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A new KOCED outdoor wind tunnel: full-scale destructive testing for category 3 typhoon

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SUMMARY:
The KOCED Wind Tunnel Center at Jeonbuk (Chonbuk) National University constructed a new outdoor wind tunnel simulating a category 3 typhoon wind speed. This open jet facility with an open test section has two convertible contraction nozzles of 4m×4m and 6m×6m, and generates sustained wind speed up to 53m/s. This facility is capable of conducting three types of experiments: full-scale destructive tests, aerodynamic tests, and industrial applications. This paper describes the planning, design and construction of the wind tunnel.

Keywords: outdoor wind generator, hurricane simulator, full scale test, drone test.

1. INTRODUCTION

For the purpose of reducing wind-hazards, a large-scale wind test facility would be most useful for conducting destructive experiments on large-scale structural systems. Urban structures that are damaged due to typhoons include road signs, traffic lights, sound barriers, billboards, signboards and hoardings at building. However, these small structures have not been designed and constructed on the basis of a rigorous wind-resistant specification. The full-scale destructive testing is the most reliable method to ensure the safety of citizens.

In addition, Aerodynamic tests such as those for small wind turbine, wind-borne debris, wind-driven rain test, and high Reynolds number test are in high demand. There is also demand for various industrial applications such as flight stability of drones and UAM (urban air mobility), radar operations, outdoor electronics, and automobiles which are hardly tested at indoor wind tunnel because of GPS and radar signal reception, specimen debris, water leakage, and blockage effects, etc.

A new wind tunnel project was initiated in 2016 and completed in 2020 in order to meet the above-mentioned test demands. With financial support from the Korea Ministry of Land, Infrastructure and Transport through the Korea Agency for Infrastructure Technology Advancement, the KOCED Wind Tunnel Center at Jeonbuk (Chonbuk) National University has developed a new outdoor wind tunnel that is capable of simulating a category 3 typhoon. The new outdoor wind tunnel is capable of conducting three types of experiments: full-scale destructive tests, aerodynamic tests, and industrial applications. This paper describes the planning, design, construction, performance and capability of the new outdoor wind tunnel.

2. CONCEPT AND DESIGN

In the planning phase of the outdoor wind tunnel, there were five design parameters: maximum wind speed, nozzle size, site size, budget, and impact on the surroundings. Since the site and budget were predetermined, other parameters were planned to achieve maximum performance within the constraints. The most potent typhoon to strike Korea in the previous 50 years, Typhoon Maemi, in 2003, provided the data for the first design parameter, the maximum wind speed. The target maximum sustained wind speed was 54m/s (120mph) corresponding to typhoon category 3 in the Saffir-Simpson scale ranging 49~ 59m/s.

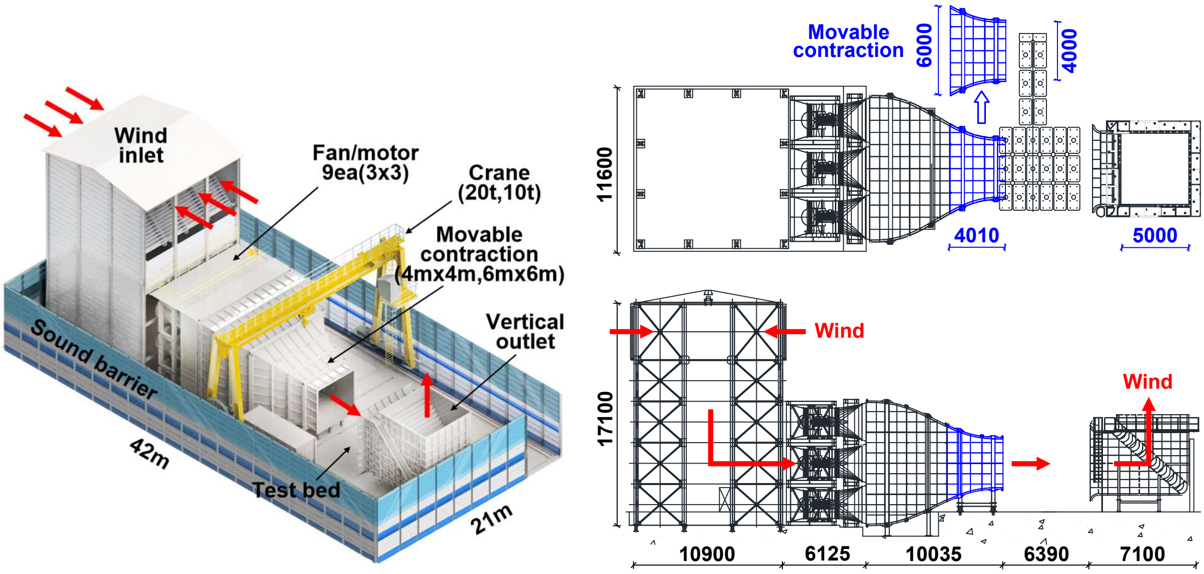


Figure 1. Perspective, plan, and front view of the KOCED outdoor wind tunnel.

Figure 2. General view and 9(3×3) fans.

Figure 1 shows a perspective, plan, and front view of the wind tunnel. The wind enters from the vertical inlet tower and changes direction horizontally through the guide vanes. The wind flows through a total of nine fans and goes out to the contraction nozzle. Due to the site's limitations, the wind flow was designed in the shape of a U, coming from the sky and exiting to the sky, to reduce its impact on the surroundings. The test specimen is fixed to a strong test bed between the contraction nozzle and vertical outlet. A vertical outlet can be used to test the multicopters such as drones and UAMs subjected to vertical winds.

As shown in Figs. 1 & 2, there are two contraction nozzles, 4m×4m and 6m×6m. By sliding the nozzle block horizontally along the rail, it automatically turns into another nozzle within 1 minute. The inflatable seal is expanded by up to 10mm between the nozzles to fill the gap. A total of 9 fans are arranged in an array of 3×3. Each fan has a diameter of 2m and is controlled by variable frequency drives. Each fan has a maximum volumetric flow rate of 6,800cmm with maximum rotation speed of 890rpm. The total peak power of the fans, each driven by an electric motor of 220kW, is 1,980 kW in total. There is a rainfall generator consisting of pumps, flowmeters, and a water tank that can simulate up to 20L of rainfall per minute.

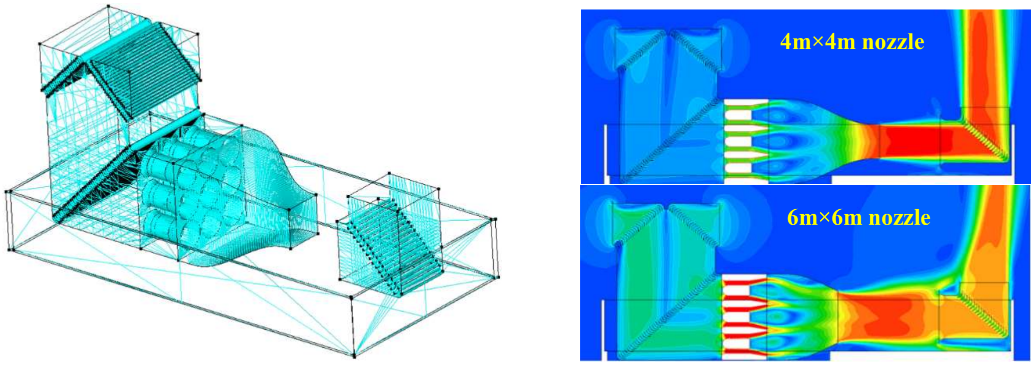


Figure 3. CFD simulation model and wind speed distribution.

3. FLOW QUALITIES AND PERFORMANCES

Flow analysis and noise analysis using the SC/Tetra software were performed during the design. The CFD simulation results shown in Fig. 3 shows that the flow in the test bed from the 4m×4m nozzle is uniform and low turbulent. The flow by the 6m×6m nozzle shows slight performance degradation but is acceptable. In order to reduce the noise, large vertical ducts are designed at the inlet and outlet, and the wind tunnel site is surrounded by a 6m high noise barrier. The effects of fan vibrations on the main steel structure are evaluated by the ANSYS software. Isolation mounts are installed in each fan module to reduce vibration transmissibility.

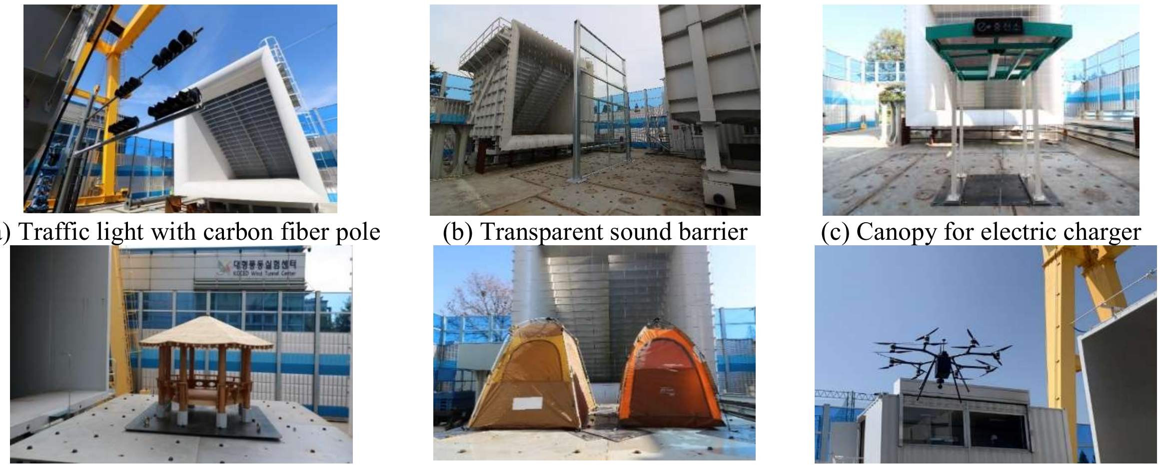
Wind velocities are measured at 9 locations in the test bed shown in Fig. 4. Table 1 summarizes the relative deviation of the wind speed from the average value ($\Delta U/\bar{U}$). At an average wind speed of 28.0 m/s, the wind variation in the 4m×4m section is 0.5% and the maximum is 0.8%. The average and maximum wind variation in the 6m×6m section at 19.5 m/s are respectively 2.5% and 4.0%. Flow uniformity of the vertical outlet 5m×5m section is less than 8%

Table 1. Flow uniformity($\Delta U/\bar{U}$), maximum wind speed, and turbulent intensity.

Section	Nozzle	U_{max}	Uniformity ($\Delta U/\bar{U}$)	Turbulent intensity
Test bed	4m×4m	> 53m/s	< ±0.8%	< 5.8 %
Test bed	6m×6m	> 28m/s	< ±4.0%	<10.5%
Vertical outlet	5m×5m	> 38m/s	< ±8.0%	-

3. CAPABILITIES AND EXPERIENCES

Various tests were performed over the past two years after completing the wind tunnel in 2020. As shown in Fig. 4, various full-scale destructive tests have been conducted for traffic lights with a carbon fiber pole, a transparent sound barrier, a traditional pergola, and a canopy for electric charging facility. In addition, we did a variety of interesting full-scale tests such as flight stability tests of various types of drones and UAMs, engine restart test, satellite reflector, wind-driven rain test of radar system and tents.



(a) Traffic light with carbon fiber pole (b) Transparent sound barrier (c) Canopy for electric charger

(d) Traditional pergola (e) Wind-driven rain test of tents (f) Drone

Figure 4. Full scale tests in the KOCED outdoor wind tunnel.

4. CONCLUSION

The KOCED Wind Tunnel Center has developed a new outdoor wind tunnel which is capable of simulating a category 3 typhoon wind speed. This open jet facility has two movable contraction nozzles of 4m×4m and 6m×6m, and generates sustained wind speed up to 53m/s and 28m/s, respectively. The uniformity and turbulence intensity of the 4m×4m section are less than ±0.8% and 5.8%, respectively, and 6m×6m section is less than ±4.0% and 10.5%, respectively. For the past two years after the completion, the wind tunnel has been fully utilized while conducting full-scale destructive tests and aerodynamic tests on various structures and facilities that could not be performed in existing wind tunnel.

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