9th Asia-Pacific Conference on Wind Engineering
Auckland, New Zealand
3-7 December 2017

Experimental Study on Aerodynamic Parameters for Steel Truss Girder of Long Span Railway Bridge

Z.G. Li[1,2], J. M. Shang[2,3], H.L. Liao[2], C.M. Ma[3]
[1]Research centre for Wind Engineering, Southwest Jiaotong University, Chengdu, Sichuan 610031, China
[2]key Laboratory for Wind Engineering of Sichuan Province, Chengdu, Sichuan 610031, China
[3]Department of Bridge Engineering, Southwest Jiaotong University, Chengdu, Sichuan 610031, China

Abstract

The objective of this paper is to explore aerodynamic parameters of the truss section by testing. This paper take Anqing Yangtze River Railway Bridge as the basic object, and study the three-component force coefficient of various truss-form sections. This paper includes discussions concerning the meaning and calculation methods of the three-component force coefficient about wind load. Next, experimental investigations were completed in the wind tunnel. The aerodynamic parameter of the truss section is analysed in detail. Finally, this paper studied the calculation methods of wind load on girder in different countries' codes, and made the calculated values and experimental values compared to come to the applicability of the truss girder's calculations of wind load on China's railway bridge. The achievement of the experimental study of the article may provide reference for engineering projects.

Introduction

Steel is a lightweight homogeneous material with high tensile strength, compression strength and shear strength. Steel bridge is often used while it is hard to build bridge utilizing other materials. Along with the augment of bridge span, building steel bridge has definitely got to be the most obvious choice, it is especial for high standard railway bridge carrying heavy loads.

Response of bridge structures to the wind is a complicated aerodynamic problem[1,2]. In the past, wind load are not the key factors of medium and small span bridge. This is one of the most important reasons which result in that we don't pay more attention to wind-resistant design[3]. However, the development of modern materials and construction techniques has resulted in the emergence of a new generation of structures that are often, to a degree unknown in the past, remarkably flexible, low in damping, and light in weight. Such structures, as well as various novel types of rigid structures, exhibit an increased susceptibility to the action of wind. Accordingly, it has become necessary to develop tools enabling the designer to estimate wind effects with a higher degree of refinement than was previously required. Wind engineering is the discipline that has evolved, primarily during the last decades, from efforts aimed at developing such tools. It is the task of the engineer to ensure that the performance of structures subjected to the action of wind will be adequate during their anticipated life from the standpoint of both structural safety and serviceability [4].

From the nineties of last century, China has entered a rapid development period of long span railway bridge construction. Across the Yangtze River and Yellow River, quite a large number of long span railway bridges have been constructed one after another, recently. China railway steel bridge of recent years, as listed in Table 1[5].

As shown in Table 1, the main girders of long span railway bridge includes highway and railway bridge in China are wildly utilized steel truss girder. It seems to be the likely direction of China railway bridge structures in the future. With the result that the opinion is advanced that it is important to take researches on wind-resistant design of railway bridge. The analysis results of this can provide the basis of such bridge design and technical guidance.

No.	Year	Name	Type	Span /m
1	1957	Wuhan Yangtze River Bridge	Continuous steel truss girder	128
2	1968	Nanjing Yangtze River Bridge	Continuous steel truss girder	160
3	1993	Jiujiang Yangtze River Bridge	Steel truss and flexible arch	216
4	2000	Wuhu Yangtze River Bridge	Steel truss low tower cable-stayed	312
5	2004	Anqing Yangtze River Bridge	Steel truss cable-stayed	580
6	2009	Tianxingzhou Bridge	Steel truss cable-stayed	504
7	2011	Nanjing Dashengguan Yangtze River Bridge	Continuous steel truss arch	336
8	2014	Huanggang Yangtze River Bridge	Steel truss cable-stayed	567
9	2015	Tongling Changjiang Highway Railway Bridge	Steel truss cable-stayed	630
10	under construction	Shanghai railway Yangtze River Bridge	Steel truss cable-stayed	1092

Table 1. China Railway Steel Bridge

Wind Tunnel Test

Model design and manufacture

As of this date, girder cross-section form, aspect ratio and webs inclination would be the main considerations of the three-component force coefficient of the ordinary section. For truss girder cross-section, the truss cross-section type including box-type, H-type and circle-type, the solidity ratio of truss and the space ratio should also be taken into account. This paper did separately analysis on these different parameters which are width, height, aspect ratio, the number of truss, the solidity ratio of truss, and the inclination of truss, and summed up the influence of three-component force coefficient by changing each parameter.

Simultaneously, considering that three truss beam is the main form of current long span railway bridge, experiment scheme design is taking the main girder form of Anqing Yangtze River Railway Bridge as the basic reference section and researching the influence of parameters on the three-component force coefficient of truss girder by changing the section's height, width, number of truss, web layout and truss inclination. In order to minimize details effect, cross-section was simplified and regardless of the train. The desired test cross-section is as follows:

Case 1: The basic reference section. Taking Anqing Yangtze River Railway Bridge as the basic object, in precondition of satisfying requirement, simplified model with a scale of 1:80 is shown in Figure 1 to Figure 3:

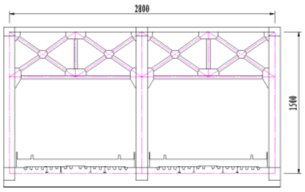


Figure 1. The basic reference section (unit: cm)

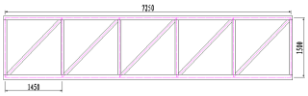


Figure 2. Arrangements of web members (unit: cm)

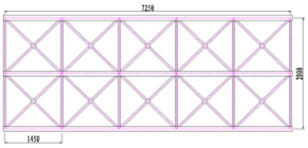


Figure 3. Arrangements of lateral bracing (unit: cm)

Case 2: The heightening section. Based on the prototype of the basic reference section, the height of section increased from 15m to 20m. Specific construction is shown in Figure 4.

Case 3: The widening section. Based on the prototype of the basic reference section, the wide of section increased from 28m to 36m. Specific construction is shown in Figure 5.

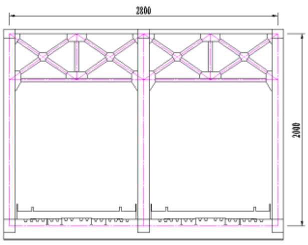


Figure 4. The heightening section (unit: cm)

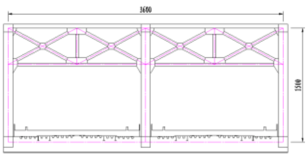


Figure 5. The widening section (unit: cm)

Case 4: Two truss section. Based on the prototype of the basic reference section, removing the middle truss. Specific construction is shown in Figure 6.

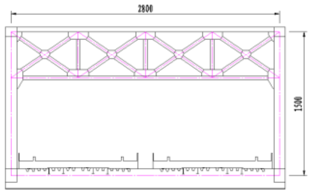


Figure 6. Two truss section (unit: cm)

Case 5: The solidity ratio increased section. Based on the prototype of the basic reference section, increasing trusses. Specific construction is shown in Figure 7.

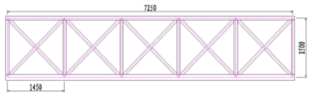


Figure 7. The solidity ratio increased section (unit: cm)

Case 6: The solidity ratio decreased section. Based on the prototype of the basic reference section, decreasing trusses. Specific construction is shown in Figure 8.

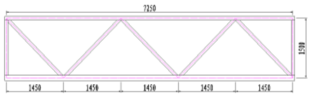


Figure 8. The solidity ratio decreased section (unit: cm)

Case 7: The truss inclination section. Based on the prototype of the basic reference section, side main trusses are dipping 20 degrees. Specific construction is shown in Figure 9.

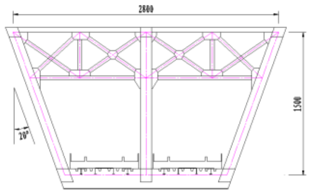


Figure 9. The truss inclination section (unit: cm)

Experimental condition and equipment

All models experiment in scale 1:80. Model length L is 916.25mm, width B ranges from 350mm to 450mm, height H ranges from 187.5mm to 250mm, aspect ratio L/B ranges from 2.01 to 2.59. All these experimental parameters can fulfil the requirements. Model blocking ratio ranges from 1.3% to 1.7% which is less than 5% that meets the general specification requirements.

Figure 10. Test modal in wind tunnel

The three-component static force of modal obtained from five-component high frequency force balance technique. The high frequency force balance which placed in rotatable piston can change attack angles from -180 degree to 180 degree. Wind velocities were measured using four channels stream line hot wire anemometry which was produced by DANTEC.

The wind tunnel test carries out in the uniform wind field. Wind velocity of 10m/s and 15m/s and attack angle of -5°, -3°, 0°, +3° and +5° have been conducted respectively.

Test Results of three-component force coefficient

The test results were shown in Table 2.

Case	V (m/s)	Angle (°)	C_H	C_V	C_M
1	10	-5	0.8813	-0.4462	-0.0190
		-3	0.8711	-0.4172	-0.0165
		0	0.8777	-0.2696	0.0116
		+3	0.9358	0.0205	0.0208
		+5	0.9759	0.2188	0.0154
	15	-5	0.8838	-0.4504	-0.0192
		-3	0.8713	-0.4229	-0.0166
		0	0.8739	-0.2913	0.0075
		+3	0.9199	0.0148	0.0207
		+5	0.9528	0.2179	0.0168
2	10	-5	0.7803	-0.4666	0.0139
		-3	0.7726	-0.4360	0.0140
		0	0.7663	-0.2998	0.0396
		+3	0.7902	-0.0218	0.0525
		+5	0.8149	0.1854	0.0509
	15	-5	0.7816	-0.4513	0.0092
		-3	0.7691	-0.4301	0.0085
		0	0.7650	-0.3185	0.0304
		+3	0.7865	-0.0319	0.0499
		+5	0.8088	0.1839	0.0507
3	10	-5	0.9396	-0.4541	0.0218
		-3	0.9373	-0.3735	0.0261
		0	0.9575	-0.0946	0.0406
		+3	1.0027	0.1696	0.0389
		+5	1.0328	0.3238	0.0223
	15	-5	0.9303	-0.4302	0.0188
		-3	0.9267	-0.3450	0.0242
		0	0.9481	-0.1092	0.0381
		+3	0.9976	0.1581	0.0419
		+5	1.0252	0.3116	0.0304

Table2. Three-component force coefficient in the body axial system. Note that the results of the other cases were measured but not list in this abstract.

Analysis of parameter influence

Influence of width

As shown in Figure12, compared with Case 1, the variation curves of drag coefficient, lift coefficient and moment coefficient of Case 3 are same and values of three-component force coefficient increased. Drag coefficient is the maximum value of these three coefficient. That means drag force is one of the major load of wind. Mean change value of drag coefficient is 0.066 and the rate of change ranges from 6% to 9% and the average rate is 7.3%. Mean change value of lift coefficient is 0.093 with large variations. Mean change value of moment coefficient is 0.027 and the rate of change ranges from 50% to 250%

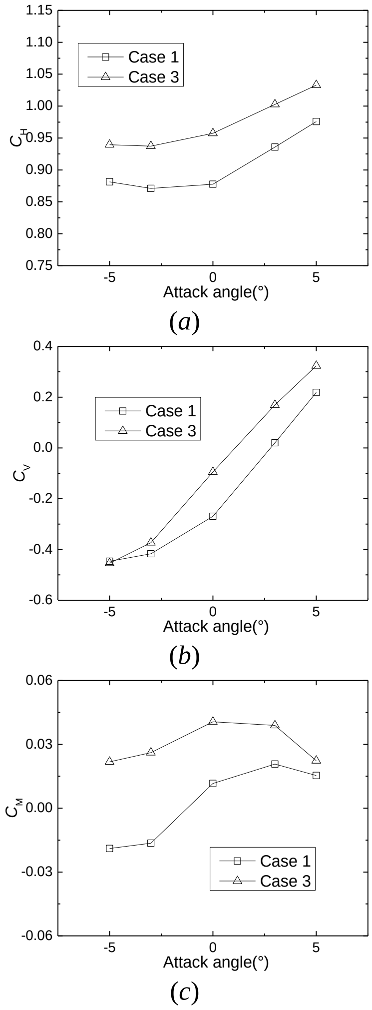
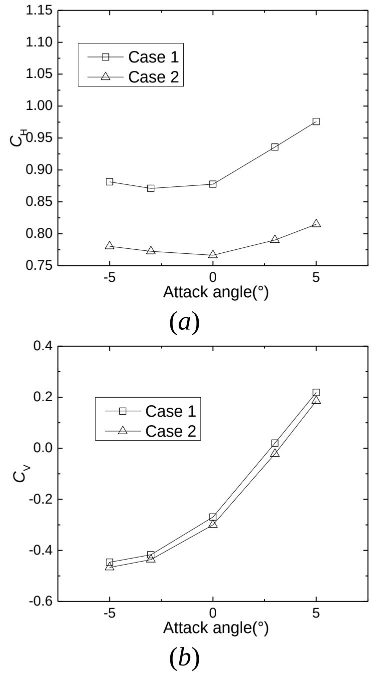
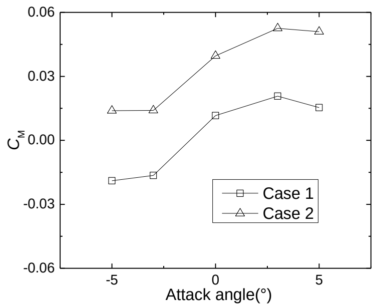


Figure12. Influence of width

Influence of height



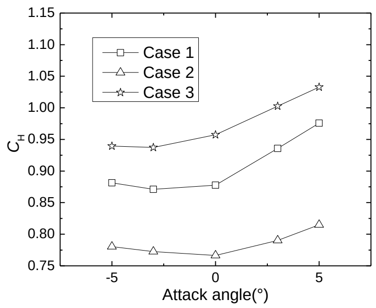


(*c*)

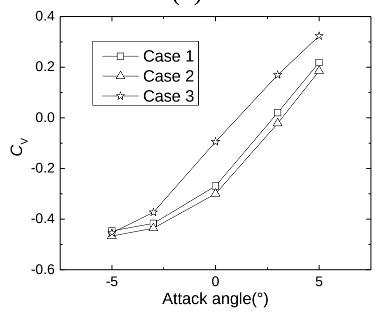
Figure13. Influence of height

As shown in Figure13, compared with Case 1, the variation curves of drag coefficient, lift coefficient and moment coefficient of Case 2 are same. Values of drag coefficient and lift coefficient decreased and moment coefficient increased. The drag coefficient showed a decreased trend with a most extent. Mean change value of drag coefficient is -0.123 and the rate of change ranges from -11.5% to -16.5% and the average rate is -13.5%. Mean change value of lift coefficient is -0.029 and the rate of change ranges from -5% to -15%. Mean change value of moment coefficient is 0.032 and the rate of change ranges from 150% to 250%.

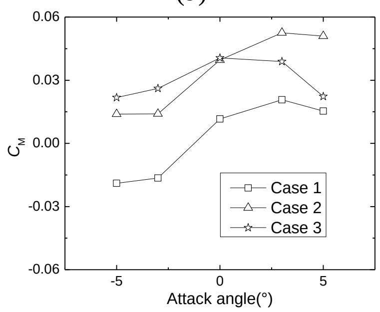
Influence of aspect ratio



(*a*)



(*b*)



(*c*)

Figure14. Influence of aspect ratio

As shown in Figure14, it has non-linear relationship between the three-component force coefficient and the aspect ratio. Overall, drag coefficient and lift coefficient increased with the increase of the aspect ratio. However, moment coefficient may not anything to do with the aspect ratio. In addition, when the aspect ratio is low, increasing the aspect ratio has a bigger effect on drag coefficient, and vice versa.

This abstract does not contain analyses of other cases

Conclusions

The three-component force coefficient increased with the increase of the width of truss girder. The width of truss girder increased by 28.6% and average rate of change of drag coefficient is 7.3%.

Drag coefficient and lift coefficient decreased with the increase of the height of truss girder. However, moment coefficient increased with the increase of the height of truss girder. The height of truss girder increased by 33.3% and average rate of change of drag coefficient is-13.5%.

Drag coefficient and lift coefficient decreased with the increase of the height of truss girder. Moment coefficient is not directly related to the aspect ratio.

When the aspect ratio is low, increasing the aspect ratio has a bigger effect on drag coefficient, and vice versa.

The curve of the three-component force coefficient changing with the attack angle goes to flat with inclination of side main trusses.

Drag coefficient and moment coefficient decreased with the increase of inclination of side main trusses. Side main trusses are dipping 20 degrees and average change rate of drag coefficient is -7.6%.

Drag coefficient and lift coefficient decreased with the decrease of main truss numbers. Moment coefficient is opposite. Removing the middle truss and average rate of change of drag coefficient is -9.2%.

Drag coefficient increased with the increase of solidity ratio. Lift coefficient and moment coefficient is opposite.

When the value of solidity ratio is fairly large, increasing the solidity ratio has a bigger effect on drag coefficient, and vice versa. Lift coefficient and moment coefficient is opposite.

Acknowledgments

Here and now, I would like to extend my sincere thanks to financial support from Project of National Natural Science Foundation of China (Grant No. 51678508, and Grant No. 51308478) and the Major State Basic Research Development Program of China (Grant No. 2013CB036301).

References

[1] Davenport, A.G., The application of statistics concepts to the wind loading of structures. Proc. ICE, 1961.

[2] Jones, N.P. et al., Wind loads and wind-induced response of long-span bridges and bridge stays. State-of-the-art wind tunnel modeling and data analysis techniques for infrastructure and civil engineering applications, 2004.

[3] Holmes, J.D. (editor) Wind loading of structures New York, Taylor & Francis, 2007.

[4] Simiu, E. & Scanlan, R.H., Wind effects on structures New York, John Wiley & Sons, Inc., 1996.

[5] Chen, Y., The study of aerodynamic parameter for steel truss girder of long span railway bridge, Southwest Jiaotong University, 2009.