Wind Analysis of High Rise Buildings in Hilly Areas by Using SAP 2000

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Abstract:* Reinforced Concrete (RC) building frames are most common types of constructions in urban India. These are subjected to several types of forces during their lifetime, such as static forces due to dead, live loadsand lateral loads. In this research paper, the effect of wind velocity and structural response of building frame on sloping ground has studied. Considering various frame geometries and slope of grounds (0º, 15º, 20º).The analysis of a G+5and G+11 storey RCC building on varying slope angles i.e., 0º, 15º, 20º is studied and compared with the same on the flat ground. Combination of static and wind loads are considered. For combination, different heights of building frames are analysed. SAP2000 v16 software has been used for analysis purpose. In present research study Storey-wise drift and Displacement, which are critically analysed to quantify the effects of various slope of ground are compared with different slopes and different heights.

Index Terms: 2D- Frames, PGA, RC.

I. INTRODUCTION

Wind load is one of the important design loads for civil engineering structures. For long span bridges, tall buildings and high towers or mast structures, wind load may be taken as a critical loading, and complicated dynamic wind load effects control the structural design of the structure. Therefore knowledge of the dynamic characteristics of an important structure under wind loading becomes a requirement in engineering design and in academic study. In the ongoing research project on tall buildings, the study of wind-induced demands is categorized as: along-wind and crosswind responses. In the modern time, such Multi-storeyed building frames are designed using SA2000 v16 software. This motivation has led to this study on effect of different sloping angle in Multi-storeyed building frames (2D-Frames). Various configurations of these building frames of sloping ground profile layout have been considered along with various load combination of dynamic analysis along wind direction and wind forces. One of the aspects building on slopes, these are more irregular and unsymmetrical blocks on hillsides which result in more prone to seismic activity. Almost all the hilly areas are more active in nature, so building on this crisis are most vulnerable; e.g. Northeast region of India. In this hilly region, traditionally material like, the adobe, burnt brick, stone masonry and dressed stone masonry, timber, reinforced concrete, bamboo, etc., which is locally available, is used for the construction of houses. A scarcity of plain ground in a hilly area compels the construction activity on sloping ground. Hill buildings constructed in masonry with mud mortar/cement mortar without conforming to seismic code provisions have proved unsafe and, resulted in loss of life and property when subjected to earthquake ground motions.

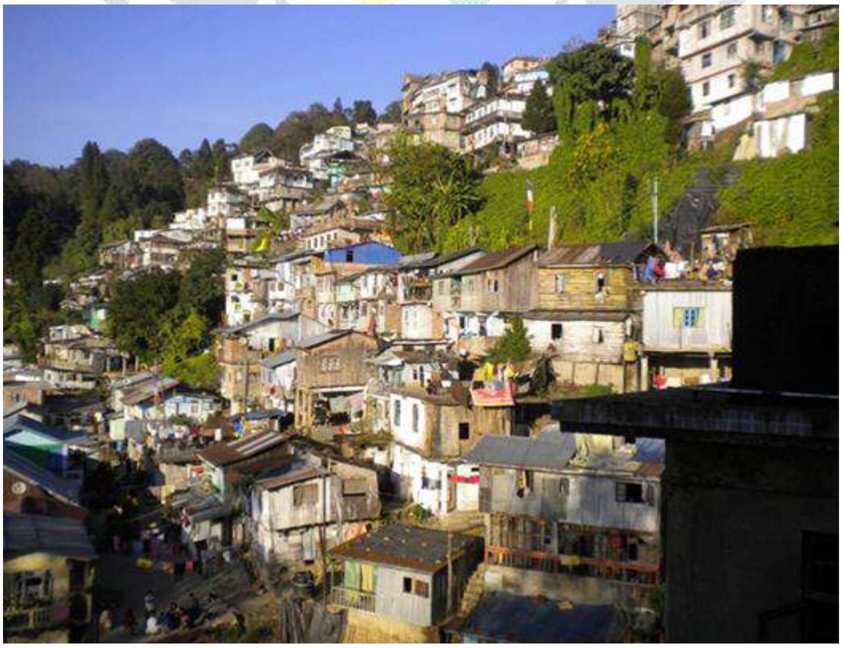

Fig.1.

II. LITERATURE REVIEW

Y. Singh &PhaniGade (2011): This paper presents some observations about seismic behaviour of hill buildings during the Sikkim earthquake of September 18, 2011. An analytical study is also performed to investigate the peculiar seismic behaviour of hill buildings.Dynamic response of hill buildings is compared with that of regular buildings on flat ground in terms fundamental period of vibration, pattern of inter-storey drift, column shear, and plastic hinge formation pattern. The seismic behaviour of two typical configurations of hill buildings is investigated using linear and non-linear time history analysis. It is observed that hill buildings have significantly different dynamic characteristics than buildings on flat ground. The storeys immediately above the road level, in case of down-hill buildings, are particularly vulnerable to earthquake action. The analytical findings are corroborated by the damage pattern observed during Sikkim earthquake.

Umakant Arya , Aslam Hussain , Waseem Khan (2014) the effect of wind velocity and structural response of building frame on sloping ground has been studied. Considering various frame geometries and slope of grounds. Combination of static and wind loads are considered. For combination, 60 cases in different wind zones and three different heights of building frames are analysed. STAAD-Pro v8i software has been used for analysis purpose. Results are collected in terms of axial force, Shear force, moment, support reaction, Storey-wise drift and Displacement which are critically analysed to quantify the effects of various slope of ground.

Sree Rama and Pradeep Ramancharla (2013) [27] observed that recent earthquakes like Bihar-Nepal (1980), Shillong Plateau and the Kangra earthquake killed more than 375,000 people and over 100,000 of the buildings got collapsed. Dynamic characteristics of the buildings on flat ground differ to that of buildings on the slope ground as the geometrical configurations of the building differ horizontally as well as vertically. Due to this irregularity the center of mass and the center of stiffness does not coincide with each other and it results in torsional response. The stiffness and mass of the column vary within the storeys that result in increase of lateral forces on the column, on the uphill side and vulnerable to damage. In their analysis they took five G+3 buildings of varying slope angles of 0, 15, 30, 45, 60° which were designed and analyzed using IS-456 and SAP2000 and further the building is subjected and analyzed for earthquake load i.e., N90E with PGA of 0.565g and magnitude of M6.7. They found that short column attracts more forces due to the increased stiffness. The base reaction for the shorter column increases as the slope angle increases while for other columns it decreases and then increases. The natural time period of the building decreases as the slope angle increases and a short column resist almost all the storey shear as the long columns are flexible and cannot resist the loads.

II. METHODOLGY

This standard gives wind forces and their effects (static and dynamic) that should be taken into account when designing buildings, structures and components thereof. The wind load on a building shall be calculated for:

- The building as a whole.
- Individual structural elements as roofs and walls.
- Individual cladding units including glazing and their fixings.

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:

$$F=(C_{pe}-C_{pi})\ A\ Pd \quad (1)$$

where
C_{pe} = external pressure coefficient,
C_{pi} = internal pressure- coefficient,
A = surface area of structural element or cladding unit,
Pd = design wind pressure.

If the surface design pressure varies with height, the surface areas of the structural element may be sub-divided so that the specified pressures are taken over appropriate areas. Positive wind load indicates the force acting towards the structural element and negative away from it. Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term 'wind' denotes almost exclusively the horizontal wind, vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 metres above ground. The buildings/structures are classified into the following three different classes depending upon their size:

- Class A - Structures and/or their components such as cladding, glaxing, roofing, etc, having maximum dimension (greatest horizontal or vertical dimension) less than 20 m.
- Class B - Structures and/or their components such as cladding, glazing, roofing, etc, having maximum dimension' (greatest horizontal or vertical dimension) between 20 and 50 m.
- Class C - Structures and/or their components such as cladding, glazing, roofing, etc, having maximum dimension (greatest horizontal or vertical dimension) greater than 50 m.

A building or a structure in general has to perform many functions satisfactorily. Amongst these functions are the utility of the building or the structure for the intended use and occupancy, structural safety, fire safety and compliance with hygienic, sanitation, ventilation and daylight standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in loading Codes by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, wind loads and other external loads, the structure would be required to bear. Strict conformity to loading standards, it is hoped, will not only ensure the structural safety of the buildings and structures, which are being designed and constructed in the country and thereby reduce the risk to life and property caused by unsafe structures, but also reduce the wastage caused by assuming unnecessarily heavy loadings without proper assessment.

III. NUMERICAL MODELLING

This thesis deals with comparative study of wind behavior of low rise and high rise structures building frames with three geometrical configurations and different slope of ground, under the wind effect as per 875(Part-III):1987 static analysis. A comparison of analysis results in terms of Maximum displacements, wind forces and drift has been carried out The modelling process consists of G+5 and G+11 Reinforced Concrete structure between the hilly slope at an angle of 0, 15, 20 degree. The following are recommended for detailed analysis:

- Linear static analysis – model analysis as per IS code using SAP - 2000 software.
- By modelling the structure using the above package for evaluation displacements drifts and wind loads.

A. Details Of Building Chosen

The following two different height of building frame (3Dframe) have been considered for analysis. The present study deals with G+5 and G+11 building:

- G+5 structure with 0º inclination
- G+5 structure with 15º inclination
- G+5 structure with 20 º inclination
- G+11 structure with 0º inclination
- G+11 structure with 15º inclination
- G+11 structure with 20 º inclination

This building is designed for gravity loads according to IS: 456-2000 and wind loads according to IS: 875 part-3. The detailed plan of the building is shown in below Figs.2 and 3.

Plan of RC Frame Considered:

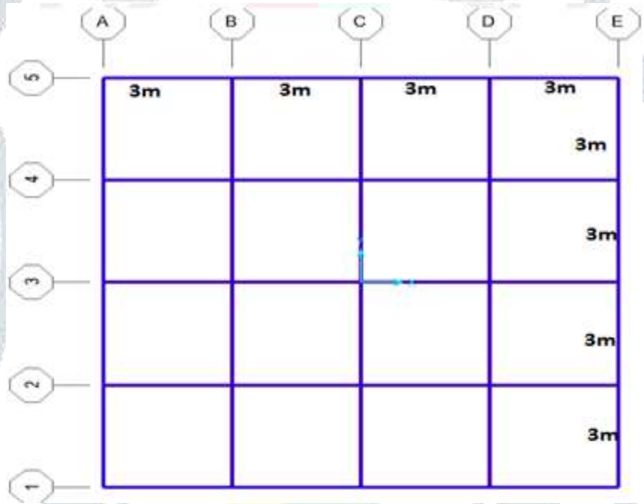

Fig.2. Plan.

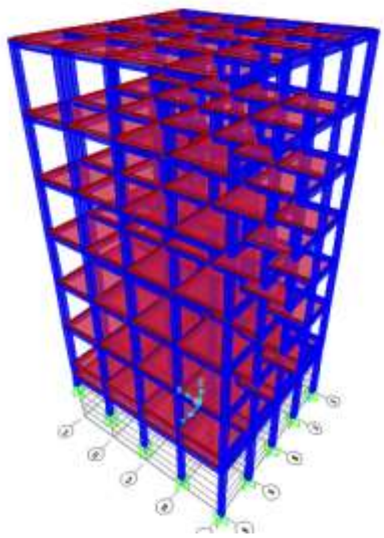

Fig.3. G+5 3D model on sloping ground.

IV. RESULTS AND DISCUSSION

A. Comparison of Displacements for G+5& G+11 (0, 15, 20 Degrees Slope)

From the analysis, maximum displacement and story drift values are evaluated for the two models. Below table and graph shows the displacement of the structure.

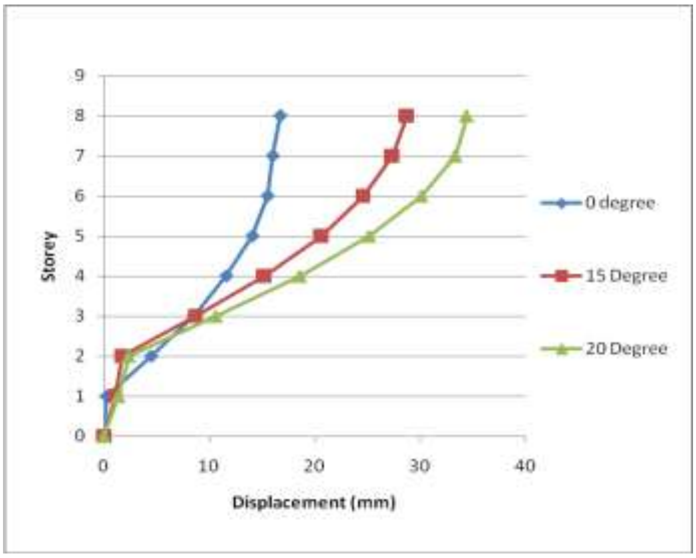

Fig.4.Comparison of G+5 Displacements.

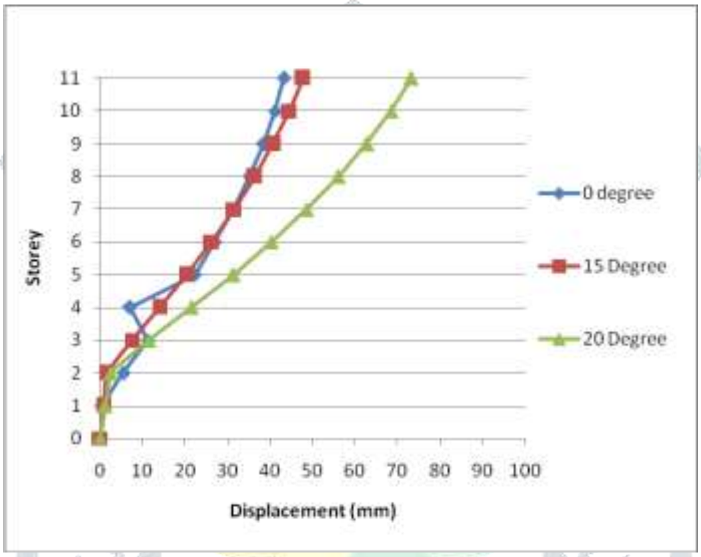

Fig.5. Comparison of G+11Displacements.

From the above Figs.4 and 5 it is observed that 0 degree sloped structure has lesser displacements and 20 degree sloped structure has larger displacements, from which we can say that as slope of the structure increases, displacement also increases, which results in the reduction in lateral stiffness of the column due to increase in lateral loads (wind loads).

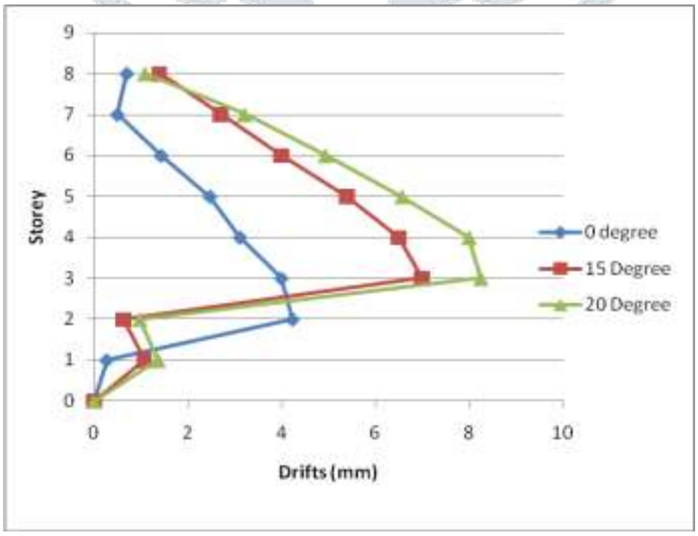

Fig.6. Comparison of G+5 Storey Drifts.

B. Comparison Of Storey Drifts For G+5 & G+11 (0, 15, 20 Degrees Slope)

Story drift is expressed as the difference of the deflections at the top and bottom of the story under consideration: this is also often expressed as a ratio between the deflection and the story, or floor-to-floor height. Drift limits serve to prevent possible damage to interior or exterior walls that are attached to the structure and which might be cracked or distorted if the structure deflects too much laterally.

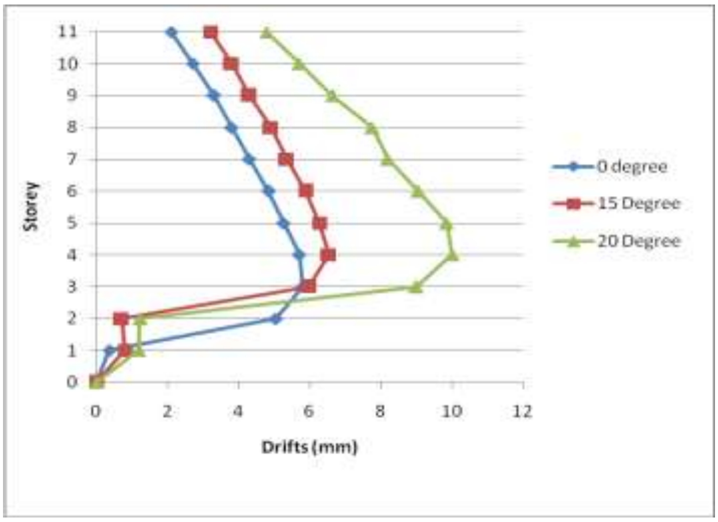

Fig.7. Comparison of G+11 Storey Drifts.

From the Figs.6 and 7, inter-storey drifts have shown a consistent trend of increasing from ground storey to top storey. Therefore as slope of the structure increases, storey drifts also increases. When the storey drifts are excessive, vertical members may become permanently deformed; excessive deformation can lead to structural and non-structural damage and, ultimately, collapse.

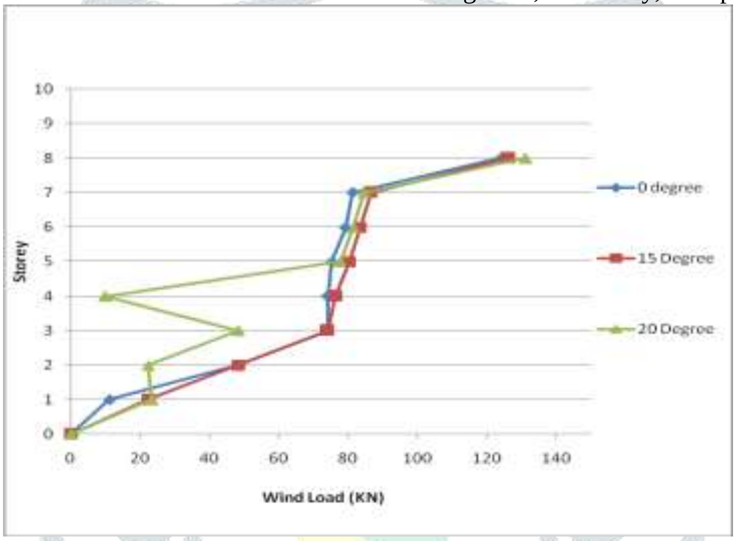

Fig.8. Comparison of G+5 Wind Loads on Diaphragm.

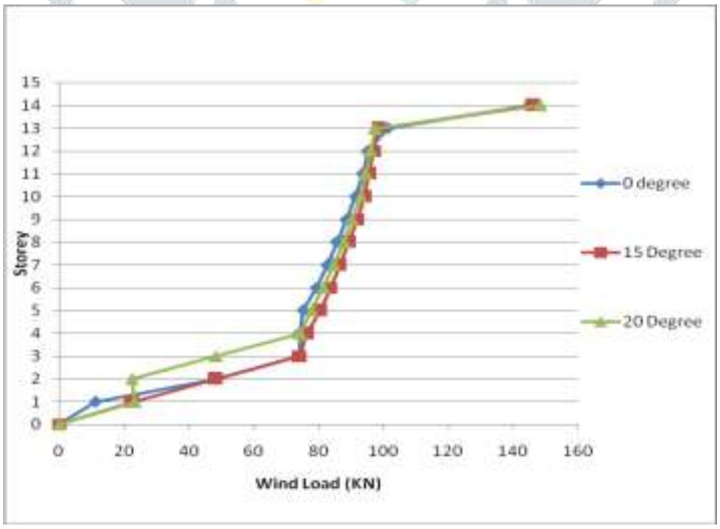

Fig.9. Comparison of G+11 Wind Loads on Diaphragms.

In G+5 structure with 20º inclination has large variations from 2nd to 5th storey and wind loads got increased from top to bottom storey. From the above Figs.8 and 9 it is observed that as slope of ground increases, wind loads on to the structure also increases. Although the top floor has larger wind loads for all the structures, first three storeys and top two storeys has more variation in wind loads than other storeys.

V. CONCLUSIONS

The present study is focused on the wind analysis of G+5 and G+11 structures on sloped ground with 0º, 15º and 20º inclination to understand the behaviour of the structure. Following are the salient conclusions of this study:

- It is observed that 0º sloped structure has lesser displacements and 20º sloped structure has larger displacements, from which we can say that as slope of the structure increases, displacement also increases, which results in the reduction in lateral stiffness of the column due to increase in lateral loads (wind loads).
- From the above graphs, inter-storey drifts have shown a consistent trend of increasing from ground storey to top storey. Therefore as slope of the structure increases, storey drifts also increases. Also the max storey-wise drift goes on increasing on the total height of the building frame increases.
- When the storey drifts are excessive, vertical members may become permanently deformed; excessive deformation can lead to structural and non-structural damage and, ultimately, collapse.
- It is observed that as slope of ground increases, wind loads on to the structure also increases.

VI. REFERENCES

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