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Research Paper

BEHAVIOUR OF TALL BUILDINGS UNDER WIND LOADS

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Abstract-

Design of high rise buildings for wind loads are dependent upon the data available in wind codes which is very limited as, considering every possible arrangement of surroundings of a building is a very difficult job. Wind loading standards and codes are developed from results of various wind tunnel tests of isolated buildings for different wind environments and terrain categories. However, when the interference effects from neighboring buildings are taken into consideration, the use of wind loading codes for the design of structures may not be accurate necessitating the adoption of wind tunnel tests with accurate simulation of the neighboring buildings in, thus the near vicinity of the building to be designed.

Neighboring structures may either decrease or increase the wind-induced forces on a building, depending mainly on the geometry and position of these structures, their orientation with respect to the direction of flow and upstream terrain conditions. Interference effects from neighboring buildings on the wind-induced along-wind and cross-wind responses, as well as torsion response of tall buildings have been investigated by researchers. Few of these studies are presented in this thesis to have a better understanding of wind loading for a safe design. In this work, analytical study of 'Square' plan shapes buildings have been carried out under various isolated condition to obtain the response of the structure due to acting wind loads using Staad pro software package. For square plan shape building, isolated condition is considered at different wind angle. Response of the structure has been studied by observing the variation of internal stress resultants namely, axial force, bending moment, twisting moment and displacement with the height.

KEYWORDS:

WIND, STAAD, FORCE, SQUARE, COLUMNS.

.INTRODUCTION

While high-rise construction serves as one of the most challenging projects undertaken by society each year, tall buildings are one of the few constructed facilities whose design relies solely upon analytical and scaled models, which, though based upon fundamental mechanics and years of research and experience, has yet to be systematically validated in full-scale. As high-rise dwellings gain more prominence worldwide, their impacts upon the global society and economy will become more pronounced, necessitating a new frontier in tall building design fully equipped to address the emerging issues of performance, economy and efficiency.

As tall-building projects push the envelope to greater heights, designers are faced with the task of not only choosing a structural system to carry the lateral loads, but also insuring a design that meets serviceability and occupant comfort requirements under complex wind environments. This latter issue strongly affects the potential economic viability of tall building projects. An additional limitation in tall building design is the inability to provide accurate estimates of structural damping in the design phase, which is critical to insure that the structure can meet both serviceability and habitability requirements. Although the building stiffness may be accurately quantified, inherent damping values are typically assumed in the design stage, resulting in estimates of response characteristics that may have significant inaccuracies. Thus, the accurate prediction of inherent damping for a given design becomes yet another critical consideration.

Wind plays an important role in designing of a tall building. Earlier, symmetric or rectangular plan shape buildings were common but due to modernization in civil and architectural field, plan of a building can be anything including square, rectangular, concave, and convex, ‘T’ shape and ‘L’ shape. Recent example is ‘Burj Khalifa’ which is a ‘Y’ shape building. There are several codes including Indian code on which designers depend for finding out the wind loads [AS/NZS: 1170.2-2002, ASCE: 7-02-2002, BS: 63699-1995, EN: 1991-1-4-2005, IS: 875 (Part-3) 1987]. But these codes give standard pressure and force coefficient values mainly for isolated conditions. So, it is very necessary to conduct wind tunnel tests on the models of buildings in a group to be designed for exact calculation of wind loads.

DESIGN PROCEDURE

Basic Wind Speed (Vb) - Figure 1 of IS875:part 3 gives basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds presented in Fig. 1 have been worked out for a 50 year return period. Basic

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wind speed for some important cities/towns is also given in Appendix A of IS875: part 3.

Design Wind Speed (Vz) - The basic wind speed (Vz) for any site shall be obtained from Fig. 1 and shall be modified to include the following effects to get design wind velocity at any height (Vz) for the chosen structure:

a) Risk level;

b) Terrain roughness, height and size of structure; and

c) Local topography.

It can be mathematically expressed as follows:

Vz, = Vb. K1. K2. K3

where

V, = design wind speed at any height z in m/s;

K1 = probability factor (risk coefficient)

K2 = terrain, height and structure size factor and

K3 = topography factor.

Risk coefficient (K1): suggested life period to be assumed and the corresponding K1 factor for different class of structures as per IS: 875 (Part 3)

Terrain and height factor (K2): Selection of terrain categories shall be made with due regard to the effect of obstruction, which constitute the ground surface.

Topography Factor (K3): The effect of topography will be significant at a site when the upwind slope is greater than about 3°, and below that, the value of K3 may be taken to be equal to 1.0. The value of K3 is confined in the range of 1.0 to 1.36 for slopes greater than 3°.

NOTE - Design wind speed up to 10 m height from mean ground level shall be considered constant.

The design wind pressure (Pd) -

The design wind pressure, Pd, is given by the following expression:-

$Pd = 0.5 \times \square \times V_d^2 = 0.6 \times V_d^2$

where,

V_d = design wind velocity in m/s at height z.

□□□□□ = mass density of air = 1.2 kg/m3

The wind loading is given in terms of pressure coefficients Cp and force coefficients Cf and can be determined as follows:-

$F = (C_{pe} – C_{pi}))\times A\times P_d$

Or

$F = C_f \times A \times P_d$

Where,

Cpe = external pressure coefficient,

Cpi = internal pressure- coefficient,

Cf = force coefficient

A = surface area of structure,

F = wind force,

Pd = design wind pressure.

Cpe and Cpi values are picked up from the relevant standards on wind loads. These pressure and force coefficient values given in code of practices are for isolated buildings only and no information is mentioned for the effect on these coefficients when more buildings or any other structures are present in the near vicinity of the concerned building. Basic wind speed map of

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India according to Indian standard code (IS-875: Part-3) is shown in Fig. 1.1.

CLASSIFICATION OF BUILDING According to Indian standard code (IS-875: Part-3) 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, glazing, 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.

C1ass C - Structures and/or their components such as cladding, glazing, roofing, etc, having maximum dimension (greatest horizontal or vertical dimension) greater than 50 m.

OBJECTIVE OF STUDY

The objective of the present study is to evaluate the effect of wind on a square plan shape tall building having 30 stories for isolated conditions under wind load applicable in 0°, 45°, 90° direction. Wind loads on these tall buildings with square shapes are calculated by considering the building in Bhopal region and force coefficient and basic wind speed taken from the Indian standard code (IS-875: Part-3) ,under isolated conditions. These loads are then applied to the structure as uniformly distributed loads in the Staad. Pro software and then the structure is analyzed. Although numerous wind flow conditions are possible, in the present study, only 3 conditions of wind flow in 0°, 45°, 90° direction are considered.

S NO.	PARTICULARS	DETAIL
1.	Number of floors	30 Storey
2.	Storey height	3.0 m
3.	Height of Building	30x3m =90m
4.	Centre to centre distance between columns	6.0m
5.	Column cross section (for 0 to 5th floor)	800mm x 800m
6.	Column cross section (for 5 to 10th floor)	800mm x 800m
7.	Column cross section (for 10 to 15th floor)	700mm x 700m
8.	Column cross section (for 15 to 20th floor)	700mm x 700m
9.	Column cross section (for 20 to 25th floor)	600mm x 600m
10.	Column cross section (for 25 to 30th floor)	500mm x 500m

Table: 1. Parameters considered for the study

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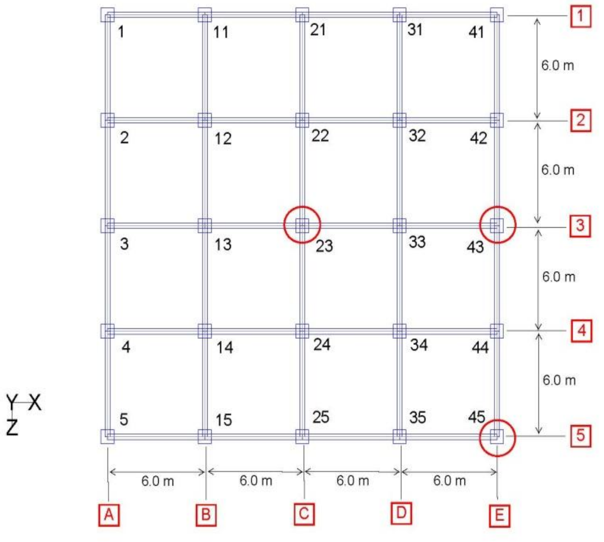

Figure showing Layout of building

S. No.	PARTICULERS	ASSUMPTION
1.0	Location	BHOPAL
2.0	Terrain	Category-II
3.0	Topography	Plane Ground Level
4.0	Basic wind speed	39.0 m/s
5.0	Age of structure	50 year
6.0	Class of structure	Class C
7.0	Risk coefficient (k1)	1
8.0	Grade of concrete	M25
9.0	Grade of steel	Fe 500

Table: 2. Details of Material & Data Assumption

MODELLING IN STAAD PRO

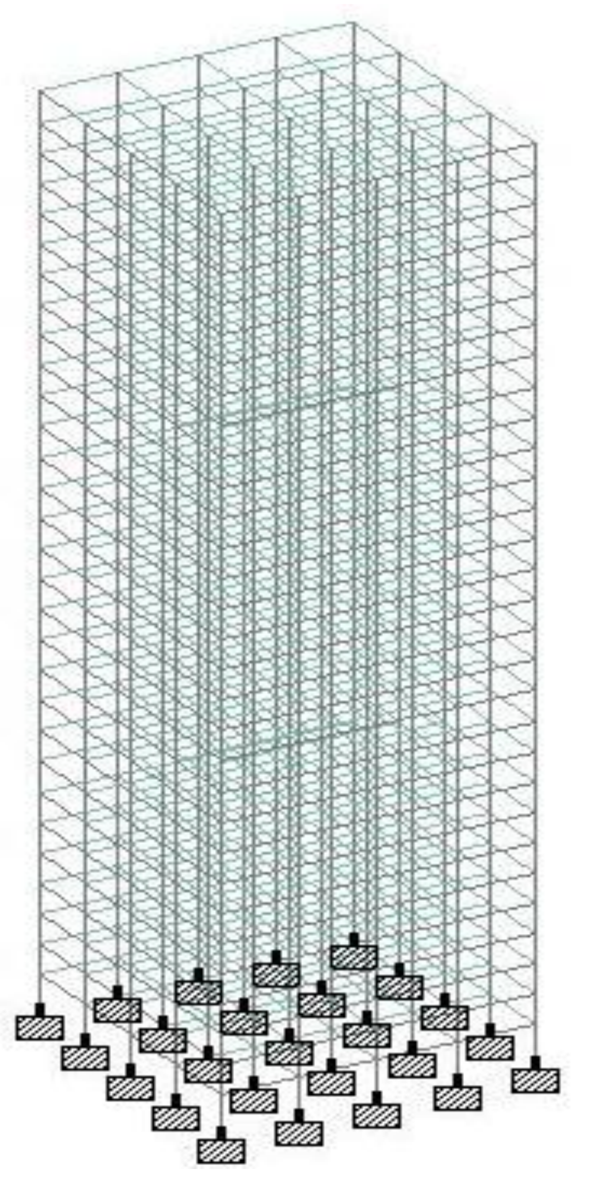

Fig: Isometric view of the modeled buildings in STAAD Pro software

LOAD CALCULATION

All the structural systems are subjected to three types of primary load cases as per the provisions of IS Code of Practice for Structural Safety of Buildings Loading Standard IS 875-1987 (Part I). They are:

1. Dead Load (From IS: 875-1987(Part I))
2. Live Load (From IS: 875-1987(Part II))
3. Wind Load (From 875-1987(Part III))

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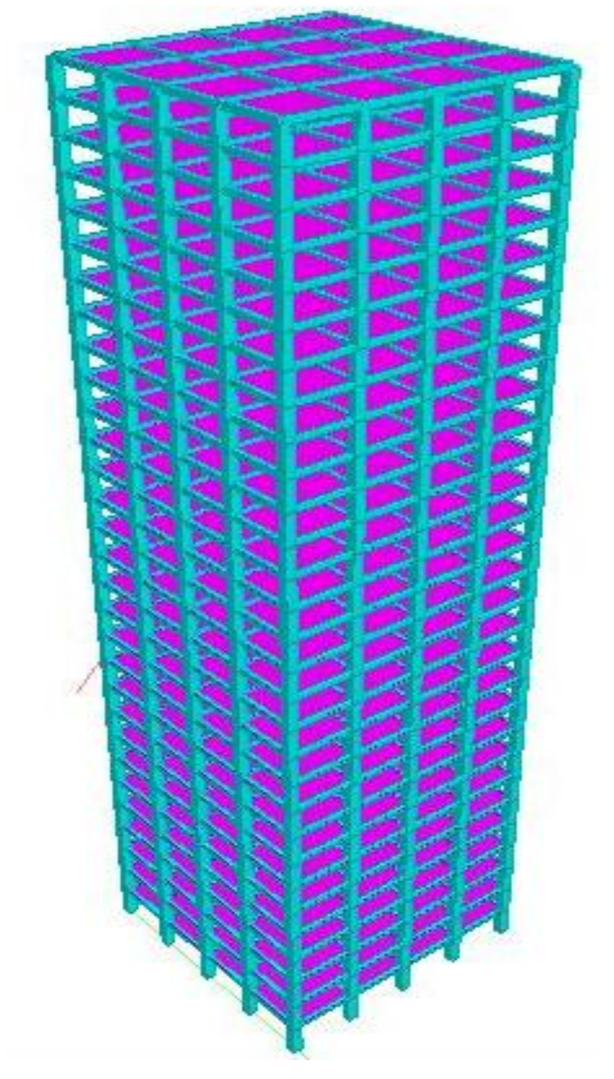

Fig : Rendered view of the modeled buildings in STAAD Pro software

Dead Load:

Self-weight : Dead load or self-weight of all members like beams and columns are calculated automatically in STAAD Pro. By applying a self load factor -1.05 in Load calculation column. Density of concrete used is 25 kN/m3 and thickness of slab used is 150mm.

Dead load of wall : Dead load of wall for density of 22 kN/m3 is calculated for 1m length and 2.80 m height and applied as UDL over external beams.

Dead load of floor finish : Dead load of floor finishing on each floor is assumed to be constant and applied in STAAD using floor load command for uniformly distributed load. Its value is taken as 1 kN/m2.

Live Load:

Live load on each floor is assumed to be constant and applied in STAAD using floor load command for uniformly distributed load. Its value is taken as 2.5 kN/m2.

Height of structure (m)	Floor under consideration	K2 factor	Vd (m/s)	Pd (KN/m2)	Cf1	F1 (KN/m)	Cf2	F2 (KN/m)
0 - 10	1 , 2, 3	0.93	36.27	0.79	1.3	**3.1**	1.1	**2.6**
10 - 15	4	0.97	37.83	0.86	1.3	**3.3**	1.1	**2.8**
15 - 20	5, 6	1	39	0.91	1.3	**3.6**	1.1	**3.0**
20 - 30	7, 8, 9	1.04	40.56	0.99	1.3	**3.8**	1.1	**3.3**
30 - 50	10 - 16	1.1	42.9	1.10	1.3	**4.3**	1.1	**3.6**
50 - 100	17 - 29	1.17	45.63	1.25	1.3	**4.9**	1.1	**4.1**

Note - Applied Load F1 & F2 on beam in respected direction as uniform distributed load in Staad.

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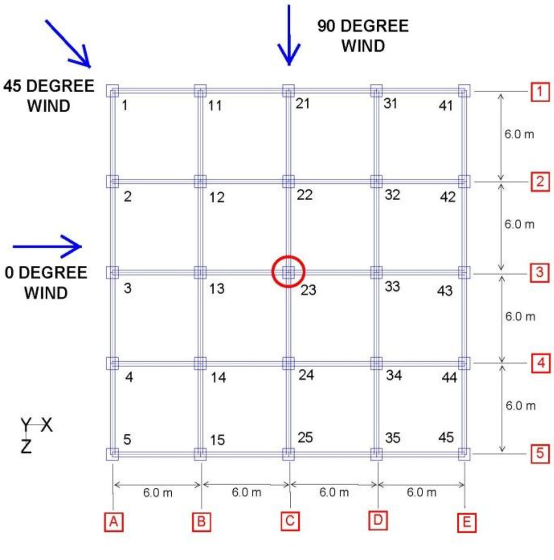
RESULTS

In order to study the effect of wind incidence angle on the response of building under wind loads, 3 wind directions namely 0º, 45º & 90º are considered. Variation of internal stress resultants in three critical column with respect to height of structure for different wind incidence angles are enlisted below which are further describe with graphical presentation in next pages.

1. Isolated study of Centre Column (Column no.-23)
2. Isolated study of Centre of outer face Column (Column no.-43)
3. Isolated study of Corner Column (Column no.-45)
4. Combined study of all three columns for support reaction
5. Deflection pattern and deflected shape of building

The direction of wind considered are shown in figure –



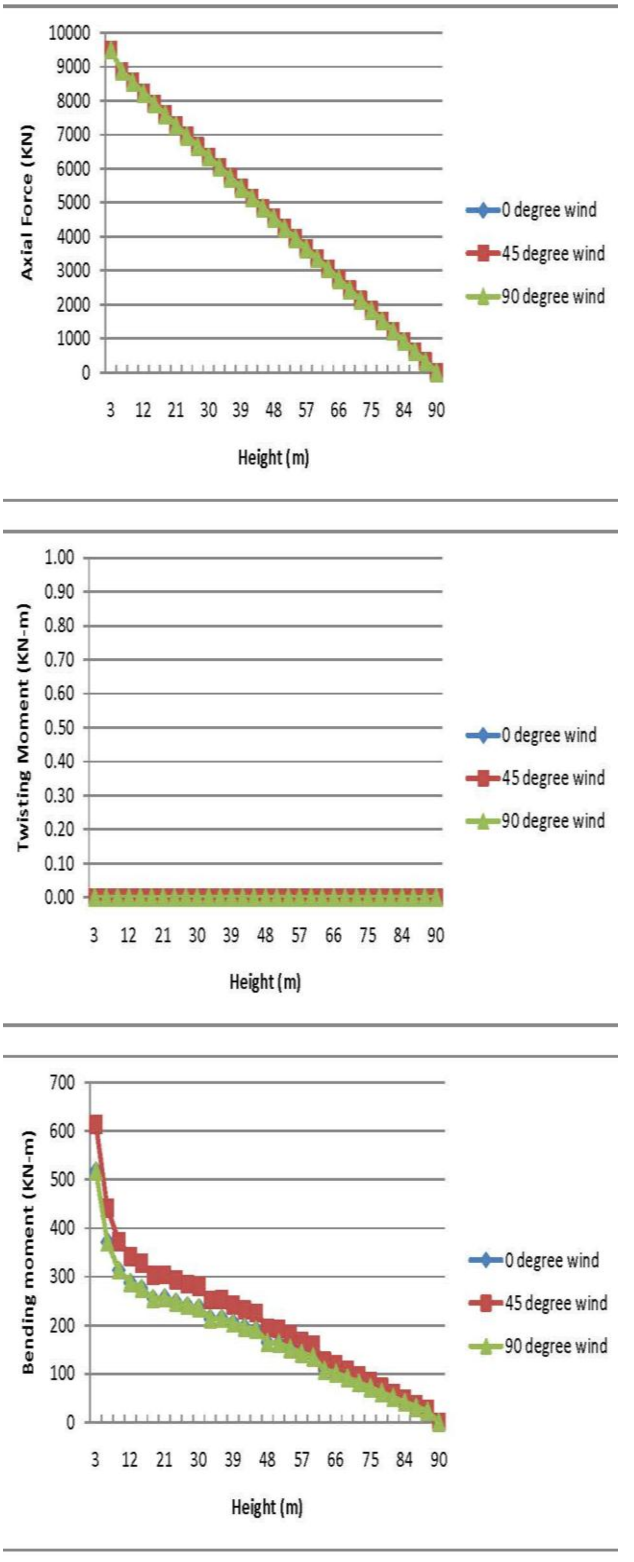


Fig: Variation of Internal stress variants vs. Height for different wind angle cases for column 23 of building under isolated condition

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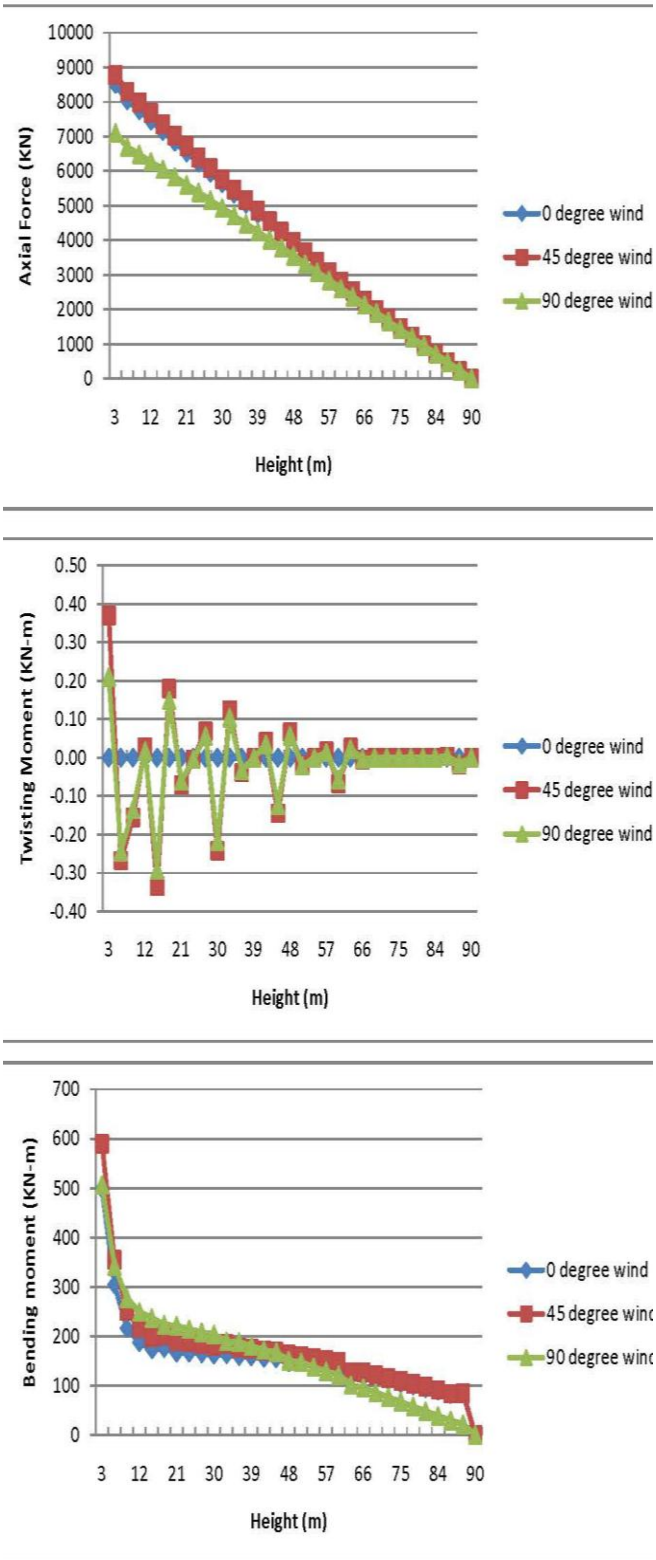

Fig: Variation of Internal stress variants vs. Height for different wind angle cases for column 43 of building under isolated condition Combined study of all three columns for support reaction

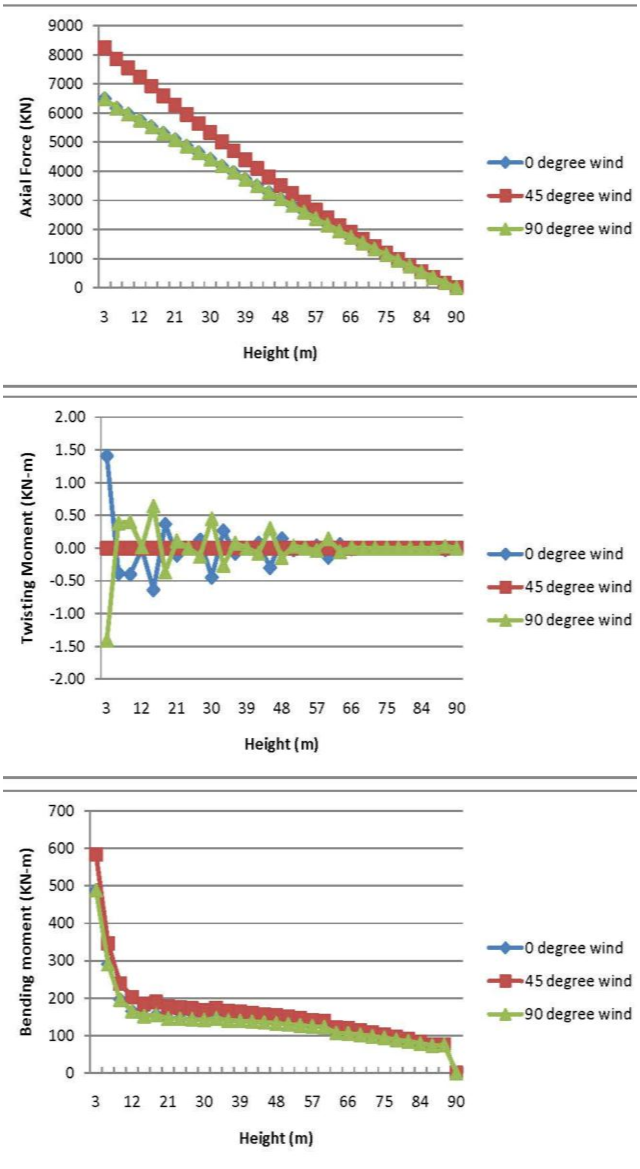

Fig: Variation of Internal stress variants vs. Height for different wind angle cases for column 45 of building under isolated condition

CONCLUSIONS

This report summarizes the results of the analytical study carried out to compare the effect of wind loading on square plan shape tall building having 30 stories under wind load applicable in 0°, 45°, 90° direction. These loads are then applied to the structure as uniformly distributed loads in the Staad. Pro software and then the structure is analyzed.

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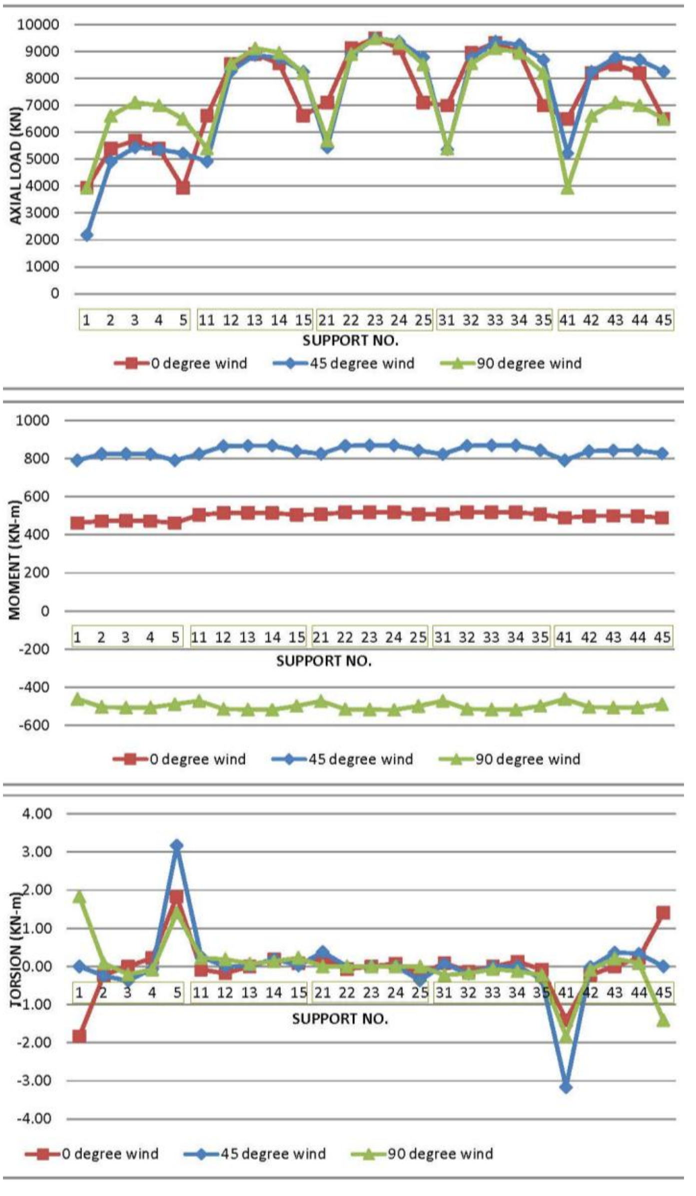

Fig 14 Variation of Internal stress variants for different wind angle cases for all column support of building under isolated condition

1. Behavior of axial forces are changed due to changing in direction of wind. This study shown a push pull effect on the structure it means the building as a whole act like a cantilever. The column which are located on wind ward side are experiencing less axial load while the axial load increases for the column of leeward side.

2. Maximum twisting moment is always occurring at columns located at corners and zero TM found at central column. The twisting effect is shown upto a height around 45 m from base which is approximately 15th floor, because of stiffness provided by the fixed ends at the base.

3. Overall twisting moment is very less but there is no fixed pattern in different wind cases. It can be reduced or increased depending upon shape of the structure, Fixity of the structure, wind load intensity, proximity of neighboring building etc. Due to fixity at base the columns are experiencing more twisting at base and the effect of twisting is reduces with height of structure.

4. Bending moment and displacement values depends on the area exposed to direct wind forces and the position of column. More area means more impact which causes more bending moment and displacement. Here, bending moments in column 23 is more compared with other columns due to present at the middle of the building and column 45 is very far from direct impact of wind loads so the bending moment is less.

It is, therefore, concluded that it is important to consider wind in all direction while designing tall buildings.

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