Simulation Techniques of fluid dynamic Pressure on hip-roof building

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Abstract

Simulation work done on low-level hip roof builds, using various computational fluid dynamics procedures (CFD). For inflow borders, boundary states, near to the wall handling, and so forth, the virtual data in the Wind Tunnel was used for the CFD investigation. In this section too, I can find brief information concerning experimental work by Shakeel et al on a related house.

The effect of such louvers on the wind induced roof loads has not been investigated; therefore, it is of great interest to assess their contribution on the wind loads on a building roof. This paper presents results from an experimental study to assess the wind loads on a hip roof building through large scale model testing.
A comprehensive numerical study of wind effects using Computational Fluid Dynamics (CFD) techniques on the low-rise hipped roof building is presented in this paper. To predict the wind loads and the flow patterns around the hip-roof building. The computed wind pressure co-efficients on the roof of the hip-roof buildings were compared with the wind-tunnel data. I was also found that the CFD techniques are an effective and alternative tool, less time consuming, easy-to-handle, as well as low cost approach for evaluation of wind effects in comparison to wind-tunnel experiments, The study effectiveness of the vents with louvers' in reducing wind induced net mean pressure co-efficient on the building roof. Future research performing to the effect of 'louvered vents' on the wind loads on a building roof must be carried out on other roof configurations.

Keywords: *Computational Fluid Dynamics, Wind force, Hip-roof building, Low-rise building, Wind Engineering, Simulation*

1. Introduction

The building roof is one of the most vulnerable building elements to wind induced damage during a hurricane. It is common practice in buildings to be fitted with 'vents with louvers' that have the mechanism to automatically close during high wind speeds (> 10 m/s) in order to prevent entry of water, while remaining open at all other times

A hip-roof, or hipped roof is a type of roof where all sides slope downwards to the walls, usually with a fairly gentle slope. Thus, it is a house with no gables or other vertical sides to the roof. Hip roofs are thus commonly seen in places of heavy wind such as in hilly regions, coastal regions so on. They are subjected to drag forces. Corners receive a relatively large outward pressure. A flat roof experiences an outward pressure or uplift, in addition to drag forces. The pressure on a pitched roof varies depending on different factors such as the slope of the roof and the building dimensions. Eaves and overhangs are affected by entrapped wind underneath them which leads to a pressure stagnation on them.

Wind flow is turbulent in nature and consists of many complex flow patterns. The field of wind engineering generally comes across with these types of flows. Wind pressures on buildings and structures depend upon the velocity profile and turbulence characteristics of the upcoming wind. These factors in turn depend on the roughness and general conformation of the upstream terrain. Wind loads generally govern the lateral strength of a building and this aspect is more evident in areas of severe wind carried out wind-tunnel tests on the models of hip-roof building on a scale of 1:50 (prototype dimension 14 m x 7 m x 2.9 m eave height) with pitch 15^o, 20^o, 30^o and studied the wind pressures on the roof. The highest peak suction at the corner was experienced with a slope of 30^o

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The worst peak suctions are much smaller on the hip-roof than on the gable roof for 15^o and 20^o roof pitches. A wind-tunnel study of the effect of geometry of hip-roof building on wind pressures on low-rise hip-roof buildings were also carried out by Shakeel et al (S. Ahmad *et al*, 2002) taking the same dimensions of the models. He concluded that variation of overhang ratio (0.17, 0.26 and 0.38) on the hip roof with 30^o roof pitch have shown moderate effects on roof pressures. Both the overhang and aspect ratio were found to influence the magnitude and distribution of pressures on the hip- roof.

The pressure taps on the overhang portions, corner regions and sharp edges of the hip-roof building in their wind-tunnel experiments. This may be due to practical difficulty in placing and fixing of pressure taps in the overhang and ridge portions. The pressure coefficients measured were either extrapolated or interpolated in those regions. So, it is not always possible to plot the exact values of pressure coefficients in all regions using wind-tunnel data. The above discrepancies in the determination of pressure coefficients on the hip-roof building can be resolved by using computational fluid dynamics techniques.

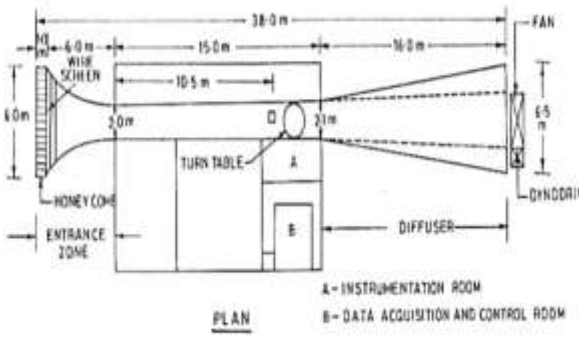
Nowadays, Computational Wind Engineering as a branch of CFD is rapidly superseding (CWE) experimental work to evaluate the interaction between wind and structures numerically offering an alternative technique to practical applications. Earlier the fundamental errors in the numerical modeling of the turbulent component of fluid flow were one of the main reasons why CFD techniques had not been fully accepted by the Wind Engineering community. But, an improved understanding now exists for the development of large suctions near leading roof edges and roof corners; the modeling of these phenomena in the wind-tunnel remains a problem. Development of improved turbulence models like LK (Launder and Kato), MMK (Murakami, Mochida and Kondo) predicted value of turbulent viscosity ratios much closer to the real values of fully developed turbulent flows for evaluation of building performance, presented the development process and results of several research projects for applying computational fluid dynamics (CFD) to architectural design. The purpose behind these works was to validate the numerical modeling and understand the interference effects of surrounding groups of buildings. A brief overview of the status of the application of CFD in building performance simulation for the outdoor environment. Concluding that CFD offers some considerable advantages compared to wind tunnel testing and simplified empirical or semi-empirical equations, its practical application in at least wind driven rain, convective heat and mass transfer. These studies indicate that the upstream buildings play a significant role on wind loads and flow pattern around the test building in straight-line winds.

Design engineers usually determine wind loads with reference to the pressure coefficients from the code of practice, which in turn are based on data from the boundary layer wind tunnels. Actual field situations are not always treated in these codes, making wind-tunnel tests necessary to determine the wind loads. As detailed wind pressure coefficients on hip roof buildings are missing in most of the international codes including IS: 875-part 3 (1987) for the purpose of design. Therefore, an extensive research is needed to evaluate pressure coefficients on hip-roof building considering various building parameters and different terrain conditions.

2. Experimental Work

The test section was 15 meters long. In addition to a square holed honeycomb at the passage (6mx6m), the circular effuser profile with a 9.5:1 constriction ratio helps create a smooth flow in the test section. The unbending model to be examined was placed 12 m downstream of the effuser at a physically operated turntable. Wind tunnel with custom roofing support with zero pressure gradient has also been fitted. In order to enhance speed estimates at different points, the wind tunnel was equipped with a remote operated crossing system for Pitot tube and hot wire experiments.

TTU models were reduced to a scale of 1:50, with different roof pitches from 10 ° to 40 °, rising by 5 ° in the hip roof construction models used for testing by Dr. Shakeel Ahmad. The roof and walls of the hip roof versions were equipped with 37 pressure taps. This experiment was carried out at the Boundary Layer Wind Tunnel of Figure 2.1



Computational Domain with Strategies of Solution

In the current study, a hip-roof model with different roofing pitches, overhang ratios and aspect ratios has been studied for the effect of measurement differences on pressure coefficients. The idea is essentially that a hip roof construction model of low-capacity with dimensions 14m x 7m with 2.9m of axis with a surplus height of 1.1m would decrease at 1:50 geometrical ratio. In the range 1.25 bis105 to 2.22 bis105 the numbers of Reynolds participating in the simulation is equal to those of Shakeel et al. in the wind tunnel experior. In a stream X path [-6.5 <([/ <22.5] 9L sideway or regular (Z) direction [-4.5, (z/B)<4.5] and 4 H vertical direction (Y) the computational domain covers 29 B (b is usually the duration of the model in the wind movement including overhills). The percentages of inspections were 1.93 and 2.22 for wind attack angles of 90° and 0° for each hip-roof model, for 30° pitch roofs, which are not quite the highest 3% of disruptive pressure needed for big wind tunnel models. In fact, the reason for a judgment is that the flow obstacle effect is exempt from influx and outflow limits.

The data used for numerical simulation were taken from the experimental study on the hip-roof building and the data used by them is also shown in Table 2.1

Table 2.1

S. No	Parameters	Value from wind-tunnel data of	
1.	Mean Wind Speed	10.8 m/s	10.2 m/s
2.	Power Law Coefficient (α)	0.15	00.14
3.	Roughness Length (Z)	10-11mm	10mm
4.	Longitudinal Turbulence Intensity	18%	20%
5.	Integral length scale	0.45m	0.8m

In order to obtain the better agreement between experimental and numerical results, the boundary conditions adopted in the numerical simulations should be the same as those in the experiments, especially for inflow boundary conditions. Therefore, the inflow boundary conditions and other parameters from the experimental study. The friction velocity ($_{u}$=0 .5, 6 -7 m / s) and ground roughness length (10-11 mm) were derived from the wind profile obtained from wind-tunnel experiments. The log law velocity profile has been simulated for the inlet boundary conditions for the CFD analysis from the simulated atmospheric boundary layer in the wind tunnel study. The inlet wind profile is shown in the Fig. 2.2 The mean longitudinal wind speed profile measured in the wind tunnel is in good agreement with full-scale profile with a power-law exponent of 0.15

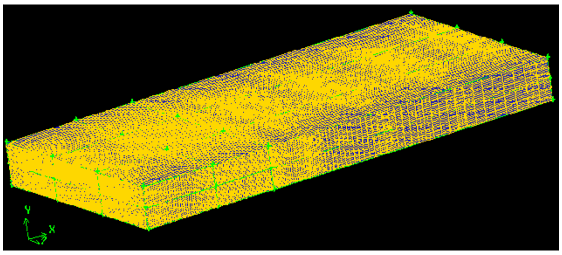


Figure 2.2 **Arrangement of Mesh for entire computational domain**

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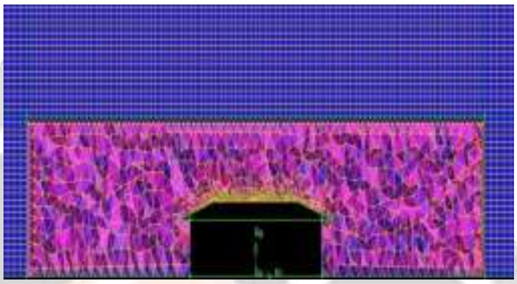

Figure 2.3 **Arrangement of Mesh parallel to the flow of the wind based on the near the building in the plane at mid length of the building**

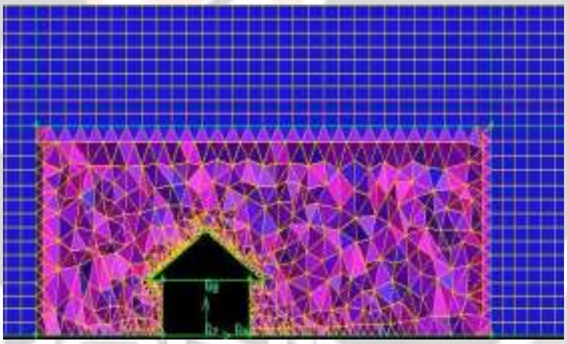

Figure 2.4 **Arrangement of Mesh perpendicular to the flow of the wind near the building in the plane at mid length of the building**

Various mesh plans for grid dependency were developed and simulated. Denser meshes have been provided in all mesh plans near the wall and the mesh becomes less popular as we disappear from the wall surface and, in each of the models, the value of the wall unit y is the same. The standard wall functions have been used and Y+ values have been kept in the 30-120 range for all of the designs. The mesh order used is actually 107 for both models and it is essential that the extremely fine network requirements be maintained to determine the large energy dissipation gradients in the near wall region and therefore decrease. The mesh action paths of the hip-roof model are seen in Figures 2.2, 2.3 and 2.4 Gambit 2.6 was used for manufacturing and mapping simulation

VALIDATION FROM THE PAST RESULTS

In order to achieve a different pressure coefficient value (for example 0°, 15°, 30°, 45°, 60, 75° and 90°), the results are contraposed and Shakeel and al and Xu and others (which is available only for a 0°, 45° and 90° in the wind tunnel) have been provided with a wide range of wind pressure ranges (as the norm is 0˚, 45° and 90°).). Wind turbulence simulations are used for the prescribed RANS. The angle of wind incidence varies in the construction of hip roofs building can be seen in Figure 2.5. The comparison of pressure coefficients values (of 0°, 45° and 90° wind incidence) obtained from the CFD methods and details on the wind tunnel

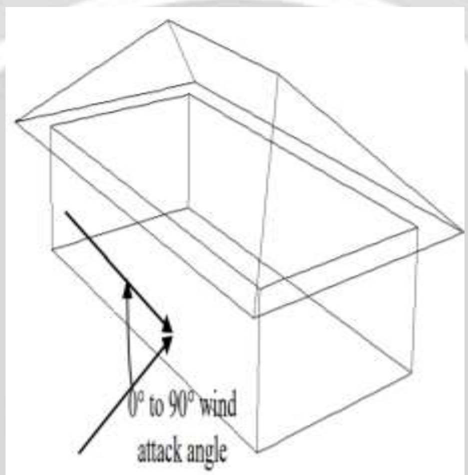

Figure 2.5 **Wind Attack Angle Changes from 0° to 90° on hip-roof building**

3. Advantages of a Hip Roof building

The main advantage of a hip roof comes down to the shape of the structure. All aspects of the construction are suited to deal with adverse weather conditions, including rain, snow and wind. Firstly, the self-bracing nature of a hip roof means there is little need for extra support. Moreover, the sloping sides of the roof mean there is no flat surface to catch the wind, which can cause issues for gabled roofs, for example. Gabled roofs are liable to catching the wind, leading to extensive damage. Steeper sides may be advisable in hurricane regions, as shallow sides can act as a plane-wing does and cause upward lift, tearing the roof from a building.

The largest benefit of a hip roof comes down to the drainage that is created from having all sides sloping toward the ground. There are no places for water to stand on a gable roof, which helps to prevent excess stress on the structure and reduces the prominence of leaks. This prevention of standing is, arguably, accentuated when considering snowfall that can build up and create large stress on a roof if the runoff is not adequate. Luckily, this is certainly the case with hip roofs.

4. Disadvantages of a Hip Roof building

Generally speaking, the main issue that arises in people's minds when talking of hip roofs is the increased cost in comparison to a gabled roof. Due to the extra materials and more complex structure of this type of roof, there is some increase in cost that has to be taken into consideration, although it is not a great deal more expensive than other roofs.

The increased number of seams, due to the need for more ridges, leads to a pronounced risk of leaks. This can, however, be avoided with proper maintenance but it is something that should be addressed in the conversation for and against a hip roof. In conclusion, the choice of roof that is right for you truly comes down to personal preference and the predicament you find yourself in; which could be financial, environmental or otherwise. However, it's important to remember that almost all issues can be prevented with proper maintenance and swiftly rectifying any issues you spot. That's said, a hip roof is a classic choice for a reason.

5.Types of hip roof building

Mansard roof

Mansard roof

A *mansard roof* is a variation on a hip roof, with two different roof angles, the lower one much steeper than the upper.

Tented roof

A *tented roof* is a type of polygonal hipped roof with steeply pitched slopes rising to a peak or intersection.

Gablet roof or Dutch gable

Gablet roof

Another variation is the *gablet* (UK terminology) or *Dutch gable* roof (U.S. and Australasian terminology), which has a hip with a small gable above it. This type simplifies the construction of the roof; no girder trusses are required, but it still has level walls and consistent eaves.

Half-hip roof

A *half-hip*, *clipped-gable* or *jerkin head* roof has a gable, but the upper point of the gable is replaced by a small hip, squaring off the top of the gable. The lower edge of the half-hip may have a gutter which leads back on to the remainder of the roof on one or both sides. Both the gablet roof and the half-hipped roof are intermediate between the gabled and fully hipped types: the gablet roof has a gable above a hip, while a half-hipped roof has a hip above a gable.

Half-hipped roofs are very common in England, Denmark, Germany and especially in Austria and Slovenia. They are also typical of traditional timber frame buildings in the Wealden area of South East England.

Half hip roofs are sometimes referred to as "Dutch hip", but this term is easily confused with "Dutch gable".

Pavilion roof

A hip roof on a square structure typically found topping gazebos and other pavilion structures, also known as a pyramid roof.

Rhenish helm or Helm roo

A pointed roof seen on a spire or a tower, oriented so that it has four gable ends. See the Church of St Mary the Blessed Virgin, Sompting in England, or Speyer Cathedral and Limburg Cathedral in Germa

6. CONCLUSIONS

Hurricanes involving high wind speeds can damage the roof of a building. Soffit louvered vents that can close automatically during high wind speeds (> 10 m/s) and remain open at all other times are commonly used in many buildings in Florida. The roof of a building is generally the most vulnerable building element to wind induced damage due to hurricanes. Limited information on the safe design of roofs fitted with these louvered vents, makes it necessary to carry out research on the effect of these louvered vents on the wind loads on the building roof. This paper presents results from an experimental study carried out at the FIU WOW on a gable roof and a hip roof building for wind directions ranging from 0 to 90 degrees. Mean and peak pressure coefficients were measured for wind directions ranging from 0 to 90 degrees, on the exterior and interior roof surfaces of both the buildings. Two different cases were considered for this study: soffit vents without louvers (Case 1) and soffit vents with louvers (Case 2). The mean pressure coefficient measured on the interior roof surface of the hip roof building was found to be positive in Case 1 (0 to 0.07) and negative (suction) in Case 2 (-0.12 to -0.24), especially at a wind direction of 45 degrees. This indicates that the presence of the soffit vent with louver (Case 2) increases internal suction, thereby having a relaxing effect on the roof lift off. The net mean pressure coefficients on the roof surface for both the buildings were lower (less suction) in Case 2 than in Case 1. For both the buildings at any given wind direction, the area averaged external WOW peak pressure coefficients do not change markedly for both the cases. Discrepancy in the area averaged external peak pressure coefficient from ASCE 7-10 and WOW data were obtained for the hip and gable roof buildings. This study shows the effectiveness of the ‘vents with louvers’ in reducing net mean pressures on the roof. Future research is needed for other roof configurations to study the effects of ‘vents with louvers’ on the safe design of building roofs.

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