

# Wind tunnel test study the influence of wind screen on wind pressure distribution above railway tracks

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**ABSTRACT:** In order to investigate the wind screen to effects of distribution on wind pressure above tracks, the wind pressure coefficients profile were tested by the wind tunnel testing used the wind pressure row tube, and numerical simulation was carried out at the same time to contrast with wind tunnel testing, the effects of wind screen arrangements, heights of wind screen, the line structure types such as the ground roadbeds, high embankments and bridges were discussed about the distribution of wind pressure on tracks, and the mechanism of aerodynamics was analyzed. It shows that the wind pressure value above tracks are significant decreased by wind screen in windward; the wind screens in leeward increased the negative pressure above tracks; in the three line structure forms, the wind pressure value above tracks on bridge are maximum, the energy dissipations are minimum, and the energy dissipations in high embankment are maximum, meanwhile, the wind pressure coefficients on catenary are decreased when the wind screens installed on high embankment.

**KEYWORDS:** wind screen; wind pressure coefficients; wind tunnel testing; line structure forms

## 1 INTRODUCTION

In recently, wind-induced accidents of trains have been reported around the world from time to time. For instance, there have been more than 30 wind-induced accidents of trains since 1872 in Japan<sup>[1, 2]</sup> (statistics to 2006). In 2005, Shinkansen train “Rice 14” of East Japan Railway Company was derailed as a result of encountering cross-wind which was much lower than the warning wind speed<sup>[3]</sup>. In China, more than 110 rail vehicle (statistics to 2002) rollover accidents by cross winds have been reported on the Lan-Xin Railway since 1959<sup>[4]</sup>, in 2007, a 5807 times train from Urumchi to Aksu was derailed by 13 class gale led to four deaths and more than 30 injured. Beijing-Shanghai (or Jing-Hu) high-speed railway has been built along the annual maximum wind speed greater than 20m/s, the number of occurrences is about 19.2<sup>[5]</sup>. In summary, it is very necessary for gale district railway to set up the precautions such as wind screens, it's one of the efficient measures for vehicle safety, wind screens were installed one or two sides along the railway to create a local environment of relatively low wind speed for trains.

Wang et al.<sup>[4]</sup> indicated that the heights of windbreak wall should be 2.4m above rail top, the construction cost per kilometer will be decreased by 33%. Ge and Jiang<sup>[6]</sup> studied the wind velocity reduced ratio in Lan-Xin railway by full-scale measurements, their results showed that the speed of the wind behind the 3m high windbreak is smaller than that outside the windbreak and the shielding scope of windbreak exceeds 38m when wind speed is 20m/s. A series of wind tunnel testing are conducted in Japan, the result shows that the effects of wind screen on the reduction of aerodynamic forces depends on the heights of wind screen, solidity ratios, configurations of vehicles and infrastructures<sup>[7, 8]</sup>. Numerical simulations were also conducted to understand the wind shield effect of wind screen. Bobi et al.<sup>[9]</sup> used the method of Navier-Stokes simulation to study the different wind screen shapes, obtained global values of efficacy greater than 90% in both viaduct and embankment situations. Jiang and Liang<sup>[10]</sup> studied the effects of the vehicle

aerodynamic performance caused by the change of height and position of wind-break wall, the result shows that position vs. height was approximately cubic polynomial relations.

In conclusion, the related research in China focused on the heavy windbreak wall in Nan Xing railway, researched on light wind screen and its mechanism is relatively limited, and the research results of foreign is difficult of direct reference. The Jing-Hu high-speed railway located in the eastern coastal of china where is vulnerable to the attack of typhoon and strong monsoon, so it is necessary to set up wind screen in the high wind speed regions. Three line structure types were chosen from Jing-Hu high speed railway: the ground roadbed, high embankment and 32m span bridges, were respectively made the wind tunnel test model. The wind pressure coefficients in different wind screens were tested, discussed the effects of arrangements, heights, line structure types, and analyzed the aerodynamic mechanism of wind screen.

## 2 WIND TUNNEL TESTING

Strong lateral wind can affect substantially the performance of the running train, the wind screen can change the ambient flow field above the railway, furthermore influence the wind loads acting on vehicles. Three types of infrastructure forms are adopted in this study, bridge, high embankment and ground roadbed.

The test of wind pressure distributions was conducted in XNJD-3 wind tunnel with a scale of 1:15, the end-plate was set up along the side of models to reduce the effect of flow around, because the width of the model is 3m while the width of the wind tunnel is 22.5m. The wind pressure pipe was vertical to flows installed in columns, and was vertical extended 0.05m to reduce the disturbing effect of pillar. There are 16 measuring points in the center of tracks with a measuring spacing of 0.03m below height of 0.25m, other spacing was 0.04m (shown in figure 1). The wind pressure coefficient profile of the center of tracks can be obtained by the synchronous acquisition system.

A pitot tube was placed in undisturbed flows to test the static pressure and velocity, if the static pressure in upper stream was considered as a reference point, then the wind pressure coefficient can be expressed as:

$$C_{pi} = (P_i - P_\infty) / 0.5\rho V_\infty^2 \quad (1)$$

Where  $P_i$  is value of wind pressure in  $i$ th wind pressure pipe (total pressure);  $P_\infty$  is static pressure in reference point of upper stream;  $V_\infty$  is velocity of upper stream;  $\rho$  is the air density; It should be noted that wall pressure coefficient is relative to the shape of the structure reflecting the surface wind load distribution on the structure, but  $C_{pi}$  is the relatively wind pressure coefficient reflecting distribution of the flow field and the total energy.

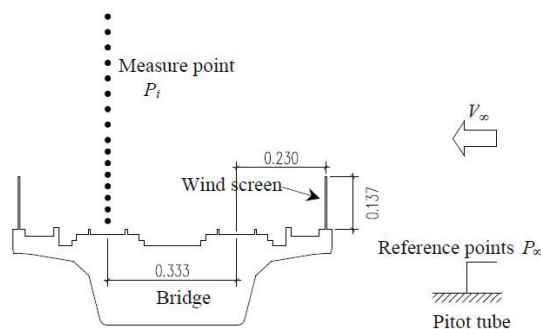


Figure.1 Schematic diagram of wind pressure profile test schemes on bridge (unit: m)

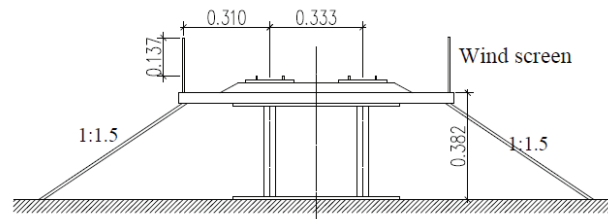


Figure.2 Wind tunnel test model of high embankment (unit: m)

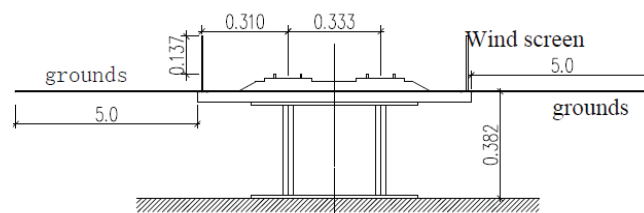


Figure.3 Wind tunnel test model of ground roadbed (unit: m)

the wind pressure coefficient profile in the center of tracks on windward side and leeward side was tested with different wind screens height and arrangement on three typical line construction forms (as shown in figure.1~figure.3) for the Beijing-Shanghai high-speed railway, the specific case is shown in table 1.

Table.1 Wind tunnel test cases

| infrastructure scenario | height of wind screen(unit:m) | Arrangement of wind screen |
|-------------------------|-------------------------------|----------------------------|
| bridge                  | 0.0、1.72、2.05                 | one side, both side        |
| high embankment         | 0.0、1.60、2.05                 | one side, both side        |
| ground roadbed          | 0.0、1.60、2.05                 | one side, both side        |

Noted: the height above orbital plans is the wind screen height, 0.0 is no wind screen, and one side is no windward wind screen.

### 3 RESULT ANALYSIS

The numerical simulation was firstly conducted at the same time for typical case, compared the results of wind tunnel test and CFD, and on that basis, the mechanism of aerodynamics was analyzed, the wind pressure distributions above tracks were discussed in different arrangements, heights and line structure types.

#### 3.1 Comparison of the wind tunnel test and CFD

A 2D wind pressure distributions with a scale of 1:15 was simulated using CFD with a 2.05m height wind screen set on the bridge (as shown in figure 1) to validate this paper test method, the turbulent model is the SST  $k-\omega$ , boundary layer thickness refer to the literature [11], the grid number is approximately 76 thousand, the comparison of numerical simulation by steady analysis and wind tunnel test is shown in figure 4, which shows that the CFD simulation results well agree with the wind tunnel test in windward tracks, although there has certain differences in the leeward side tracks, but the law are similar; In addition, the wind pressure coefficient in scope of

shading is smaller than external flow by the reason of energy dissipation of turbulence according to the ideal fluid Bernoulli Equation. Therefore, the wind pressure distributions tested by row tube is feasible.

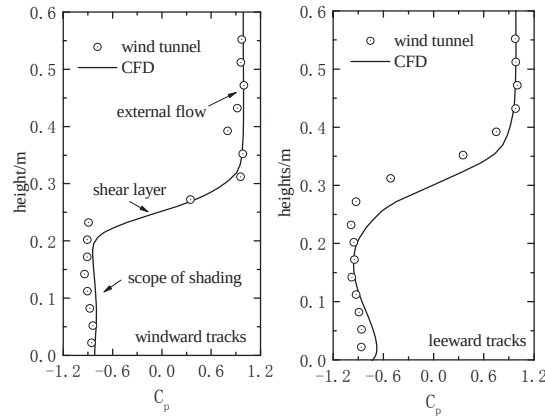


Figure.4 Comparison of wind tunnel test with CFD

### 3.2 Effects of windscreen arrangement

Comparison of wind pressure coefficient profile, setting one side, both side and without wind screen with a height of 2.05m on the bridge is shown in figure 5 to investigate the effect of wind-screen arrangement. The value of pressure in the center of tracks was reduced as the wind screen was set on one side or both sides. Compared the wind pressure coefficients with one side and both side cases, it is easy to learn that both side case were increased with respect to one side case in the scope of shading. Because the leeward wind screen blocked the around flow coming from windward wind screen, which increased the backflow above tracks, increased the pressure coefficient, and reduced the energy dissipation in scope of shading.

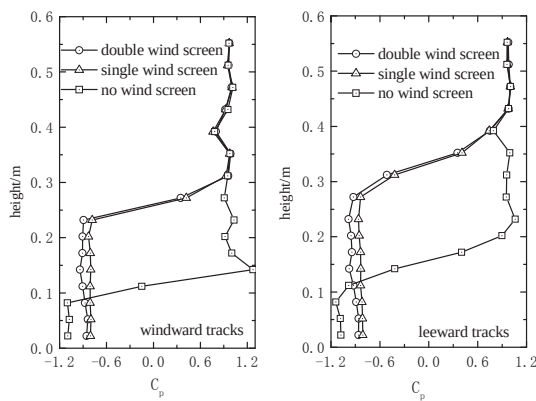


Figure.5 Effects of position of wind screen

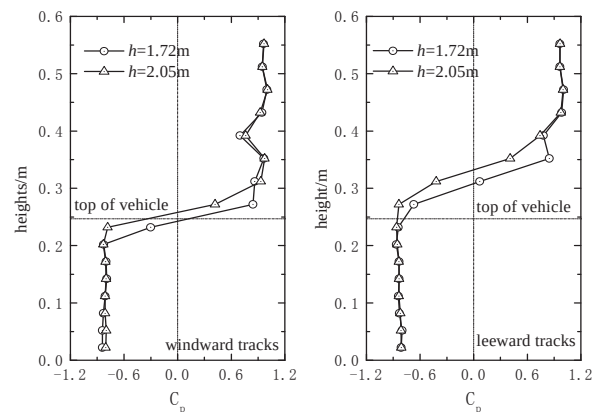


Figure.6 Effects of height of wind screens

### 3.3 Effects of height

The wind pressure profile of two heights of wind screens (1.72m and 2.05m) on one side is shown in figure 6 to investigate the effects of height. It shows that the change law of wind pressure coefficient profile is similar, and the height of the shear layer increased with the height of wind screen increasing. The height of vehicles in practice is generally in 3.5m to 4.0m such as

the vehicle of CRH2 is 3.7m above orbital plane with a value of 0.247m after scale. There is negative pressure in the windward tracks beneath the height of vehicles when the heights of wind screen are 2.05m. But the vehicles are partly subjected to positive pressure when the heights of wind screen are 1.72, and smaller than 2.05m. The shear layer of wind pressure coefficients in leeward wind screen are above the top of vehicle, and there has little difference in the scope of shading. Therefore, the wind shield of 1.72m wind screen is better than 2.05m if the wind pressure coefficient is considered as evaluation index.

### 3.4 Effects of line structure type

The profile of wind pressure distributions in bridges (shown in figure 1), high embankment (shown in figure 2), grounds roadbed (shown in figure 3) was tested to check the effect of line structure type. The wind pressure distributions for three kinds of infrastructure forms with wind screen set on one side are shown in figure 7. It shows that the wind pressure coefficient in bridge is largest, while the high embankment is smallest, it because the effect of slope in high embankment leads to change the attacks of wind, and improved the height of shear layer, meanwhile, the wind pressure coefficients on catenary was decreased when the wind screens is installed on high embankment.

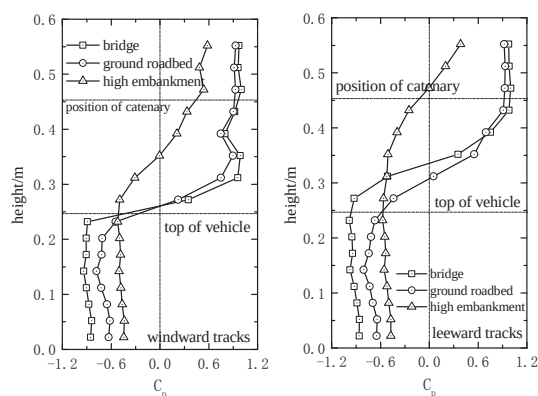


Figure.7 Effects of line structure types with wind screens

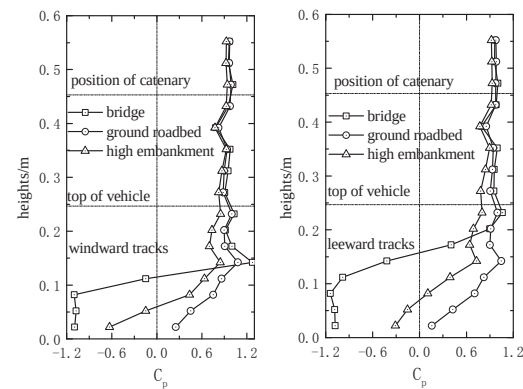


Figure.8 Effects of line structure types without wind screens

The wind pressure coefficient above tracks in different line structure types without wind screen were compared from the perspective of energy dissipation as shown in figure 8. Combined with figure 7, it is easy to learn that that the line structure types have a significant effect on the wind shield of wind screen, the distribution of wind pressure above tracks without wind screen have a remarkable difference, the energy dissipation in high embankment is maximum, the bridge is minimum. Therefore, it should be pay attention to the adverse effect of sudden change of vehicle wind load as a result of the change of line structure types.

## 4 CONCLUSION

The wind tunnel test has been performed investigating the effects of the wind screen on the three line structure types as well as an analysis of the flow field distribution, and derived the following conclusions.

1. The existence of windward wind screen reduced the wind pressure value, and the shear layer height increases with the height of the wind screen.

2. the wind pressure distribution have a significant difference in varied lines structure type, and the difference of energy dissipation is obvious, the energy dissipation is minimum on the bridge, is maximum on high embankment which can reduce the wind pressure coefficients on catenary.

## ACKNOWLEDGMENT

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