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The evaluation of aerodynamic capacity for a cable-stayed bridge with sloped 2-edge box girder

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ABSTRACT

In recent years, length of bridge is longer and longer according to develop new material and construction technology. Under wind induced, to evaluate behavior is divided to: static and dynamic efficiency. Through the development of the bridge cross section can be improved the static and dynamic wind resistance performance. This study is one of them. And especially it is about the 2-edge box girder type bridge case. As applying the sloped edge box, wind capacity of a girder bridge is improved. The aerodynamic capacity of a bridge could be evaluate the size of vibration force by vortex. The sloped edge box is expected to have some effects that to decrease the vibration force. Through Performing wind tunnel test, it is checked the static wind coefficient, vortex shedding and flutter velocity. And also, it is checked the decreasing effect of the vibration force.

1. INTRODUCTION

Many researchers have carried out investigations for the development of bridge performance under wind induced. A research about the cross-section bridge shape is a kind of them. There are various attempts to improve bridge cross-section shape. For example, recently there are new type sections which are a twin-box section and a triple-box section. This study is one of them. And especially it is about the 2-edge box girder type bridge case. By changing the bridge cross-section shape, the wind flow can be induced to be less impact on the bridge. As applying the sloped edge box, wind capacity of a girder bridge is improved. The aerodynamic capacity of a bridge could be evaluate the size of vibration force by vortex. The sloped edge box is expected to have some effects that to decrease the vibration force. For inspection, wind tunnel test and CFD analysis are performed.

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2. Basic concept

The 2-edge box girder type bridge is one of the most general types in case of composite bridge. Like this type bridge, it can be cost-effective construction. But it has some typical weakness points. Aerodynamic instability is one of them. There are many types of aerodynamic instability: vortex shedding, buffeting, galloping, flutter, else. In this case, especially it is vulnerable to flutter phenomenon. In order to improve these disadvantages, we use sloped box type girder.

Aerodynamic stability of the bridge is governed by wind vibration force. According to wind vibration force is increased, aerodynamic instability of the bridge is increased. The key concept of the sloped box is decreasing the wind vibration force. It is illustrated in Fig. 1.

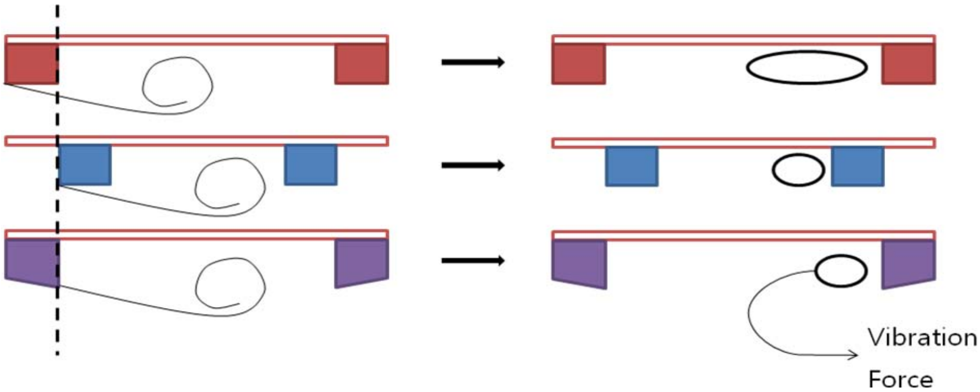

Fig. 1 Concept of sloped box type girder bridge

As hold over a starting point of vortex, wind vibration force can be decreased. This phenomenon has similar effective to inner box type girder.

3. Target section

This cross-section is applied sloped box concept. The width is 34 meters, the depth is 4 meters and the edge angle is 16.4°. It can be found that detail information is illustrated in Fig. 2.

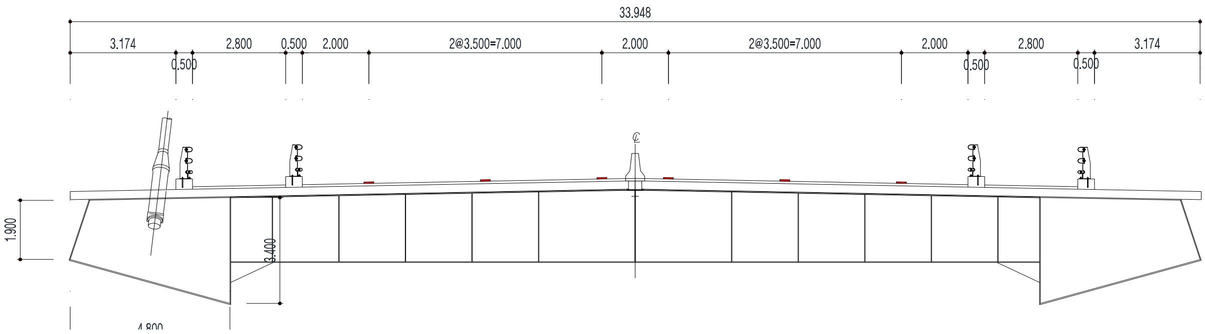

Fig. 2 Target section

4. CFD analysis

The CFD analysis is performed by Fluent 6.3. Analysis condition is following;

Table. 1 CFD analysis condition

	analysis	note
Section Scale	1:70	-
Dimension	2D	-
Number of Grid	≒ 700,000	-
Equation	Navier-stokes eqn.	FVM
Turbulence model	Reynolds stress model (RSM)	-
Wall function	Be used	-
Lange of y+	30< y+ < 100	-
Aerodynamic Coefficient Velocity	4 m/s	-

The purpose of this CFD analysis is focused on inspecting pressure gradient. It is illustrated in Fig. 3.

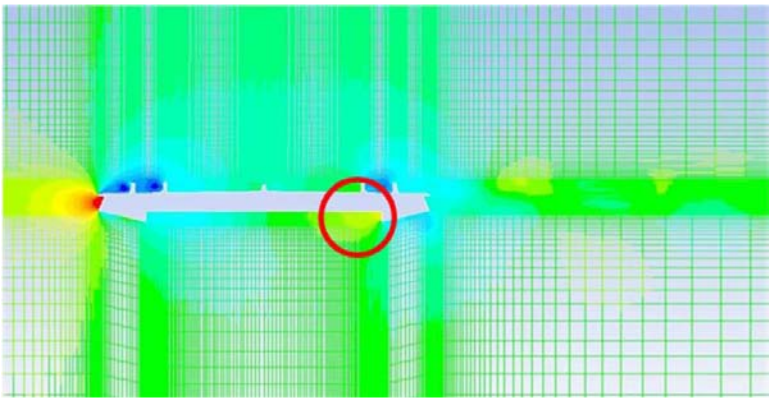

Fig. 3 CFD analysis(pressure gradient)

It can be found vortex(wind vibration force) in the illustration(remarked red circle).

5. Wind tunnel test

5.1 Test setting

There are two kinds of wind tunnel test. One is static test that is focused only aerodynamic force coefficients. Another one is dynamic test that is focused on vibration like vortex, buffeting, flutter, etc. These test performed Korea university wind tunnel test laboratory. Size of wind tunnel inlet part is 1.0mX0.8mX4.5m (WXHXL). Test model is used 70:1 scaled, it is applied fluid similarity. Scaled parameters about 70:1 model is shown Table 2.

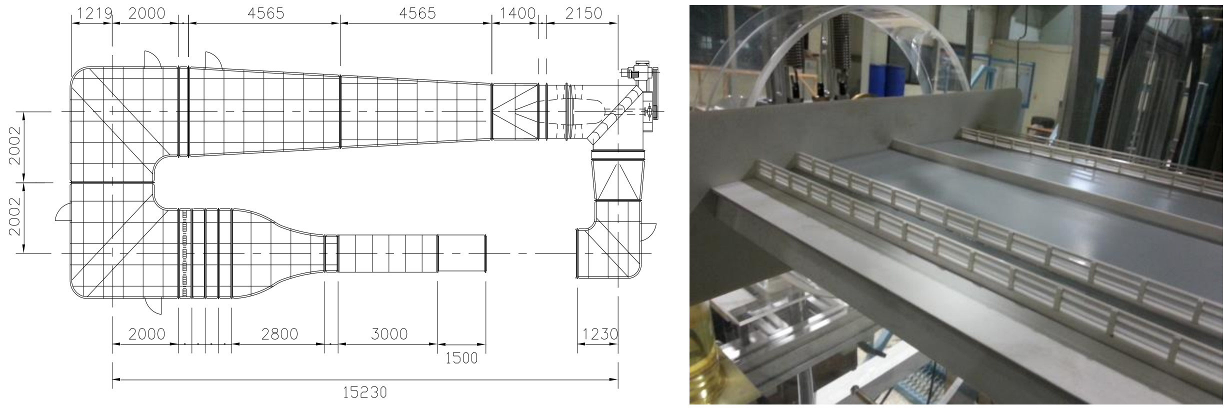

Fig. 4 Korea university wind tunnel test laboratory and Test section

Table. 2 Parameters of scaled model cross section

Title	Value	Scaled value
Scale	1	1/70
Vertical frequency	0.258(Hz)	2.159(Hz)
Torsional frequency	0.508(Hz)	4.250(Hz)
V/T ratio	1.969	1.969
Mass	52,279.4(kg/m)	9.069 (kg/m)
Mass moment of inertia	7,015,087(kN/g·m2)	0.248 (kN/g·m2)

5.2 Test case

Test case variables are attack angle, laminar and turbulent flow. Table. 3 is shown static and dynamic test case.

Table. 3 Wind tunnel test case

	Flow type	Attack angle
Static test	Laminar	-10°, -8°, -6°, -4°, -2°, 0°, 2°, 4°, 6°, 8°, 10°
	Turbulent	
Dynamic test	Laminar	-5°,-3°, 0°, 3°, 5°
	Turbulent	

6. Test result

6.1 Static test result

In this static wind tunnel test, it can be get 3 aerodynamic force coefficients(Cd, Cl, Cm). The test is performed under two condition(laminar and turbulent). It is next two figures. Left side figure is the result under the laminar condition. Right side figure is the result under the turbulent condition.

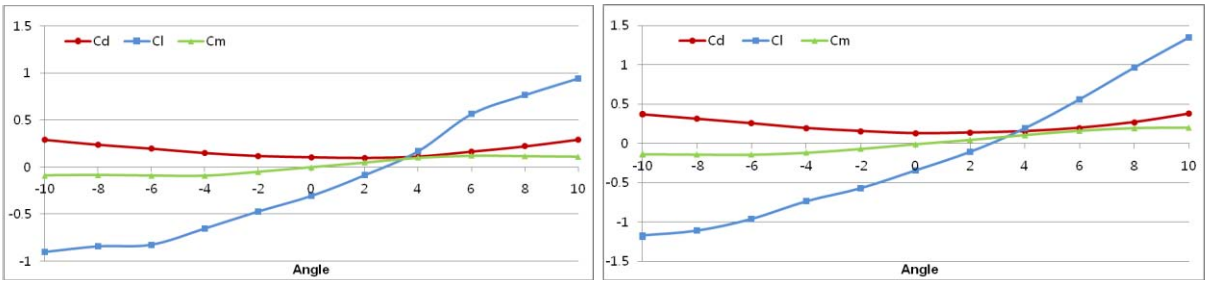

Fig. 5 Aerodynamic coefficient in laminar flow and turbulent flow

The Characteristic length is bridge width(B) 34meters. When the condition is under the laminar flow and a attack angle is 0°, drag coefficient is 0.104. In the case of a bridge, drag coefficient is most important above other coefficients. Because this coefficient is closely related to wind load. This 0.104 value is quite satisfactory values.

6.1 Dynamic test result

In dynamic wind, data is get using laser displacement sensor. The gained displacement data is processed vertical displacement mean and rms values, torsional displacement mean and rms values of bridge deck. From this result we can confirm the behavior under wind induced. (The ‘CW’ means clock wise, the ‘CCW’ means count clock wise. For example, the ‘CCW5’ means that the attack angle is count clock wise 5°.)

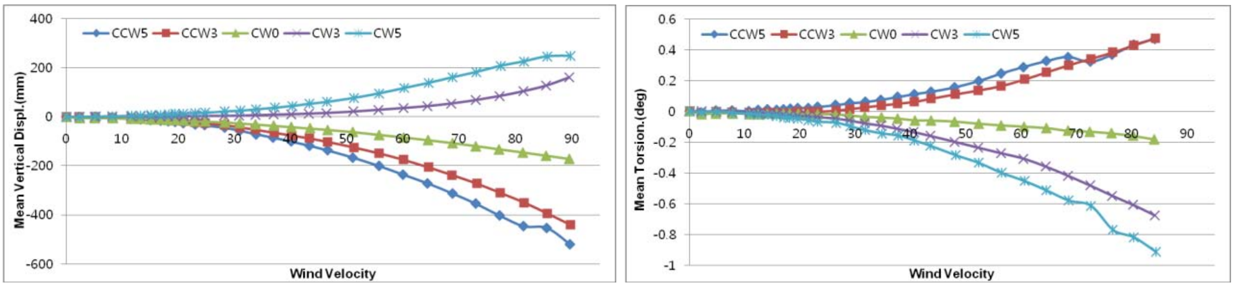

Fig. 6 Mean vertical displacement and torsional angle under the laminar flow

The Fig. 6 is shown the mean values according to attack angle variation. There is no special phenomenon. The larger the angle of attack is greater the mean value.

But the Fig. 7 is shown that has some harmful aerodynamic vibration. In cases of ‘CCW5’ and ‘CW5’, flutter phenomenon occurs about 70m/s wind velocity.

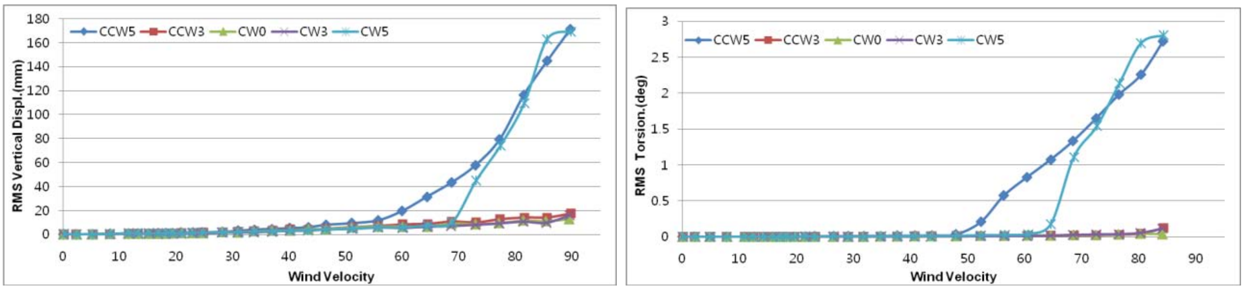

Fig. 7 RMS vertical displacement and torsional angle under the laminar flow

Also, the Fig. 8 is shown the mean values according to attack angle variation. There is no special phenomenon. The larger the angle of attack is greater the mean value. It is quite general.

But the Fig. 9 is shown that has some harmful aerodynamic vibration. In case of 'CCW5', flutter phenomenon occurs about 80m/s wind velocity.

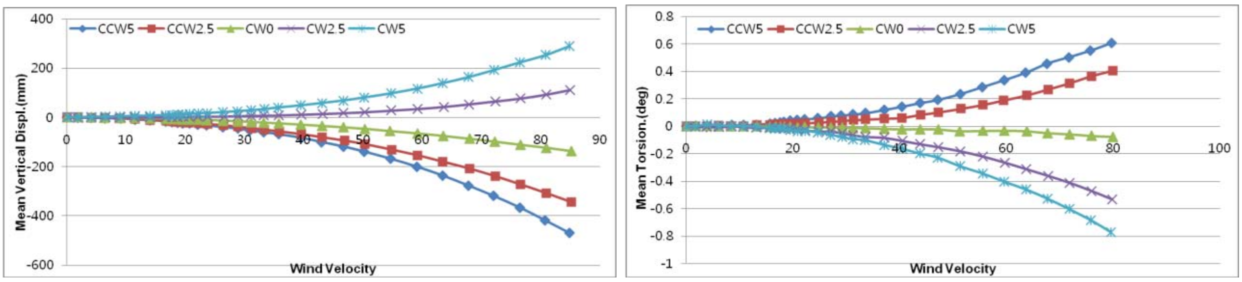

Fig. 8 Mean vertical displacement and torsional angle under the turbulent flow

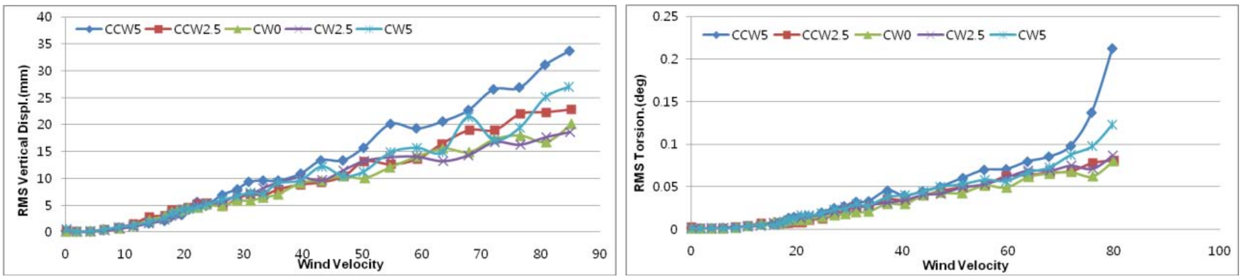

Fig. 9 RMS vertical displacement and torsional angle under the turbulent flow

7. CONCLUSIONS

Aerodynamic stability of the bridge is governed by wind vibration force. According to wind vibration force is increased, aerodynamic instability of the bridge is increased. The key concept of the sloped box is decreasing the wind vibration force. So, the smaller wind vibration force can be found by CFD analysis.

In the case of a bridge, drag coefficient is most important above other coefficients. Because this coefficient is closely related to wind load. In this case, drag coefficient is 0.104 value, and it is quite satisfactory values.

The mean displacement graph has no special phenomenon under both condition(laminar and turbulent). But the RMS graph has been found harmful vibration. Under the laminar flow, 'CCW5' and 'CW5', flutter phenomenon occurs about 70m/s wind velocity. And Under the turbulent flow, 'CCW5', flutter phenomenon occurs about 80m/s wind velocity.

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