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ORIGINAL ARTICLE

Variation of wind load distribution on gable roof building

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Abstract

Wind forces and their impact on the structural integrity of roofs and walls are pivotal considerations in architectural and engineering design. This study discusses the effect of wind load on gable roof buildings with varying slopes. Gable roof structures find extensive application in industrial construction projects. Based on wind tunnels with rigid models, wind pressure distributions on gable roof buildings with different aspect ratios were measured simultaneously. Special attention is required for the safe design of the building. Information regarding the wind pressure coefficients on buildings is available in codes of practices of various countries dealing with wind loads; however, such information is very limited.

The present study will examine the suitability of four building models with roof angles of 10º, 15º, 20º, and 25º and will be analyzed using IS 875 (Part 3), and various forces will be calculated. Then, the same buildings will be modeled using STAAD-Pro/SAP2000, and the comparison of the analysis will be made. Further, a building situated at various slopes on a hill will be modeled using STAAD-Pro/SAP2000, and the variation of Wind Forces along the slope will be studied.

The expected results of this study will be finding out the most critical slope of a gable roof on a building and reducing the effect of wind forces on it. Furthermore, the most savior location of a building along the hill slope will be investigated, and the ways to reduce the effect of these wind forces will be studied.

1. Introduction

Gable roof structures find extensive application in industrial construction projects. Based on wind tunnels with rigid models, wind pressure distributions on gable roof buildings with different aspect ratios were measured simultaneously. Ensuring a safe building design demands particular attention and care [1-3]. Information regarding the wind pressure coefficients on buildings is available in codes of practices of various countries dealing with wind loads; however, such information is very limited. Efforts of several researchers have been focused on the determination of wind loads in typical low-rise buildings [4, 5]. A large number of various architectural features are involved in low-rise buildings. Architectural features like the length-width ratio of the building, boundary wall, etc, can modify wind flow patterns in and around the buildings and affect the wind loads on buildings. This area of study continues to have a significant scope for investigation. Wind pressure in low-rise buildings with gable roofs under isolated conditions is determined using wind Codes [6]. However, wind tunnel investigations continue to be a vital tool to investigate the pressure on standard types of gable/hip roofs. Further, to cover up the limitation of Codal practice for the influence of interference of neighboring

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building(s), objects, and the boundary wall, the wind tunnel plays a vital role [7-9].
The survey of wind damage demonstrates that the destruction or collapse of low-rise buildings mainly causes the loss. At the same time, most of the destruction of low-rise buildings results from the failure of the roof structure. Therefore, it is significant to study wind pressure characteristics on the roofs of low-rise buildings. Large numbers of tests are carried out in academia for this purpose.

2. Objective

- To study the various design codes required in analysis of wind forces on abuilding.
- To study the effect of Wind forces on various slope angles of a roof.
- To study the effect of Wind forces on a building situated at different heights (slopes) along a hill at two different cities. (Shimla & Almora).
- Comparison of the analysis both manually and by using software (STAAD-Pro).

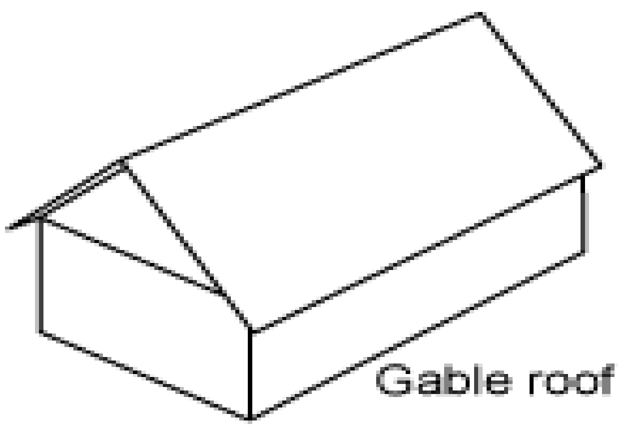

Figure 1: Schematic diagram of Gable roof

3. Methodology

The present study will examine the suitability of the current wind provisions of the Indianstandard code IS 875 (Part 3) & SP-64 for design wind load on gable roof of intermediate roof angles (10º-25º). The study is initiated by the discrepancies found in recent research projects again the current design wind loading provisions for such roofs.

3.1 Calculation of wind pressure (is-875 part 3)

Step 1. Design Wind Speed (V_Z) (IS:875 Part-3, Sec 5.3).

The basic wind speed, V_b corresponds to certain reference conditions. Hence, to account for various effects governing the design wind speed in any terrain condition, modifications in the form of factors k_1, k_2, k_3, and k_4 are specified. The basic wind speed for any site shall be obtained from Fig.1 and shall be modified to include the following effects to get design wind speed, Vz at any height, Z for the chosen structure: (a) Risk level, (b) Terrain roughness and height of structure, (c) Local topography, and (d) Importance factor for the cyclonic region. It can be mathematically expressed as follows:

$$V_z = V_b .k_1 .k_2 .k_3$$

Where

V_b = basic wind speed
V_z = design wind speed at any height z in m/s
K_1 = probability factor (risk co-efficient) (IS:875 Part-3,Table 1)
K_2 = terrain roughness and height factor (IS:875 Part-3, Table 2)
K_3 = topography factor (IS:875 Part-3, Sec 5.3.3)

Step 2. Design Wind Pressure (P_z)

The wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind speed:

$$P_z = 0.6 V^2_z$$

Where

P_z = wind pressure in N/m^2 at height z and
V_z = design wind speed in m/s at height z
The design wind pressure P_d can be obtained as,

$$P_d = K_d K_a K_c P_z$$

Where

K_d = wind directionality factor
K_a = area averaging factor
K_c = combination factor

Step 3. Wind Load Calculation (IS:875 Part-3, Sec 6.2.1).

When calculating the wind load on individual structural elements such as roofs and walls, and individual cladding units and their fittings, it is essential to take account of the pressure difference between opposite faces of such elements or units. For clad structures, it is, therefore, necessary to know the internal pressure as well as the external pressure. Then the wind load, F, acting in a direction normal to the individual structural element or cladding unit is:

$$F = (C_{pe} – C_{pi}) A P_d$$

Where

F = wind load
C_{pe} = external pressure coefficient
C_{pi} = internal pressure coefficient
A = surface is of structural element or cladding
P_d = design wind pressure

Step 4. Estimation of Frictional Drag (*F′*) (IS:875 Part-3, Sec 6.3.1)

A force due to frictional drag shall be taken into account in addition to those loads specified in 6.2 (IS:875 Part-3, Sec 6.2). For rectangular clad buildings, this addition is necessary only where the ratio d/h or d/b is greater than 4. The frictional drag force, *F′*, in the direction of wind is given by the following formulae:

$H<b\ F'=C'_f(d-4h)b.p_d+C'_f(d-4h)\ 2h.p_d$
$H<b\ F'=C'_f(d-4b)b.p_d+C'_f(d-4b)\ 2h.p_d$

Values of C'_f are given in (IS:875 Part-3, Sec 6.3.1) for different surfaces.
C_f' = 0.01 for smooth surfaces without corrugations or ribs across the wind direction,
C_f' = 0.02 for surfaces with corrugations or ribs across the wind direction,
C_f' = 0.04 for surfaces with ribs across the wind direction.

4. Results and discussion

After the analysis of the given gable roof and applying the IS code provisions for Manual calculating the wind pressure the following results were obtained: For different roof angle

1. Total Frictional Drag on gable roof of roof angle 10º is 1682.95 N/m^2
2. Total Frictional Drag on gable roof of roof angle 15º is 1991.05 N/m^2
3. Total Frictional Drag on gable roof of roof angle 20º is 2202.563 N/m^2
4. Total Frictional Drag on gable roof of roof angle 25º is 2366.639 N/m^2

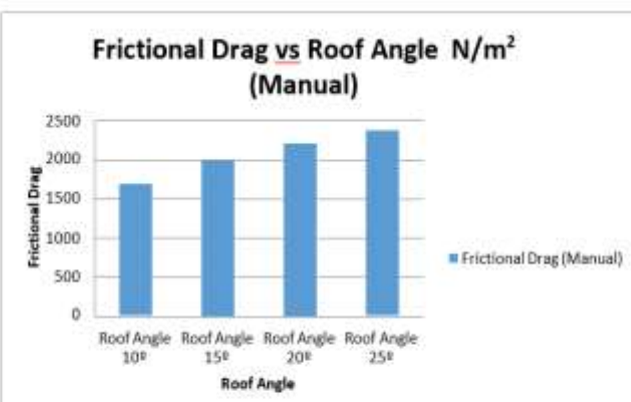

Figure 1: Frictional Drag of different roof angle after manual calculation

After the analysis of the given gable roof with Software (STAAD-Pro) and the wind pressure the following results were obtained: (For different roof angle)

5. Conclusions

1. Total Frictional Drag on gable roof of roof angle 10º is 1503.66 N/m^2
2. Total Frictional Drag on gable roof of roof angle 15º is 1794.216 N/m^2
3. Total Frictional Drag on gable roof of roof angle 20º is 2021.351 N/m^2
4. Total Frictional Drag on gable roof of roof angle 25º is 2183.213 N/m^2

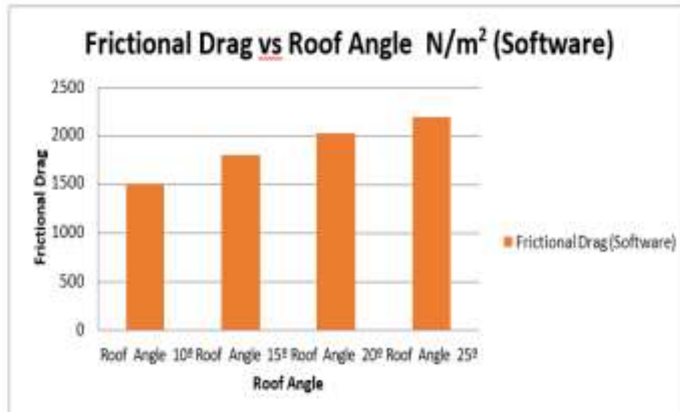

Figure 2: Frictional Drag of different roof angle after software (STAAD-Pro)

4.1 Comparison of Result. (For different roof angle)

After the analysis of buildings having different roof slopes, the following observations were made:

Table 1: Frictional drag at various roof angle

Roof Angle	Frictional Drag (Manual)	Frictional drag(Software)	Percentage variation
Roof Angle 10 º	1682.95 N/m^2	1503.66 N/m^2	10.65%
Roof Angle 15 º	1991.05 N/m^2	1794.216 N/m^2	9.88%
Roof Angle 20 º	2202.563 N/m^2	2021.351 N/m^2	8.22%
Roof Angle 25 º	2366.639 N/m^2	2183.213 N/m^2	7.75%

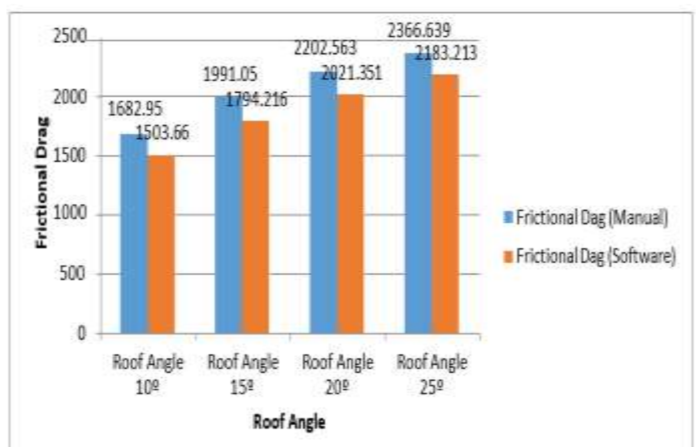

Figure 3: Frictional Drag of different roof angle after manual and software (STAAD-Pro)

After the analysis of buildings having different roof slopes and situated at ground level, the following consolation are made:

- For roof Angle 10° when the building situated at flat ground level, the fractional drag obtained manual calculation was 1682.95 N/m^2 and software calculation was 1503.66 N/m^2, percentage variation was 10.65 %.
- For roof Angle 15° when the building situated at flat ground level, the fractional drag obtained manual calculation was 1991.05 N/m^2 and software calculation was 1794.216 N/m^2, percentage variation was 9.88 %.
- For roof Angle 20° when the building situated at flat ground level, the fractional drag obtained manual calculation was 2202.563 N/m^2 and software calculation was 2021.351 N/m^2, percentage variation was 8.22 %.
- For roof Angle 25° when the building situated at flat ground level, the fractional drag obtained manual calculation was 2366.639 N/m^2 and software calculation was 2183.213 N/m^2, percentage variation was 7.75 %.
- So were conclude that increase the roof angle increase the frictional drag on the building, so appropriate measure is to be taken during the design of sloping roofs.

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