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Wind Load Response Assessment of Multi-Storey Structures on Different Sloping Ground Conditions using STAAD Pro V8i

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ABSTRACT: Image inpainting is the process of restoring the lost or damaged regions or modifying the image contents imperceptibly. It refers to the process of filling-in missing data in a designated region of the visual input. In this paper, the technique presented is for detection and removal of text from images. The system detects text using morphological operations, connected component labelling and a set of selection criteria which helps to filter out non text regions. So, the resultant image is the image with only texts. Text Inpainting is done in two steps. The first step detects the text region automatically, without user interaction and in the second step; the text is removed from the image using exemplar based Inpainting algorithm.

KEYWORDS: Text detection, Inpainting, Morphological operations, Connected component labelling.

I. INTRODUCTION

Structures are buildings that people use for living, working, or carrying out activities. Nowadays, there isn't enough land to build more structures quickly, especially in private and modern areas. Because of this, vertical development has become very important, and tall buildings are being built on a large scale.

Twisting, which is a movement caused by wind, has two main effects on tall buildings.

First, it applies forces and moments on the structure and its outer covering. Second, it affects the air movement around and inside the building, which is called wind pressure. Sometimes, due to the unpredictable nature of wind, it can cause serious damage during strong storms. This can even disrupt the building's internal ventilation system when the wind enters. Therefore, studying airflow is becoming increasingly important when designing a building and its surroundings. Wind forces are studied in four main categories of building structures:

- i) tall buildings
- ii) Low buildings
- iii) Equal-sided block buildings
- iv) Roofs and cladding

Studies are not commonly done on the first two categories because structural failures are rare, and the designs for materials and cladding are not always precise.

However, tall buildings are flexible and can vibrate at high wind speeds in all three directions (x, y, z). Also, building codes do not usually include the normal maximum wind speed for the building's lifespan and do not consider high local wind suction, which can cause major damage. Because of these factors, wind load calculations for tall buildings are especially important.

Wind load is one of the key design loads for structural building systems.

For long spans, tall buildings, and high towers or pole structures, wind load is often considered a primary load. Complex wind load effects influence the structural design of the building. Therefore, understanding the dynamic

behavior of a structure under wind load is essential in building design and academic study. In ongoing research on tall buildings, wind-induced forces are categorized as along-wind and crosswind responses. These forces are caused by different factors. Along-wind response is due to turbulence effects, while crosswind response is related to windstorms. Along-wind response is particularly important for comfort criteria. The loading conditions on tall buildings may differ from low-rise buildings because of the number of floors and the importance of wind-induced loading. On the other hand, the effect of wind load on tall buildings is distributed over a larger area and has greater force. Moreover, in high-risk seismic zones, seismic performance of structures is considered a key factor. The impact of seismic forces in such areas may be greater than the forces caused by wind, which means seismic load determines the frame and final design of the structure (assuming that, according to all global codes and standards, wind and seismic loads do not act on the structure at the same time).

1.1 Sloping Topography

The effect of step-like sloping geology on seismic ground movement has not been fully studied before, even though there is clear evidence of its importance since the late 1960s.

In fact, this type of surface geology has received minimal attention from researchers compared to slopes and ravines, despite its significance in construction. One possible reason is the non-symmetric geometry of step-like slopes, which makes it difficult to develop general analytical approaches and often requires site-specific numerical simulations whose results are hard to summarize, making it challenging to apply these findings to sloping areas.

An examination of how step-like ground slopes behave in uniform visco-flexible soil, under vertically spreading seismic waves and distinctive twist zones, aims to investigate the impact of slant geometry, common excitation repetition, and span, as well as dynamic soil characteristics on ground movement in a parametric way. This provides both subjective and quantitative insights into the marvel.

Calculating ground slope is essential for many traditional Geographic Information Systems (GIS) applications. Slope is an important part of scientific, military, and civilian analyses. There are several methods for calculating slope. Manual slope generation, based on contour line data, is a long-established and widely accepted method. However, with automated tools for performing analysis, analysts often assume that the algorithm used is accurate and comparable to the manual method of slope generation. Wind flowing around buildings creates eddies.

Buildings between 75 feet and 491 feet (23 m to 150 m) in height are considered elevated structures.

Structures taller than 492 feet (150 m) are classified as high-rises. The materials used for the main structure of tall buildings are reinforced concrete and steel. Most American-style high-rises have a steel frame, while private tower blocks are mostly built with concrete. High-rise buildings have certain characteristics. These structures are tall and subject to higher vertical and lateral loads (primarily due to torsion concerns) compared to lower structures. Some examples of elevated structures.

1.2 Behavior of Wind

Wind speed consists of a mean and a fluctuating component.

A temporary deviation of the fluctuating component from the mean value is responsible for the formation of gusts. Both components of wind speed vary with height and depend on the surrounding landscape and geography. Figures 1.17 and 1.18 show the variation of wind speed with time and height, respectively. Since turbulence is generated at the surface, the surface wind speed is much less than the wind speeds at higher elevations.

For strong winds, the shape of the vertical profile of wind speed depends mainly on the roughness of the surface. This means the overall drag effect of structures, trees, and other obstacles that hinder the flow of wind at the surface. There is a boundary layer within which the wind speed changes from nearly zero at the surface to the free wind speed at a height known as the roughness height. The thickness of this boundary layer depends on the type of terrain. The roughness height in a large urban area is much higher than it is over the ocean.

1.3 Classification of Wind Load

A mean wind force acts on a building.

This mean wind force is obtained from the mean wind speed and the fluctuating wind force created by the fluctuating wind field. The effect of the fluctuating wind force on the building or part thereof depends not only on the characteristics of the fluctuating wind force but also on the size and dynamic characteristics of the building or part thereof. Therefore, to assess the design wind load, it is important to evaluate the characteristics of fluctuating wind forces and the dynamic characteristics of the building.

The following factors are generally considered in determining the fluctuating wind force.

- 1) Wind turbulence (temporary and spatial variation of wind)
- 2) Vortex generation in the wake of buildings
- 3) Interaction between building vibration and surrounding wind flow

Fluctuating wind forces act on building surfaces due to the above factors.

Fluctuating wind forces change temporarily, and their dynamic characteristics are not uniform at all positions on the building surface. Hence, it is best to assess wind load on structural elements based on general building behaviour and that on components/cladding based on the behaviour of individual building parts. For most structures, the impact of fluctuating wind force produced by wind turbulence is predominant. In this case, flat wind load on principal edges in the along-wind direction is important. However, for generally flexible structures with a large aspect ratio, even wind loads on structural edges in the across-wind and torsional directions should not be overlooked. For roof loads, the fluctuating wind force created by separation spill from the main edge of the roof often prevails. Hence, wind load on principal edges is divided into two parts: flat wind load on principal edges and roof wind load on principal edges.

1.4 Combination of Wind Loads

The combination of wind loads in the along-wind, across-wind, and torsional directions has not been considered specifically, as the design wind speed has been used without considering the impact of wind direction.

However, with the introduction of wind directionality, the combination of wind loads in the along-wind, across-wind, and torsional directions has become essential. Therefore, it has been decided to explicitly include a control for the combination of wind loads in the along-wind, across-wind, and torsional directions. Wind pressure distributions on the surface of a building with a rectangular area are unbalanced even when wind blows perpendicular to the building surface. Hence, wind forces in the across-wind and torsional directions are not zero when the wind force in the along-wind direction is a maximum.

Table 1.1: Wind zones in India

S. No.	Wind Zone	Basic Wind Speed (m/s)
1	Zone 1	33
2	Zone 2	39
3	Zone 3	44
4	Zone 4	47
5	Zone 5	50
6	Zone 6	55

1.5 Design Criteria

When creating a structure that can handle wind from the side, certain important design rules must be followed.

- I. The structure must remain stable and not tip over, lift up, or slide as a whole.
- II. The parts of the building need to be strong enough to handle the loads placed on them without breaking during the structure's lifetime.

III. The building must also work well in everyday use. For example, in structures where people rely on staying inside without breaking, it's important to control how the building moves and floats. This is especially important for tall buildings to prevent damage to non-essential parts like the outside walls, inside areas, and roof. Most general building codes use a specific maximum wind speed, called the ultimate wind speed, to ensure safety and meet quality standards. In many codes, this wind speed has a 5% chance of being exceeded in a 50-year period.

Table 1.2: General facts for designing Wind Loads

General wind speed in the region	Source : IS code
Terrain	Wind Speed will increase as it passes over or between hills, and slow down as it passes over rougher terrain (drag effect) accelerate over open and flat expanses of land or water
Large expanse of water nearby, e.g. sea or a lake	During the day, solar gain will heat the land mass, resulting in an increase in temperature relative to an adjacent large body of water. As air warmed by the land rises, cooler air from over the water will replace the rising air, resulting in the generation of afternoon, on-shore breezes.
Adjacent building / vegetation	Wind speed: is lower when a site is surrounded by taller buildings will increase where it funnels around or b/w building is slowed by trees and vegetation
Building height	The higher the building, the more exposed it will be to higher winds, particularly where the building is taller than adjacent building or vegetation.

1.6 Estimation of Wind Load on Tall Buildings

The wind load on a tall building can be calculated in two main ways:

(a) Using the analytical method, as described in code IS 875: part 3-1987, which was developed by A.G. Davenport. This method is usually suitable for buildings with regular shapes and sizes, and it is based on the building's geometric features without considering the effects of nearby buildings.

(b) Additionally, wind load estimation can be done through wind tunnel testing using a scaled model of the building. In wind tunnel testing, the dynamic analysis of the scaled model is conducted using Balendra's approach for the basic design, and surface pressure measurement is performed using a pressure measurement system for the cladding design. The influence of nearby buildings is also considered as interference effects for the structures, using the same method as for an isolated building model.

II. LITERATURE SURVEY

Arunkumar N pattar et.al. (2015) presented a comparative study on a tall structure of (G+21) in which wind load is considered as per I.S. 875 part 3 using staad pro, etabs and manual method. This paper is mainly focused to distinguish the best method which will be economical and to justify variations in results as concluded in which maximum bending moment, shear force, axial force and designing is considered, and concluded that designing with manual method is economical as compared to the use of softwares.

Ambadkar et al. (2012) broke down for different varieties, for example, 1) Terrain with few on the other hand no impediments having statures beneath (1.5m to 2m). 2) Terrain with impediments having heights between (1.5 to 10 m). 3) Terrain with numerous closely spaced obstructions having the extent of building structures upto 10 m in stature. 4)

Terrain with various extensive high firmly separated checks. Results obtained from STAAD-expert v8i investigation are utilized for acquiring critical relations of minutes, powers and dislodging with various wind speeds. Minutes, powers and removal got from all cases are contrasted and twist speeds, as indicated by their rate of opening accommodated different varieties. They inferred that as the wind speed expands My, Mz values additionally increments as per the classification, opening when contrasted with Mz values My qualities increment all the more quickly. As the wind speed increments Fy, Fz values additionally increments as per the class, opening as contrast with Fz values Fy values expanded all the more quickly. Dislodging increments as the wind speed increments for different sorts of opening, classification.

Hemal J shah et al. (2014) [44] presented a comparative study of plain ground and sloping ground of 23 degree and 27 degree slope are considered with same loading conditions and properties for 5 storey and 10 storey in medium soil and seismic Zone is taken as zone V structure using SAP2000 and it is observed that The building on 23 degree slope has lowest time period so it is more rigid building and gives higher earthquake forces.

Kalyanrao et al. (2014) [45] studied sloping ground structure subjected to seismic load as assessed in ATC40 and FEMA356. Here pushover analysis is done using analysing software ETABS in which three cases of ground is considered asset-back, step-back or step-back setback to study the behavior of structures during earthquake relies on the dissemination of mass and solidness in both planes and it is concluded that the maximum base shear is induced in Set-back-Step-back structure. The base shear obtained by "pushover analysis" increases the performance point as compared to the design base shear and it is concluded that Step-back-Set-back structure may be favoured on sloping ground which increases the performance.

Kumar et al. (2012) studied the wind effects on structures located on the costal belt of the country as well as in the interior part of the country. Based on the study, important conclusions are short comings in the existing code and proposed draft is pointed out. They conclude that in the static method a new variable is introduced called importance factor. This factor is useful in the cyclonic regions. So the static pressures in the coastal regions of the country calculated by the proposed draft are more compared to the existing code. This is because of the effect of the importance factor, but the basis of this factor is not mentioned in the draft.

Rahman et al. (2012) observed that for the design of tall structures, drift must take into the consideration. Although there are no specific requirements in the effects of drift, it is an important issue which may significantly impact the buildings structural behavior and economy. Drift is a common phenomenon for high rise and this may hamper the integrity of the structure and cause serious loss of life and properties in case of a major earthquake. So every high rise structure should consider the effect of drift. Then the loss of life and property will be attenuated. For these study only regular shaped structures has been considered only. Estimation of drift is carried out for rigid frame structure, coupled shear wall structure and wall frame structure. This study indicates that the drift on high rise structures has to be considered as it has a notable magnitude. So every tall structure should include the drift due to earthquake load as well as wind load.

Agrawal et al. (2011) presented a comparative study of different wind characteristics pertaining to dynamic wind load for three terrain categories namely: sub-urban, heavy sub-urban and urban as given in different international wind codes and standards. The different codes used in his study include Japanese, Australia, New-Zealand, American, British, European, Canadian, Hong-Kong, Chinese and Indian [existing (1987) as well as proposed (2011)]. The differences in various codes standards for the above parameters have been discussed with reasons.

Bakhshi et al (2011) observed that the structure with lower height or number of stories in which parameters dominant in seismic loading and with increasing in height of buildings, rate of influence of wind load along the height is larger than seismic loading and the results of wind and earthquake characteristics was compared in the form of power spectral density (PSD). Dynamic wind force is not constant along the height but also it becomes larger and more intense with increasing height. In his research the effect of dynamic time history wind load is considered and when it's applied along the height of tall buildings, the fluctuating wind speed is simulated as an ergodic multivariate stochastic process, and the Fast Fourier Transform is needed to estimate the fluctuating wind speed components acting on the structure. Peak drift and displacement are two important parameters for comfort criteria that affect human perception to motion in the low frequency range of 0-1 Hz encountered in tall buildings.

III. METHODOLOGY

Exemplar This thesis focuses on comparing how wind affects high-rise building frames with three different shapes and various ground slopes, based on the static analysis guidelines from IS-875 (Part-III):1987. The study compares the results in terms of maximum displacements, wind forces, maximum bending moments, maximum axial forces, maximum shear forces, drift, and reactions.

The study was carried out in the following steps:

Step 1: Choosing the building geometry, which includes three bays and 10, 14, and 18-story 3D frames.

Step 2: Selecting ground slope angles of 0° & 7.5° .

Step 3: Choosing five wind zones with speeds of 33, 39, 44, 47, and 55 m/s, as per IS-875 (Part-III):1987.

Step4: Formation of load combination (8 load combinations in x & z-direction)

TABLE 3.1: Wind zones for different cases and building frame

Case	No Of Bays	Height Of Building Frame	Slopes	Wind Zones As Per Is 875 (Part-III):1987
Case-I	3	57 meter (G+18)	$0^\circ, 7.5^\circ$	33,39,44,47 and 55 m/s

Step 5: Creating models of the building frames using STAAD-Pro v8i software.

Step 6: Performing analysis for different building heights, ground slope angles, wind zones, and load combinations (total of 60 cases).

Step 7: Conducting a comparative study of the results, including wind forces, maximum bending moments, maximum axial forces, maximum displacements, story-wise displacements, maximum shear forces, and maximum axial forces.

IV. EXPERIMENTAL RESULTS

4.1 Modeling of Building Frames Using STAAD Pro Software

4.1.1 Buildings Frame with the Following Three Geometrical Types Are Considered for Analysis

Case-1: 16m x 16m in plan area and 18 storey high.(Analysis 3D-frame in critical condition).

4.1.2 Modelling of Building Frames

STAAD-Pro is a general-purpose program used for analyzing and designing various types of structures.The basic activities involved in achieving this goal include:

Model generation

Performing calculations to get analytical results.

Verifying the results.

All these are supported by tools in the program's graphical environment.

4.1.3 Height of Building Frames

The following three different heights of building frame (2D-frame) have been considered for analysis.

1) Type-A: Model 54 meter building height, 00 inclined footing level.

2) Type-B: Model 54 meter building height, 7.50 inclined footing level

The size of the column is 350mm x 350mm, and the beam size is 350mm x 350mm.

4.2 Material and Geometrical Properties

The following material properties have been considered in the modeling:

- Density of RCC: 25 kN/m³

- Density of Masonry: 18.5 kN/m³

The foundation depth is considered to be 1.50m below the sloping ground level, and the typical storey height from floor to floor is 3.0m.

The sections of the columns are considered to be 350mm x 350mm, and the sections of the beam size are 350mm x 350mm.

4.3 Loading Conditions

The following loading is adopted for analysis:

Dead Loads:

a) Self weight of slab considering 125mm thickness. Slab = $0.125 \times 25 = 3.1225 \text{ kN/m}^2$

b) Floor Finish load = 1 kN/m^2

c) Infill Load = $0.10 \times 3 \times 18.5 = 5.55 \text{ kN/m}$

Live Loads:

a) Live Load on typical floors = 3 kN/m^2

Wind Load:

Calculation of wind load as per IS Code 875 (Part-III): 1987 Calculation of wind pressure on the windward face of the building. Effective area is calculated on the windward face of the building frame to determine the wind force acting on the junction of the structures and the sloping ground of the building frame. All the building frames are analyzed for 5 wind zones.

1) The wind loads are derived for the following wind parameters as per IS: 875 (1987)

2) Wind zones - 33 m/s, 55 m/s

3) Wind Induced Lateral Force on Structure.

This will be calculated at every story level and windward direction, with three cases in this problem. While the wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind speed.

V. WIND LOAD ANALYSIS OF BUILDING FRAME

There are following cases for analysis of different sloping ground

5.1 16mx16m in plan area with 18 stories and wind intensities at 0-degree Structure

5.2 16mx16m in plan area with 18 stories and wind intensities at 7.5-degree Structure

eliminate small objects, connected component labelling is applied to the resultant image. (c) represents text detection by applying second set of criteria which eliminates all the objects whose area is less than 300 and filled area is less than 500.

5.1. SLOPE - 00

5.1.1.1 Maximum B.M. in 0 degree slope in 33 m/s wind intensity

Table 5.1: Maximum Bending moment (kN-m) in 0 degree slope

Intensity in m/s	Maximum B.M. in 0 degree slope in 33m/s wind intensity		
	10 storey	14 storey	18 storey
	65.188	114.783	135.589

5.1.1.2 Maximum B.M. in 0 degree slope in 55 m/s wind intensity.

Table 5.2: Maximum Bending moment (kN-m) in 0 degree slope

Intensity in m/s	Maximum B.M. in 0 degree slope in 55m/s wind intensity		
	10 storey	14 storey	18 storey
	65.188	114.783	176.808

5.1.2.1 Maximum Shear Force in 0 degree slope in 33 m/s wind intensity

Table 5.3: Maximum shear force kN in 0 degree slope

Intensity in m/s	Maximum shear force in 0 degree slope in 33m/s wind intensity		
	10 storey	14 storey	18 storey
	62.734	102.565	112.745

5.1.2.2 Maximum Shear Force in 0 degree slope in 55 m/s wind intensity

Table 5.4: Maximum shear force kN in 0 degree slope

Intensity in m/s	Maximum Shear Force in 0 degree slope in 55m/s wind intensity		
	10 storey	14 storey	18 storey
	62.734	102.565	112.745

5.1.3.1 Maximum axial force in 0 degree slope in 33 m/s wind intensity

Table 5.5: Maximum axial force (kN) in 0 degree slope

Intensity in m/s	Maximum axial force in 0 degree slope in 33m/s wind intensity		
	10 storey	14 storey	18 storey
	1887.406	4300.715	5321.75

5.1.3.2 Maximum axial force in 0 degree slope in 55 m/s wind intensity

Table 5.6: Maximum axial force (kN) in 0 degree slope

Intensity in m/s	Maximum axial force in 0 degree slope in 55m/s wind intensity		
	10 storey	14 storey	18 storey
	1887.406	4300.715	5321.75

5.4 SLOPE – 7.5 °

5.4.1.1 Maximum B.M. in 7.5-degree slope in 33 m/s wind intensity

Table 5.7: Maximum bending moment in 7.5 degree slope

Intensity in m/s	Maximum B.M. in 7.5 degree slope in 33m/s wind intensity		
	10 storey	14 storey	18 storey
	64.21	113.445	134.808

5.4.1.2 Maximum B.M. in 7.5-degree slope in 55 m/s wind intensity

Table 5.8: Maximum bending moment in 7.5 degree slope

Intensity in m/s	Maximum B.M. in 7.5 degree slope in 55 m/s wind intensity		
	10 storey	14 storey	18 storey
	64.21	113.445	176.584

5.4.2.1 Maximum Shear Force in 7.5 degree slope in 33 m/s wind intensity

Table 5.101: Maximum shear force (kN) in 7.5 degree slope

Intensity in m/s	Maximum shear force in 7.5 degree slope in 33m/s wind intensity		
	10 storey	14 storey	18 storey
	62.451	101.938	111.25

5.4.2.5 Maximum Shear Force in 7.5 degree slope in 55 m/s wind intensity

Table 5.105: Maximum shear force (kN) in 7.5 degree slope

Intensity in m/s	Maximum shear force in 7.5 degree slope in 55m/s wind intensity		
	10 storey	14 storey	18 storey
	77.542	125.374	170.5

5.4.3.1 Maximum Axial Force in 7.5 degree slope in 33 m/s wind intensity

Table 5.106: Maximum axial force (kN) in 7.5 degree slope

Intensity in m/s	Maximum axial force in 7.5 degree slope in 33m/s wind intensity		
	10 storey	14 storey	18 storey
	1887.406	4308.783	5425.75

5.4.3.5. Maximum Axial Force in 7.5 degree slope in 55 m/s wind intensity

Table 5.110: Maximum axial force (kN) in 7.5 degree slope

Intensity in m/s	Maximum axial force in 7.5 degree slope in 55m/s wind intensity		
	10 storey	14 storey	18 storey
	1887.406	4308.783	5425.75

VI. CONCLUSION

We Following are the conclusions as per study-

6.1.1 Maximum bending moment

- Maximum bending moment is seen in 18 storey structure and minimum in 10 storeys therefore 10 storeys is stable.
- In wind zones, maximum bending moment is seen in zone-VI and minimum in zone-I means zone-I provide better stability.

- As comparing slopes, maximum bending moment is seen in 7.5 degree sloping ground and minimum in 0 degree sloping ground, means as slope is increasing bending moment is also increasing.
- In this comparative study Zone-I, 10 storey, 0 degree slope is economical as it shows less moment means less reinforcement.

6.1.2 Maximum shear force.

- Maximum shear force is observed in 10 storey is critical.
- In seismic zones, maximum shear force is seen in zone-VI and minimum in zone-I means zone-I provide better stability.
- As comparing slopes, maximum shear force is seen in 7.5 degree sloping ground and minimum in 0 degree sloping ground, means as slope is increasing shear force is also increasing.

6.1.3 Maximum axial force

- Maximum axial force is seen in 18 storey is critical.
- In wind zones, maximum axial force is seen in zone-VI and minimum in zone-I means zone-I provide better stability.
- As comparing slopes, maximum axial force is seen in 7.5 degree sloping ground and minimum in 0 degree sloping ground, means as slope is increasing axial force is also increasing.

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