Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 54(5) (2022) 201-204
DOI: 10.22060/mej.2022.20500.7250

Experimental Study of Impact Angle of Microburst Effects on a Cubic Structure – Part A: Stationary Microburst Observation

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ABSTRACT: A Downburst can produce divergent outflow wind on the ground surface, which is different from the behavior of atmospheric boundary layer flows. In this research, the effects of downburst on a cube-shaped structure in two different directions of flow (α), four different ground surface angels relative to the downburst direction (θ), and different radial distances (X/D) relative to the downdraft center were investigated by a simulator that was made for this thunderstorm. Simulation of this flow is created by a blower whose task is to uniformize the flow created by the fan embedded behind it. The velocity and turbulence intensity of flow was measured at different X/Ds. also, the distribution of pressure coefficient on the sides of the model was measured at the X/D locations. In addition, a good agreement has been observed between the data comparison of this study and previous studies. It was observed that at the center of the downburst for all θs, the structure has a positive pressure coefficient along its sides. By moving away from the center of the storm, the flow behavior is similar to the boundary layer flows. By increasing θ, it was found that the difference of pressure coefficient between the windward side relative to the roof and the backward sides, increased, which in the worst case has changed by about 80%. By examining the direction of flow to the model, it was found that the force coefficients when the model is at α=45°, are about 35% less than when the model is at α=0°. Finally, it was found that at X/D=1, the maximum force coefficient is applied to the structure.

Review History:

Received: Sep. 08, 2021
Revised: Nov. 01, 2021
Accepted: Dec. 25, 2021
Available Online: Jan. 19, 2022

Keywords:

Downburst thunderstorm
Cube-shaped model
Pressure & force coefficient
Impact angel
Experimental simulation

1- Introduction

With their unique behavior, downdrafts can have unpredictable effects on various structures [1]. These flows make strong surface winds which have caused damage to short and lightweight structures. Investigation of downdrafts is essential because the basis for calculating wind loads on structures is boundary layer wind loads [2]. To date, several studies have been conducted to evaluate the effect of downburst and its effects on cube-shaped models as a general form of structures. They have been done experimentally and sometimes numerically [3-15]. These studies still have gaps in investigating the effects of storms on structures on sloping lands when the storm hits the structure. Therefore, the purpose of this study is to provide an efficient simulation of a microburst and its effects on the pressure distribution and the forces acting on a standard cubic structure. Also, changes in wind force due to changes in the impact angle of the surface flow concerning the structure and the ground slope will be another important goal of this research.

2- Methodology

In this research, a blower with a nozzle diameter (D) of 0.2m has been used to simulate the flow of a downburst. The reference velocity of outflow from the blower is equal to 12m/s. The velocity and the flow turbulence intensity were measured at the blower outlet and by a rake. A hotwire was used to measure the flow velocity. Also, a series of pressure sensors are used to measure pressure and forces acting on the model surfaces. To investigate the effects of the downburst, the cube-shaped model is placed on a test plate in front of the blower airflow. The test plate is located at four different angles with respect to the jet flow direction (θ). In addition, the model is placed in two directions of zero and 45 degrees relative to the surface flow (α). Also, in all cases, the model is placed in five different radial locations relative to the center of the nozzle (X/D) and examined. Fig. 1 shows a schematic view of this laboratory system.

3- Results and Discussion

To better understand the flow of the downburst, the blower is set at three different speeds (10, 12, and 14 meters per second), and the velocity profile is measured parallel to the nozzle and the ground. These data were measured in the range of $0.6 \pm D$ and at three different intervals ($0D$, $0.5D$, $1D$). These results showed that the storm, with increasing distance from the nozzle, was slightly dispersed, and its core did not

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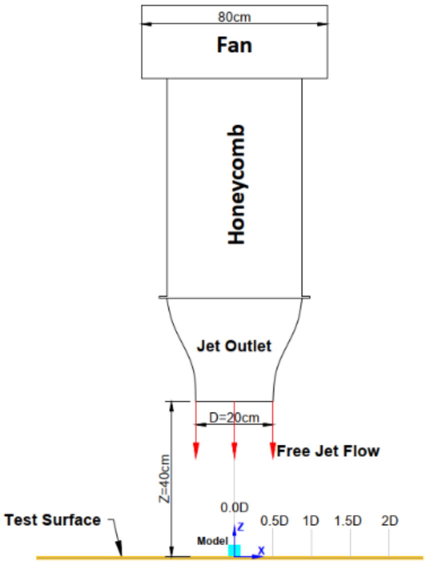

Fig. 1. Laboratory system's schematic top view

weaken. Also, in a study of the characteristics of downburst flows near the surface and at three different speeds, it was found that the maximum value of flow velocity occurs in the height range of the model and at *X/D*=1. The least amount of flow turbulence occurs at *X/D*=1 and in the height range of the cube-shaped model. Also, the output flow velocity changes did not change the storm behavior, indicating this flow's behavioral stability at these three different velocities. Fig. 2 shows a graph of the flow velocity near the surface at an output velocity of 12m/s.

In the study obtained from the pressure distribution on the sides of the model, it was found that all sides of the model are subjected to intense and uniform pressure at the central point of flow (*X/D*=0). However, at *X/D*>0.5, the pressure difference between the windward and the other sides of the cube becomes much more remarkable. In addition, it can be seen that the roof of the model has more negative pressure than the leeward.

Also, with increasing flow angle (θ), the pressure difference between the windward, with the roof pressure, and the leeward, increases even at the storm's center. The maximum force in the *X* direction was applied to the model at *X/D*=1, and in the *Z* direction, it also occurred at the center of the downburst. In addition, it can be seen that placing the model at α=45˚ reduces the force on the model relative to the direction α=0˚. Fig. 3 shows the force coefficient in the *X* direction at α=0˚.

4- Conclusions

In this research, the effects of the angle of the cube-shaped model on the downburst flow and the effect of the slope of the surface on the flow have been investigated in a laboratory. Also, to better understand this storm, the velocity profile of this flow has been measured at different speeds and places. By measuring the velocity profile of the outlet at different distances, it was found that this flow, apart from its fall velocity value, has a high uniformity. These results also show that the maximum amount of flow velocity occurs near the wall and in the height range of the model. It is positioning the model in the impact direction of α=45° causes the interval of pressure changes on the model to be less than the α=0° direction, which causes the pressure difference on different sides of the model to be less than each other. Increasing the angle θ has increased the pressure difference between the windward with the roof and the leeward. This can be seen even at the center of the downburst and can put the flowing sides of the structures in a more critical condition.

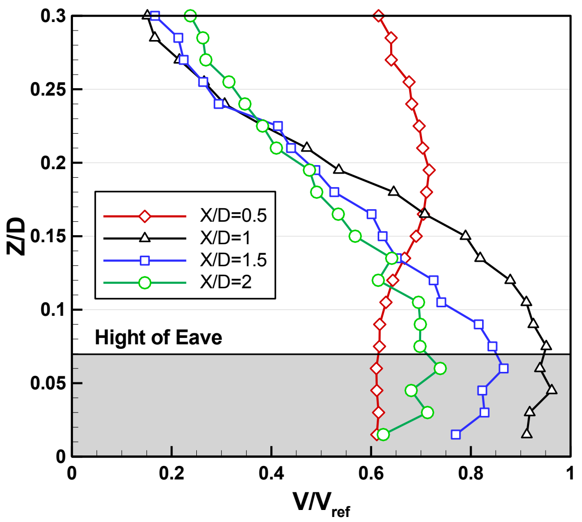

Fig. 2. Velocity and turbulence intensity of different X/Ds at 12 m/s

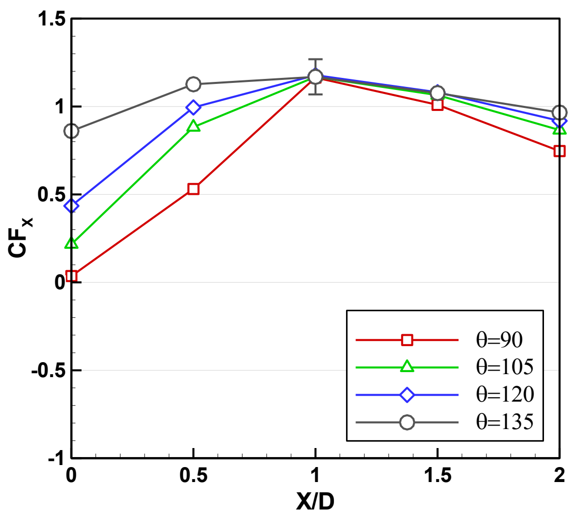

Fig. 3. Comparison of force coefficient in the X direction at α=0˚

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HOW TO CITE THIS ARTICLE

M. Hojaji, N. Asgari, S. J. Hosseini, A. H. Rezvani, B. Sharifzade, Experimental Study of Impact Angle of Microburst Effects on a Cubic Structure – Part A: Stationary Microburst Observation, Amirkabir J. Mech Eng., 54(5) (2022) 201-204.

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