THE FINITE ELEMENT ASSESSMENT OF WIND AT HIGH SPEED ACTING ON A HOUSE STRUCTURE

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Abstract. In this paper we analyzed the wind impact on a typical house with the help of finite element method programs. During a hurricane, wind forces are carried from the roof down to the exterior walls, down to the foundation. The buildings can be damaged when wind forces are not properly transferred to the ground. In the houses durability study there were found the areas that should be checked for weakness such as windows, doors, the roof, the garage door. The real model of a house was build and then we simulated the wind at a top speed of 140 km/h. In this simulation we identified the areas that were the most affected by the wind forces.
Keywords: wind, house, finite element method, air pressure, experimental model, simulation.

1. INTRODUCTION

Houses may be damaged or destroyed by high winds during severe thunderstorms or hurricanes. Debris flying through the air can break windows and doors, allowing high winds inside the house. In extreme wind storms, the force of the wind alone can cause the failure of houses weak places. Air conditioners, storage sheds, fences, trees are items susceptible to wind around the house, items like lawn furniture, portable spas, and trampolines are backyard items susceptible to wind, and awnings, gutters, shutters, patio covers, television antennas, chimneys, siding and windows are items susceptible to wind on the house.

Certain building configurations are more likely to sustain wind damage. In general, the higher the building, the more it is exposed to the wind and the greater it's its potential for damage. Houses not anchored properly can also slide off their foundations at relatively low wind speeds. Houses with attached garages sustain greater wind damage when the garage doors fail inward allowing wind pressure to lift the garage roof or push the garage walls outward. High profile gable roofs are more prone to wind damage than low profile hip roofs.

Wind interacting with a house is deflected over and around it. Inward pressure is applied to the windward walls and outward pressure is applied to side and leeward walls. Uplift pressure is applied to the roof especially along windward eaves, roof corners, and leeward ridges. The roof is particularly susceptible to wind damage since it is the highest building component above the ground. If the building is breached, wind enters creating internal pressures that can lift off the roof. Thus, damage caused to a house by wind typically begins at roof level and progresses downward and inward. The last place where wind damage occurs is the house interior. A house catastrophic damage consists of the failure of wall/foundation connections or roof/wall connections. Therefore it is important to examine these critical areas on a building. Roof systems typically are held in place by gravity. Thus, minimal attention is given to wind uplift effects. Typically, the rafters or trusses are toe nailed to the wall top plates and this type of connection will meet most building codes. However, this connection is inherently weak when uplifted. Rafters or trusses will break away from the top plates. It is less common for the top plates to separate. Metal straps or clips can secure all of these members together.

2. EXPERIMENTAL MODEL

The experimental model for the simulation was built in CAD program using as-built dimensions of a real house from our city. The property is composed of a house with balcony and canopy, a car garage and a surrounding fence. The model is presented in Figure 1 and Figure 2 and the dimensions are shown in Table 1.

Initial Conditions. The model was transferred into a program using finite element method for the simulation. Because winds can tear the roofs from buildings and throw debris through windows we run an analysis with the wind maximum speed encountered in our region.

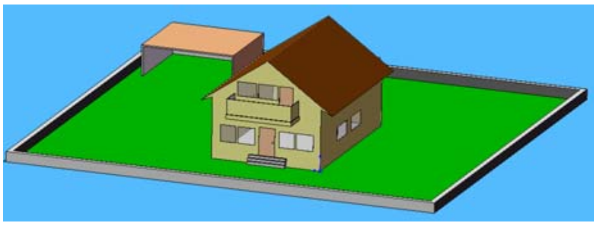

Fig. 1. Front view of the model.

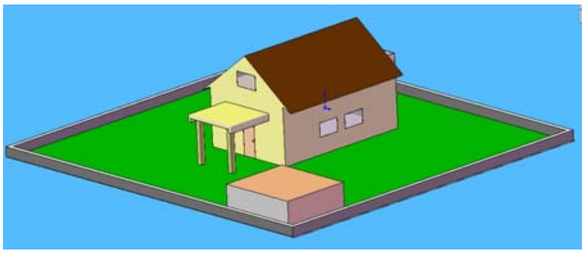

Fig. 2. Back view of the model.

Table 1. **Model dimension**

Component parts	Length [m]	Width [m]	Height [m]
House	15	10	11
Fence	40	38	1
Garage	7	8	3
Balcony	6	2	1,2
Steers	3,5	0,5	0,8
Rear canopy	6	4,9	0,4
Supporting pole	0.5	0.5	4,5

In simulation we put the following initial conditions:

– wind speed of 140 km/h;
– air temperature of 20^{o}C;
– ambient pressure.

3. SIMULATION OF WIND WITH FINITE ELEMENT PROGRAM

The real simulation of a house in wind tunnels are too expensive and the easiest way to provide information about the flow is to use a computational fluid dynamics (CFD) method in order to simulate the air flow of a three dimensional objects. In fact the simulation provides more information about the flow that the test in a real wind tunnel.

The results obtained during the simulation are presented in the diagrams in Figures 3-14.

4. RESULTS INTERPRETATION

The simulation proved that the wind acting on a building roof surfaces could cause negative pressures tending to create a lifting force. This is one of the most common ways a building can be destroyed during a storm. Gravity alone may not be sufficient to prevent the roof lifting off the rest of the building. Once this occurs, the building is weakened considerably and the rest of the building will likely fail as well.

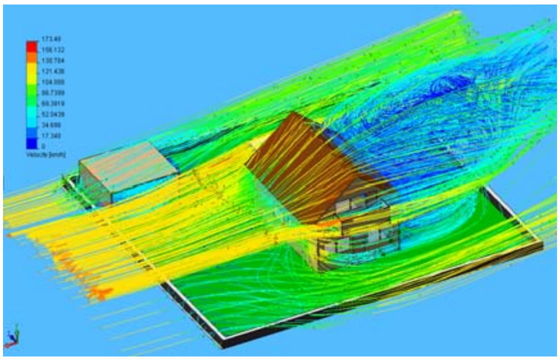

Fig.. 3. Front view of the velocity plot.

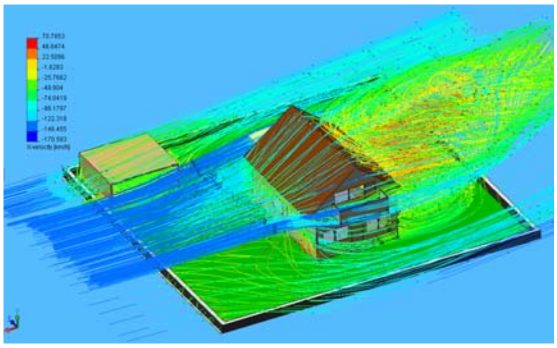

Fig. 4. Back view of the velocity plot.

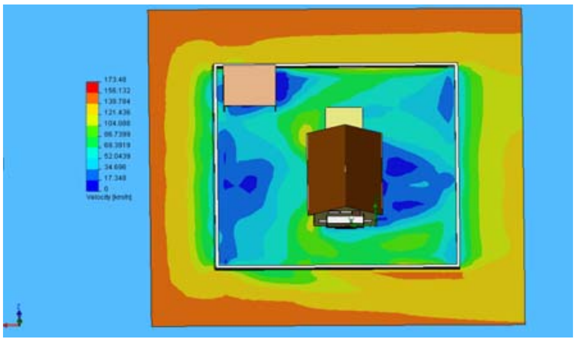

Fig. 5. Top view of the velocity plot.

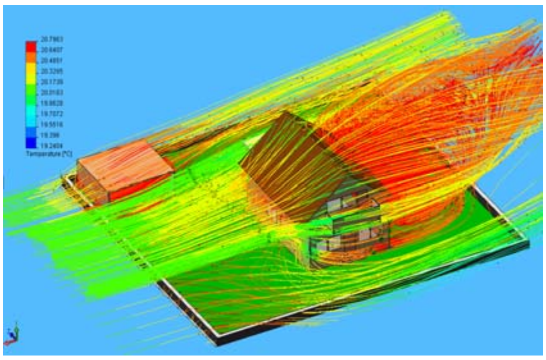

Fig. 6. Front view of the temperature plot.

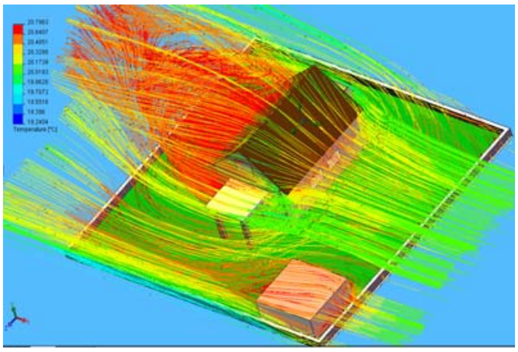

Fig. 7. Back view of the temperature plot.

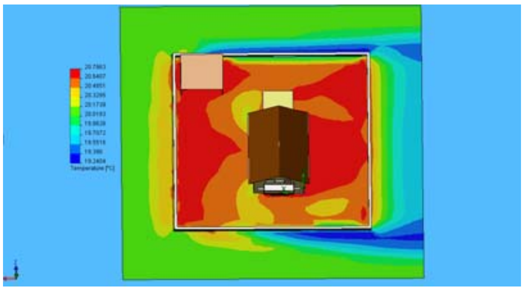

Fig. 8. Top view of the temperature plot.

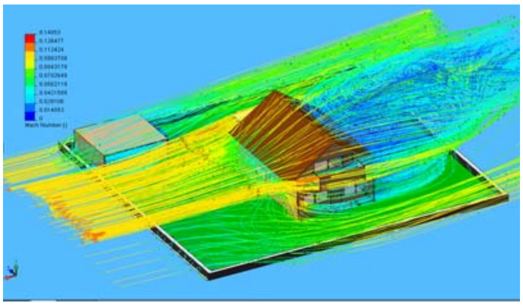

Fig. 9. Front view of the Mach Number plot.

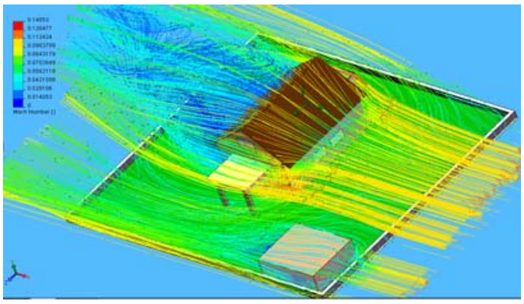

Fig. 10. Back view of the Mach Number plot.

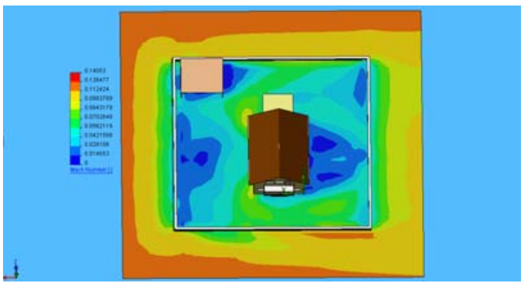

Fig. 11. Top view of the Mach Number plot.

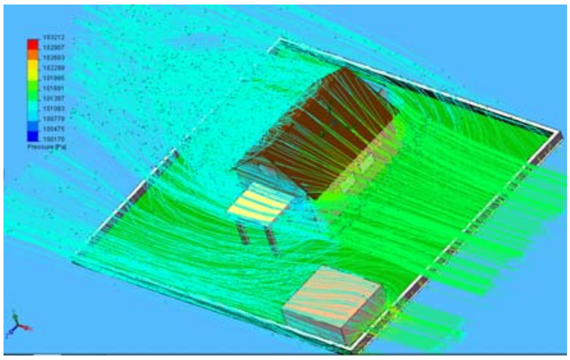

Fig. 12. Back view of the Pressure plot..

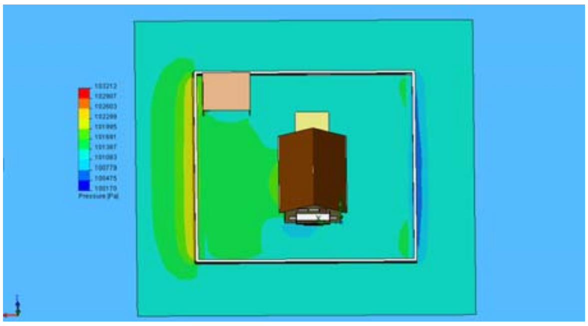

Fig. 13. Top view of the Pressure plot.

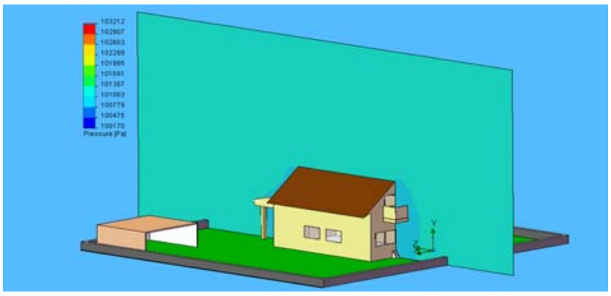

Fig. 14. Lateral plan view of the Pressure plot.

The simulation gave us information about the areas that are most exposed to the wind loads. The velocity plot shows that the wind had the maximum value on the corner of the house and canopy and the lowest value behind the house, fence and garage. The wind's velocity exerted pressure also on objects in its path. In Table 2 and 3 the values for the left wall of the house on the wind direction are presented.

5. CONCLUSION

Evaluating a house for wind loads involved careful examination of the building components. This paper presented a method to examine the wind loads on a typical house using a finite element method program.

The simulation showed the areas affected during events with high winds. Wind interaction with a house was deflected over and around it. Inward pressure was applied to the windward walls and outward pressure was applied to side and leeward walls.

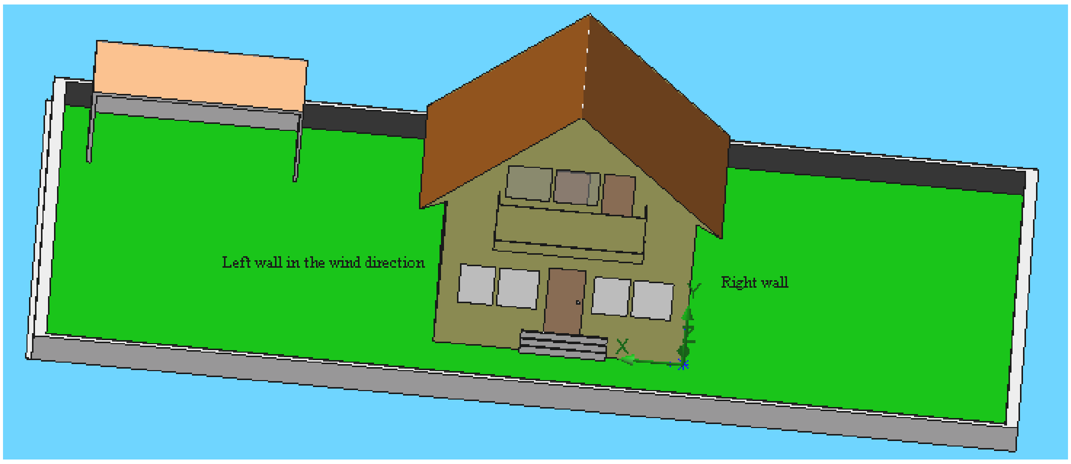

Fig. 15. Wall positioning on the house.

Table 2. **Integral parameters for the left wall**

Parameter	Value	X-component	Y-component	Z-component	Surface Area [m^2]
Normal Force [N]	50727,2	-50689,9	1905,33	-393,174	82,1735
Shear Force [N]	63,3153	-2,13394	-63,26	-1,56483	82,1735
Force [N]	50727	-50692	1842,07	-394,739	82,1735
Torque [N*m]	431792	-14422,5	-382420	199979	82,1735
Surface Area [m^2]	82,1735	76,8835	-0,17466	-0,783505	82,1735
Torque of Normal Force [N*m]	432108	-14888	-382434	200598	82,1735

Table 3. **Local parameters for the left wall**

Parameter	Min.	Max.	Average	Bulk average	Surface Area [m^2]
Pressure [Pa]	100603	102371	101987	101988	82,1735
Temperature [°C]	20,5916	20,7465	20,6831	20,6831	82,1735
Density [kg/m^3]	1,19417	1,21323	1,20954	1,20955	82,1735
Shear Stress [Pa]	1,92863E-08	4,17457	1,19991	1,1999	82,1735
Temperature [°C]	20,5916	20,7465	20,6831	20,6831	82,1735

Uplift pressure was applied to the roof especially along windward eaves, roof corners, and leeward ridges. The roof is particularly susceptible to wind damage since it is the highest building component above the ground.

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