[7] Zhang Juan. Wind Disaster vulnerability analysis of Light steel structure factory building [D]. Southwest Jiaotong University, 2015.
[8] Zhang Wenying, Liu Xiyu, Zhao Jinyou, Jiang Ziqin, Li Yi. Comparative analysis of Tensile Capacity design Methods for cold-formed Steel Self-tapping Screw Connection [J]. Journal of Beijing University of Technology, 2022, 48(01): 95-104.
[9] Li Yunxin. Study on Wind Resistance of Screw Joints of Light Steel roofing [D]. Beijing Jiaotong University, 2016.
[10] Ge Hanwen. Fatigue damage calculation model of self-tapping napping joints of light steel roofing and its application in post-disaster assessment [D]. Beijing jiaotong university, 2019. DOI: 10.26944 /, dc nki. Gbfju. 2019. 000933.
[11] Zhao Mingwei, Gu Ming. Probabilistic Analysis of Wind Disaster Vulnerability of Light Steel Structures [J]. Journal of Central South University (Natural Science Edition), 2012, 43(09):3609-3618.
[12] Xue Qiusheng. Discussion on Wind Resistance Technology of canopy roof in Xi'an North Railway Station [J]. High Speed Railway Technology,2014,5(03):59-62+71.
[13] An Yucheng. Research on Wind Resistance Design of Slope Roof of Railway Building [J]. High-speed Railway Technology, 2014, 5(05):18-21.
[14] Zhao Caiqi, Zhao Ling. Structural Mechanics [M]. Nanjing Southeast University Press: 201108.357.