

# Numerical simulation and experimental study of aeolian sand load under aeolian sand environment

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**Abstract.** Concrete structures in a sandstorm environment suffer from sandstorm erosion for a long time, which reduces the durability of concrete buildings, and then threatens the safety of buildings. Therefore, it is of great practical significance to study the aeolian sand load under the aeolian sand environment. In this paper, by numerical simulation of the sand load on the surface of bridge and simulation test of the sand load on the surface of the concrete in the sand environment, the variation law of the sand load under different sand parameters is studied. Through comparative analysis, it is concluded that the variation law of aeolian sand load in numerical simulation and test tends to be consistent with the variation of aeolian sand velocity and sand content ratio.

## 1 Introduction

The concrete structure located in a strong wind sand environment is often subjected to erosion wear of the wind sand flow, which causes the cement spallation on the surface of the concrete structure and the acceleration of the micro-crack expansion between the cement and the aggregate, thus reducing the durability of the concrete structure. Therefore, it is of great engineering significance to study the sand load in the strong sandstorm area to ensure the normal service of concrete buildings in the strong sandstorm area.

Wang S T [2] studied the influence of wind-blown sand flow under different sand volume percentages on the wind-blown sand pressure of high-rise buildings through numerical simulation. The results showed that with the increase of sand content in the wind-blown sand flow, the wind pressure would increase and the wind load on the building surface would increase. In 2012, Li C M [3] et al. studied the aeolian sand pressure of buildings in aeolian sand environment through numerical simulation software Fluent, and the results showed that the aeolian sand pressure had the greatest impact on the windward side of the building, while the aeolian sand pressure on the leeward side of the building was negative. In 2015, Wang S Y [4] studied the influence of aeolian sand under different aeolian sand flow rates and sand content on the surface aeolian sand pressure of low buildings through wind tunnel test combined with numerical simulation. The results showed that the influence of aeolian sand flow on

building surface was much higher than that of pure wind, and the aeolian sand pressure had a positive relationship with the aeolian sand flow rate and sand content ratio.

In this paper, the numerical simulation and experimental study of the wind-blown sand flow field of bridge structures in wind-blown sand environment are carried out, and the variation law of wind-blown sand pressure on the wind-blown surface of the bridge is analyzed with different wind-blown sand velocity and sand content.

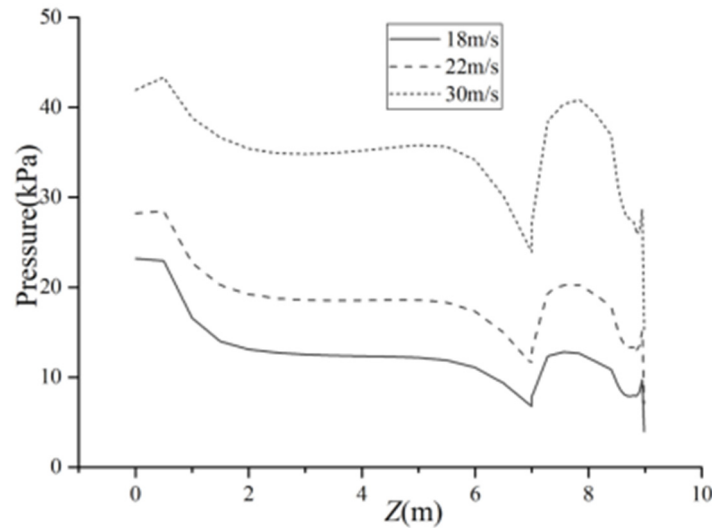
## 2 Numerical simulation of aeolian sand load on bridge surface under aeolian sand environment

According to the existing research conclusions, the most unfavorable situation is when the Angle of attack is 90°. Therefore, the sand flow field at different wind velocities and sand content is simulated with the Angle of attack of 90° to analyze the change of wind pressure on the windward side of the bridge.

### 2.1 Variation of the pressure on the windward side of the bridge at different wind sand flow rates

When the sand content is 2% and the flow rate of wind-blown sand at the entrance  $v=18\text{m/s}$ ,  $22\text{m/s}$  and  $30\text{m/s}$ , the variation of wind-blown sand pressure on the windward side of the bridge along the pier height is shown in Figure 1.

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**Figure 1.** Variation of sand pressure on the windward side along the pier height direction.

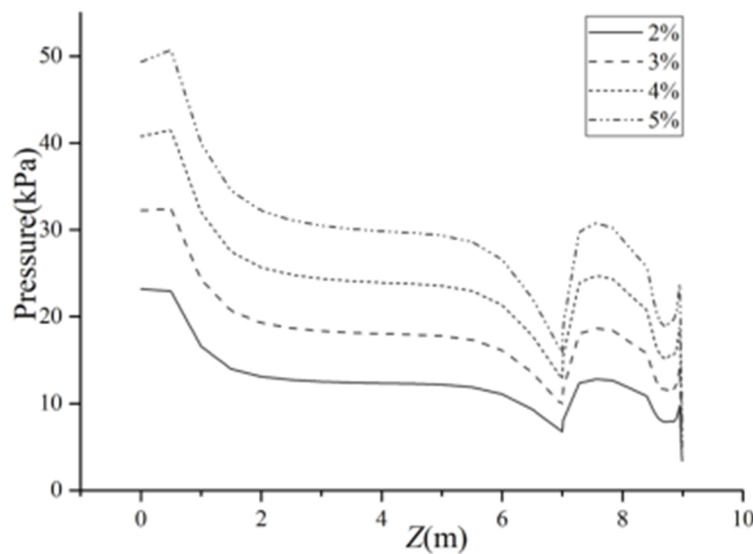
According to Figure 1, the following conclusions can be drawn:

- The maximum sand pressure on the windward side of the bridge appears at the bottom of the pier. When the inlet wind sand flow rate is  $v=18\text{m/s}$ ,  $22\text{m/s}$ , and  $30\text{m/s}$ , the maximum sand pressure on the windward side is  $25\text{kPa}$ ,  $30\text{kPa}$ , and  $45\text{kPa}$ , respectively. The maximum sand pressure on the girder appears in the middle of the girder, and the sand pressure gradually decreases from the middle to the edge of the girder.
- At the same inlet wind sand flow rate, the wind sand pressure on the windward side of the bridge gradually decreases with the increase of the height, and the wind sand pressure reaches the maximum at the bottom of the pier, while the

wind sand pressure in the middle of the pier is similar. At different inlet wind sand velocity: with the increase of inlet wind sand velocity, the wind sand pressure gradually increases; The greater the flow velocity of the inlet wind, the greater the change of wind pressure, and the greater the added value of the wind pressure on the main girder.

## 2.2 Variation of windward surface pressure of bridge with different sediment content

When the velocity of aeolian sand is  $18\text{m/s}$  and the sand content is 2%, 3%, 4%, and 5% respectively, the aeolian sand pressure on the windward side of the bridge along the pier height direction is shown in Figure 2.



**Figure 2.** Variation of sand pressure on the windward side along the pier height direction

According to Figure 2, the following conclusions can be drawn:

- The maximum windward sand pressure of the bridge appears at the bottom of the pier. When the sand content is 2%, 3%, 4% and 5%, the maximum windward sand pressure is 25 kPa, 35kPa, 42kPa, and 50kPa, respectively. The maximum wind-sand pressure of the main girder appears in the middle of the main girder.
- The variation trend of the windward side of the bridge with different sediment content is similar, and the aeolian sand pressure changes sharply at the bottom of the pier. Because of the large sediment carrying capacity near the ground surface and the active movement of aeolian sand flow, the maximum aeolian sand pressure appears at the bottom of the pier. Under the condition of the same sand content, the wind sand pressure on the windward side of the bridge decreases with the increase of the height, because the amount of wind sand carried by wind decreases with the increase of the height. Under

the conditions of different sand content, with the increase of sand content, the pressure on the windward side of the bridge increases continuously, that is, the more serious the desertification is, the greater the pressure generated by the sand flow and the greater the influence on the surrounding structures.

### 3 Aeolian sand load test on the concrete surface under aeolian sand environment

The sand load on the concrete surface was studied by the airflow sand-carrying injection method.

#### 3.1 Load test of aeolian sand when wind speed changes

Tests were carried out at particle size of 0.3mm, sand content of 76.32g/min, and sand velocity of 18m/s, 22m/s, 26m/s and 30m/s, respectively. The corresponding relationship between the sand pressure and the wind speed was obtained as shown in Figure 3.

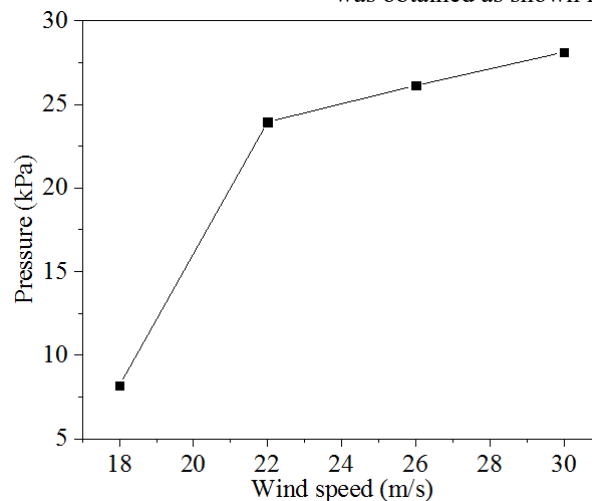
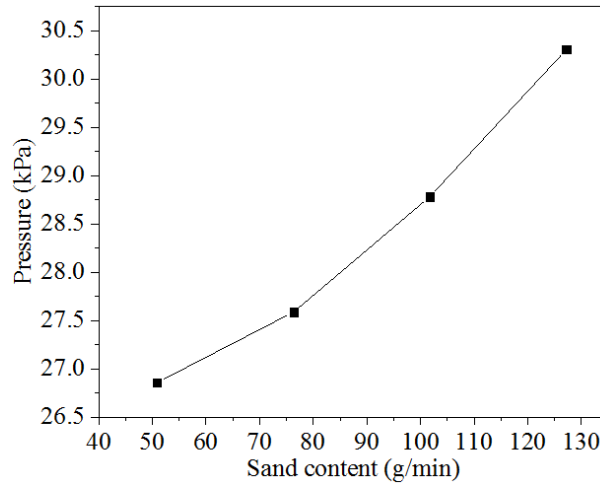


Figure 3. Relationship between the wind speed wind-sand and pressure

As it can be seen from Figure 3, when the wind speed changes, the sand pressure on the surface of the concrete specimen increases with the increase of wind speed. As the wind speed increases, the kinetic energy of the sand flow increases, and the normal stress of the sand flow acting on the surface of concrete specimen increases, the sand pressure increases accordingly and ultimately leads to the increase of wind erosion rate and strength loss.

#### 3.2 Load test of aeolian sand when sediment concentration changes

The test was carried out under the conditions of sand concentration of 50.88g/min, 76.32g/min, 101.76g/min and 127.2g/min respectively. The aeolian sand velocity was set as 26m/s and the sand particle size was set as 0.3mm. The corresponding relationship between sand concentration and aeolian sand pressure was obtained from the test results, as shown in Figure 4.



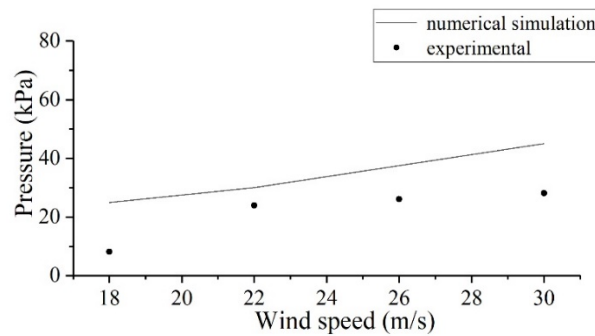
**Figure 4.** Relationship between sediment concentration and acolian sand pressure

From Figure 4, you can see that sediment concentration changes of concrete specimen surface wind pressure increase with the increase of sediment concentration, sediment concentration, the greater the impact per unit time to the grains of sand on the surface of the specimen, the surface of the specimen has hit number increase, concrete specimen surface wind pressure increase, eventually lead to increase the surface wear.

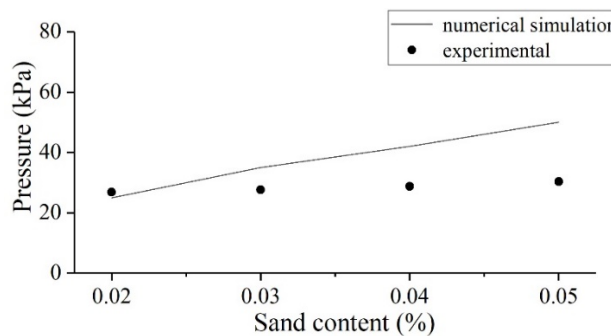
The variation law of the wind sand pressure on the bridge surface obtained from the numerical simulation shows that the maximum wind sand pressure appears at the bottom of the bridge pier, which is in good agreement with the experimental results. Therefore, the maximum sand pressure at the bottom of the pier is compared with the sand pressure obtained from the test.

The comparative analysis of the numerical simulation and the experimental sand pressure is shown in Figures 5 and 6.

#### 4 Numerical simulation and experimental results were compared and analyzed



**Figure 5.** Numerical simulation and experimental wind pressure at different wind speed



**Figure 6.** Numerical simulation and experimental wind pressure under different sand content

As can be seen from Figure 5, when the velocity of aeolian sand is different, the variation law of aeolian pressure obtained from numerical simulation is similar to that obtained from the test. As the velocity of aeolian sand increases, the aeolian load on the surface of concrete structures also increases. The experimental sand pressure is smaller than that of numerical simulation.

As can be seen from Figure 6, when the sand content is different, the variation law of the aeolian sand pressure obtained from the numerical simulation is similar to that obtained from the test. As the sand content increases, the aeolian sand pressure increases. The experimental sand pressure is smaller than that of numerical simulation.

## 5 Conclusion

This article has carried on the numerical simulation and experiment of dunes environment wind load, wind velocity, sand content not concrete structures at the same time, the change rule of surface wind load and the numerical simulation and experiment of sand pressure changes were analyzed, the following conclusions: different wind velocity and sand content, sand maximum stress appears at the bottom of the pier. The comparison between the numerical simulation and the test shows that the variation of aeolian sand pressure is similar. The reliability of the numerical simulation results is proved, which provides a basis for the further study of aeolian sand load in aeolian sand environment.

## Acknowledgments

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