PARAMETRIC STUDY ON EFFECT OF WIND LOAD ON TALL BUILDING WITH AND WITHOUT INFILL WALL BY CONSIDERING EQUIVALENT DIAGONAL STRUT

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Abstract : The assessment of wind loads on structure is generally carried out using existing codes/standards. The specifications of these codes are based on wind tunnel experiment performed on an isolated building. However, the buildings seldom exist in isolated condition. Neighbouring building may either increase or decrease the wind loads on principal building, this effect is known as interference effect. In that case wind tunnel is better approach for different topography conditions and wind environments in interference effects. Here, in this paper attempt has been made to study wind interference effect on tall building by using available experimental results. The masonry infill walls influence greatly the response of the RC structures under lateral loading due to their contribution to strength and stiffness. In this study, the equivalent diagonal strut model is considered for modelling of infill walls. The basic parameter of this strut is its equivalent width. It has been noted that by providing diagonal strut as infill wall it increases the stiffness of building under lateral load.

***IndexTerms* - tall building, wind interference effect, infill wall, equivalent diagonal strut.**

I. INTRODUCTION

Nowadays, the trends for construction of tall buildings are rapidly increased due to growth of population day by day, lack of land, and increase in land prices in metropolitan cities. The development of advanced equipment and materials such as high strength concrete and steel and improvement in structure analysis and design has made construction of tall building more feasible. Design of tall building is mainly design for lateral load like earthquake and specially wind loads hence estimation of wind load for tall building is significant.

Wind load plays an important role while designing tall building. Earlier, symmetric plan shape buildings were used but due to development of technologies in civil and architectural field, asymmetric plan of buildings can be possible like ‘T’ and ‘Y’ shape. Present tallest building of world ‘Burj Khalifa’ which is a ‘Y’ shapes building. There are several codes along with Indian code on wind loads [IS 875 (Part-3) 2015, ASCE: 7-02-2002, BS: 63699-1995, AS/NZS: 1170.2-2002, EN: 1991-1-4-2005]. But these codes give standard pressure and force mainly for isolated buildings.

However, tall building is rarely shown isolated in urban areas. The existing of surrounding buildings affects the wind pattern flow around the buildings. Neighbouring buildings may increase or decrease the wind loads on principal buildings. Hence it is very significant to conduct wind tunnel tests on the models of building together for accurate calculations of wind loads. The main parameters of the interference effects on principal building are size and shape of the buildings, wind direction, velocity of wind, types of terrain, location of interfering buildings.

Interference effects:

A body or structure when placed in a wind flow experiences forces and pressures. When one or more structures are existing upstream or downstream of structure, the wind forces and pressures for isolated building may increase or decreased. This phenomenon is called Interference Effect. Interference will occur on flexible as well as rigid body. If it is rigid, then ‘wake’ of one body affects the other, while the body is flexible, deflections of the body may affect the wake itself. The phenomenon of interference is experienced greatly in practice but it is very complicated to quantify in general because of the variability of situation involved.

The existing neighbouring building may increase or decrease the wind loads on a principal building, depending mainly on several parameters like geometrical, structural and wind parameters, including size, section shape, relative position of these buildings, wind velocity, number of the adjacent buildings, upstream terrain conditions etc.

The ratio of the value of a typical response parameter for a structure due to interference by the corresponding value of the isolated is called Interference Factor.

Nowadays, mostly reinforced concrete buildings are constructed with masonry infill walls. Masonry infill walls are used only for privacy point of view and often used to fill the voids between the vertical and horizontal resisting elements of the building frames with considering that these masonry infill walls will not resist any kind of load either axial or lateral. Hence, generally it is not considered for both strength and stiffness in the analysis of the frame.

Moreover, non-availability of realistic and simple analytical models of infill becomes another obstruction for its consideration in analysis. The masonry infill walls influence greatly the response of the RC structures under lateral loading due to their contribution to strength and stiffness. Here, several approaches for different types of modelling the infill walls discussed in the literature. In this study, the equivalent diagonal strut model is considered. The basic parameter of this strut is its equivalent width.

II. RESEARCH METHODOLOGY

In this work, analytical study has been done on ‘T’ shape buildings in ETABs (2017) software by using pressure coefficient values obtained from experimental study done on these models previously by Ahlawat (2015). Compare the models with and without providing Equivalent Diagonal Strut as masonry wall. This study includes comparison of various parameters, namely, axial force, displacement and bending moment between isolated and interference cases.

2.1 Details of Building

Buildings considered here are ‘T’ plan shape buildings having total height of 100 m. The buildings are assumed to be located in Delhi in terrain category 2. Columns 1 and 2 are considered for analysis in T shape buildings (Figure 1). Dimensions in the modelling are given table 1 (Ahlawat 2015) and load values in table 2.

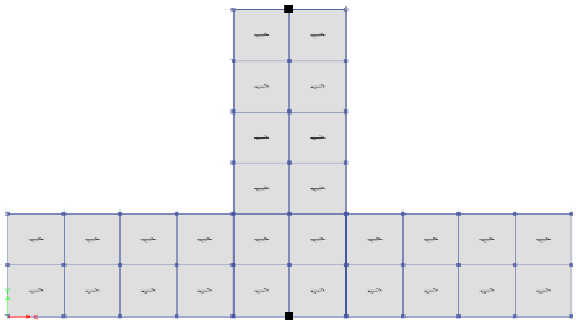


Figure 1: Plan of the modelled building and columns which are considered for analysis

Table 1: Description of the building and frame elements

Sr. No.	Particulars	Details
1.	Storey height	4m (ground floor) and 3.2m (other floors)
2.	Number of floors	31 (G+30)
3.	Height of Building	100 m
4.	Centre to centre distance between columns	5m in both directions
5.	Column cross section (for 0 to 8th floor)	800mm * 800mm
6.	Column cross section (for 9th to 16th floor)	700mm * 700mm
7.	Column cross section (for 17th to 21st floor)	600mm * 600mm
8.	Column cross section (for 22nd to 26th floor)	500mm * 500mm
9.	Column cross section (for 27th to 31st floor)	400mm * 400mm
10.	Beam cross section	500mm * 300mm
11.	Slab thickness	150mm
12.	Wall thickness	250mm

Table 2: Details various loads

Details of various loads	
Dead load	self-weight of all building element
	Density of external wall = 19 kN/m^3
Live load	4 kN/m^2 on typical floor
Wind load	Wind speed = 47 m/s
Load Combination	1.2* (DL + LL + WL)

These dimensions are finalized after assuming some random dimensions and designing it in ETABs (2017) for dead load and live load. Dead load of wall is taken over outer beams instead of actual wall consideration in ETABs as it would make the building stiff and results would be modified accordingly. Then the second model the masonry wall is modelling as diagonal strut. Isometric view of T shape model with and without diagonal strut in ETABs are shown in Figure 2.

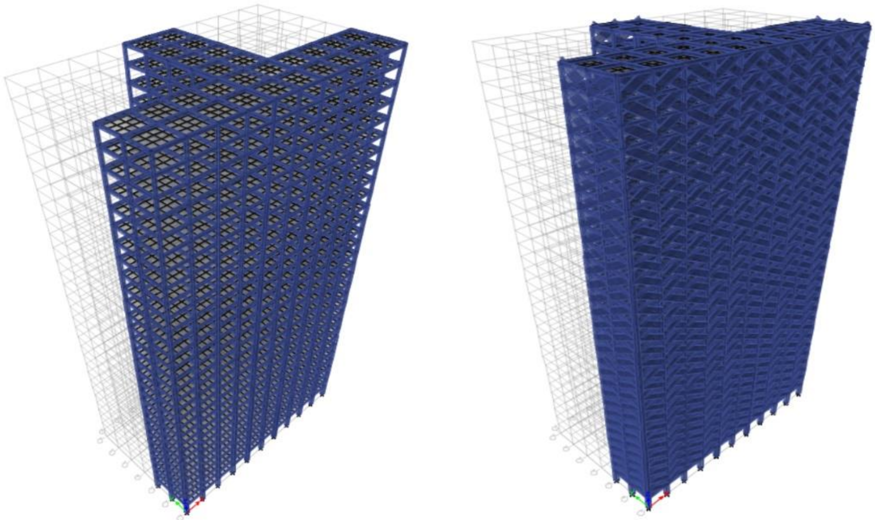
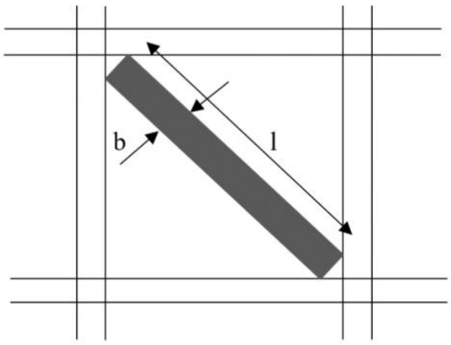


Figure 2: Isometric view of modelled building in ETABs software

2.2 Modelling in ETABs

In building model M30 grade concrete is used as material for beams and slabs whereas M60 grade is used for columns. For simplicity in modelling, length of each beam is kept to be 5m. Height of columns in ground floor is 4m and in other floors is 3.2m. There are no walls provided either partition or external, but loads due to external walls is considered by applying uniformly distributed load (UDL) over all beams in the periphery of the building. All the supports on ground are fixed. Dead, Live and Wind loads are applied and response is obtained for one load combination.

The masonry infill walls influence substantially the response of reinforced concrete buildings under lateral loading due to their contribution to strength and stiffness. If structural plan density (SPD) is exceeds 20 % then infill modelling should be done as per IS 1893:2016 (Part-I). SPD for considered models is 20%. For infill wall modelling two methods have been proposed in order to properly simulate the behaviour of masonry infill walls, namely the micro-model method and the macro-model method which has been introduced in 1960 by Polyakov [2]. Micro-model method gives good results and can be used for understanding local and global response but it is rarely used due to its complexity in generating the model and tedious calculation. Macro-model method, also called the equivalent diagonal strut method, has been developed to study the global response of masonry infill frame buildings.



t = Thickness of strut = 250 mm
l = length of diagonal = 5.682 m
E = Modulus of Elasticity = 3630 MPa
f'm = Compressive Strength of Brick Prism = 6.6 N/mm^2
Weight per unit volume = 19 kN/m^2
b = width of diagonal strut (As per IS:1893-2016)
= $0.175 \times \alpha_h^{-0.4} \times l$ = 896.3 mm (For column 800 × 800 mm)

Figure 3: Details of equivalent diagonal strut

III. Results and Discussion

Analysis of buildings are done using ETABs software and results are plotted in graphs showing variation of different parameters of considered columns with respect to height. In building, columns 1 and 2 are considered which are shown previously in Figure 1. Parameters, known as internal stress resultants, considered for this study are Axial forces, Bending moments and Displacements.

Various cases considered for this study are as follows:

1. Isolated cases for 0° and 180° wind angles with and without Diagonal Strut.
2. Interference case for 0° and 180° wind angles with spacing 0 mm with and without Diagonal Strut.

3.1 Isolated Study of Building under 0° and 180° Wind Angles with and without Diagonal Strut

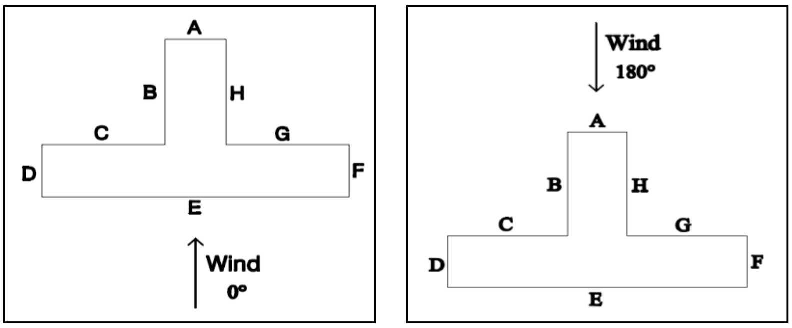


Figure 4: Wind directions considered on isolated T-shape building [Ahlawat, 2015]

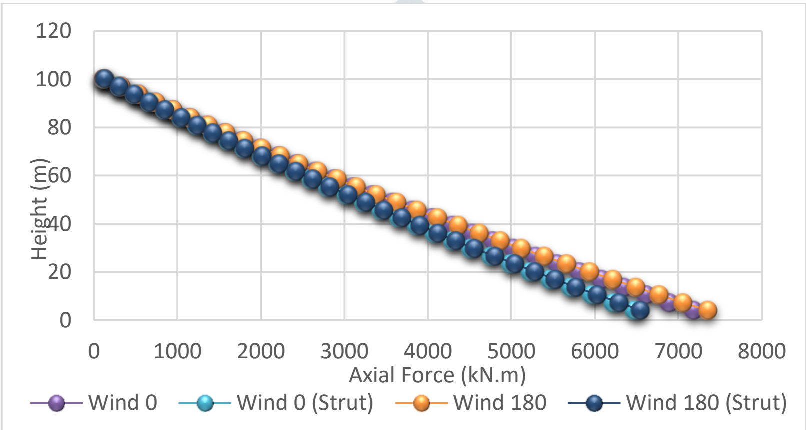


Figure 5: Axial force vs. Height for wind angle cases for column 1 of building under isolated condition

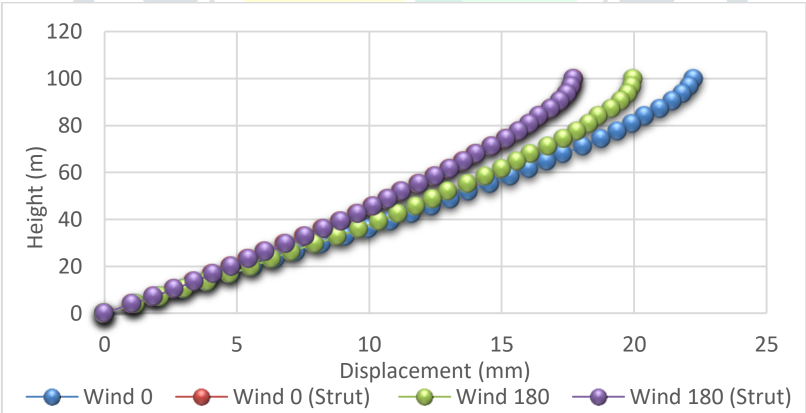


Figure 6: Displacement vs. Height for wind angle cases for column 1 of building under isolated condition

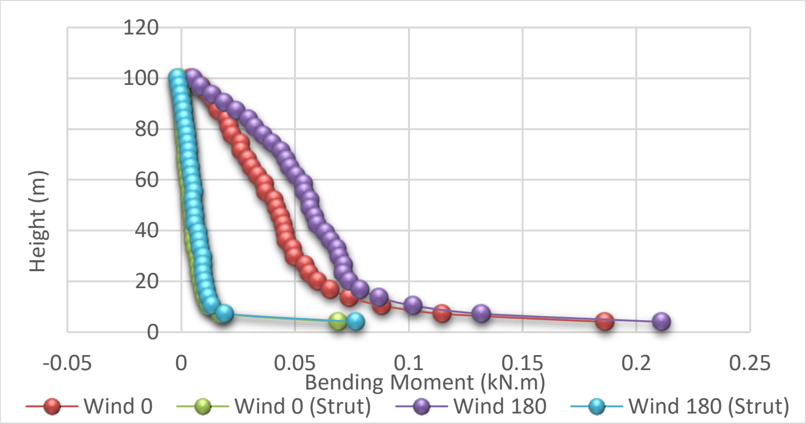


Figure 7: Bending moment vs. Height for wind angle cases for column 1 of building under isolated condition

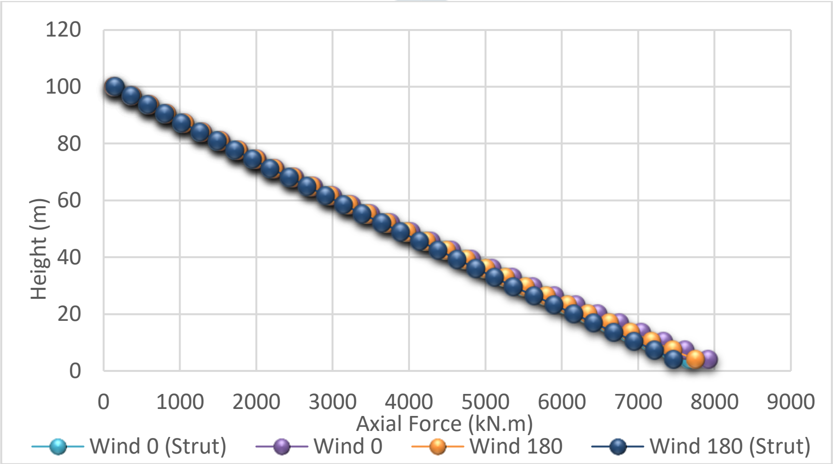


Figure 8: Axial force vs. Height for wind angle cases for column 2 of building under isolated condition

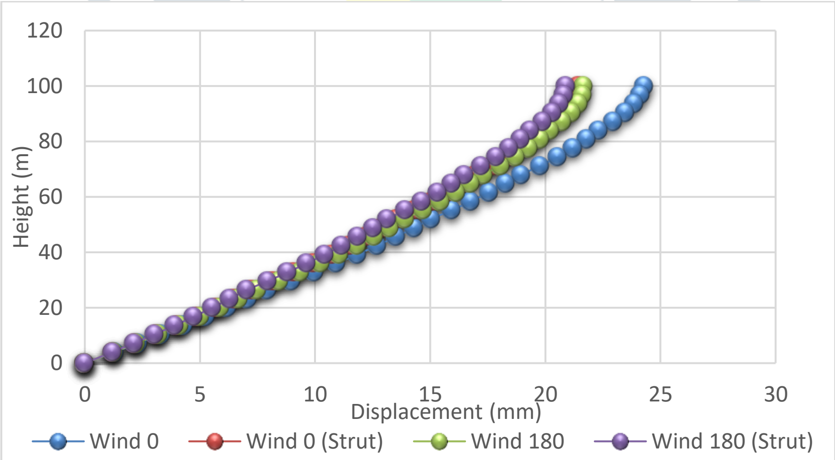


Figure 9: Displacement vs. Height for wind angle cases for column 2 of building under isolated condition

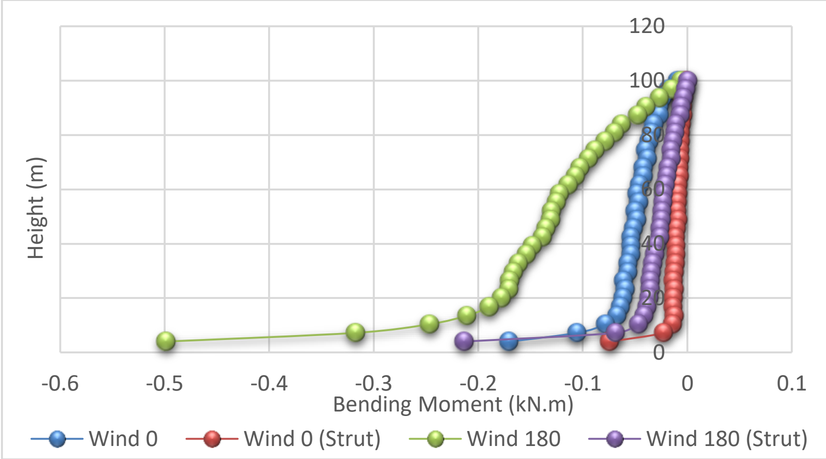


Figure 10: Bending moment vs. Height for wind angle cases for column 2 of building under isolated condition

- It is seen from figures that axial forces are almost same in both wind 0 degree and 180-degree case for all the columns. Which shows that it is directly related to dead load. Axial force is increasing from top storey to bottom storey.
- By providing diagonal strut it has been noted that axial forces are 8 to 10 % decreased in column 1 and 3 % in column 2. Bending moment is increasing from top storey to bottom storey. Bending moment is negative for the all the cases in column 2 and positive for all the cases in column 1 due to direction of wind. Due to effect of diagonal strut bending moment is decreases up to 80 to 85 % for wind 0 degree while 70 to 75 % in wind 180-degree case.
- Displacement is related to the area exposed to wind directly. which is increases as bottom storey to top storey.

3.2 Interference Study Of Building With 0 Mm Spacing For 0° And 180° Wind Angles With And Without Diagonal Strut

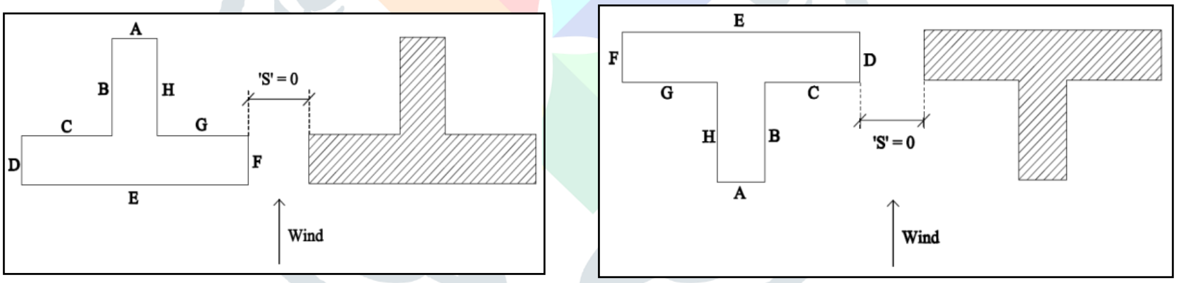


Figure 11: Wind interference conditions with 0 mm spacing for 0° and 180° wind angles on T-shape building [Ahlawat, 2015]

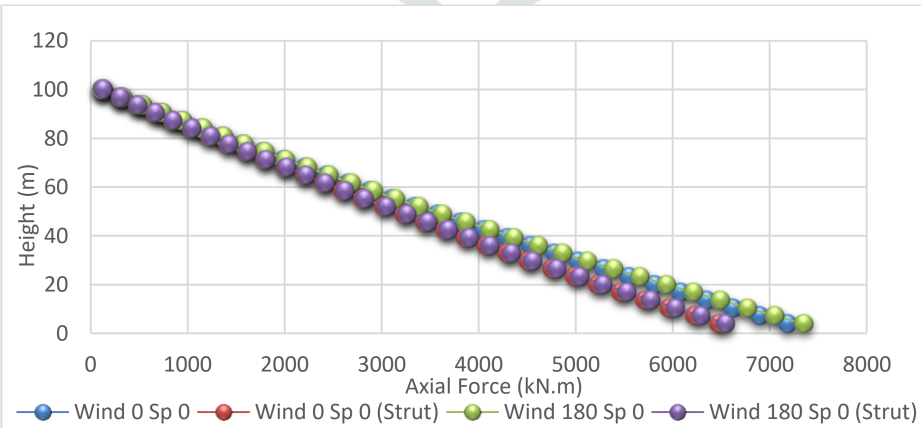


Figure 12: Axial force vs. Height for wind angle cases for column 1 of building under interference with 0 mm spacing condition.

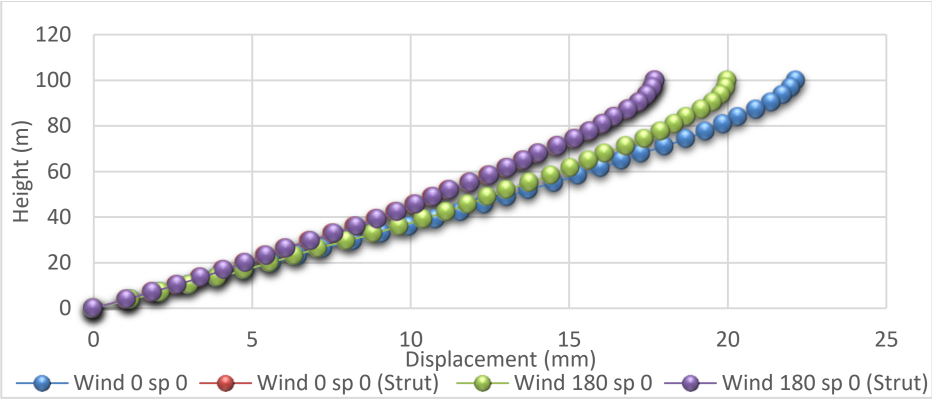


Figure 13: Displacement vs. Height for wind angle cases for column 1 of building under interference with 0 mm spacing condition.

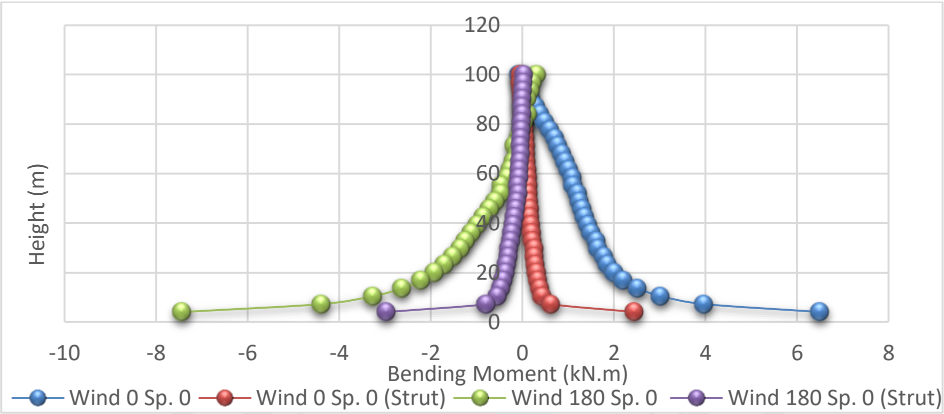


Figure 14: Bending moment vs. Height for wind angle cases for column 1 of building under interference with 0 mm spacing condition.

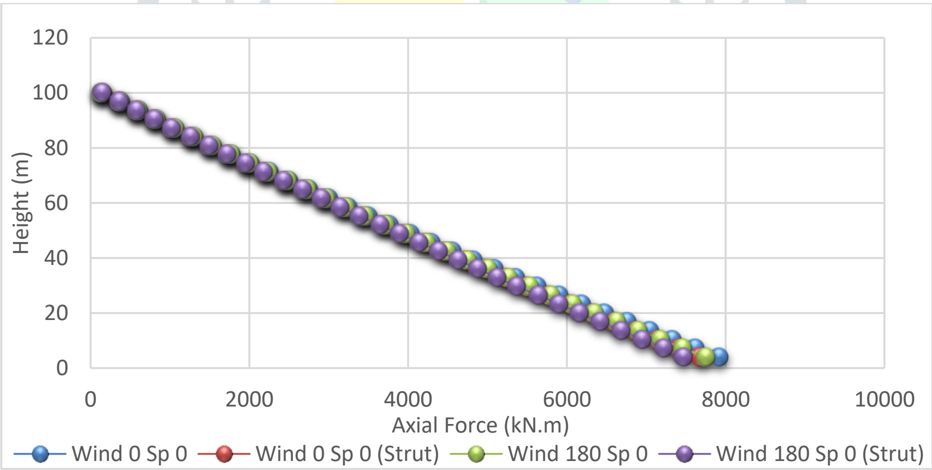


Figure 15: Axial force vs. Height for wind angle cases for column 2 of building under interference with 0 mm spacing condition.

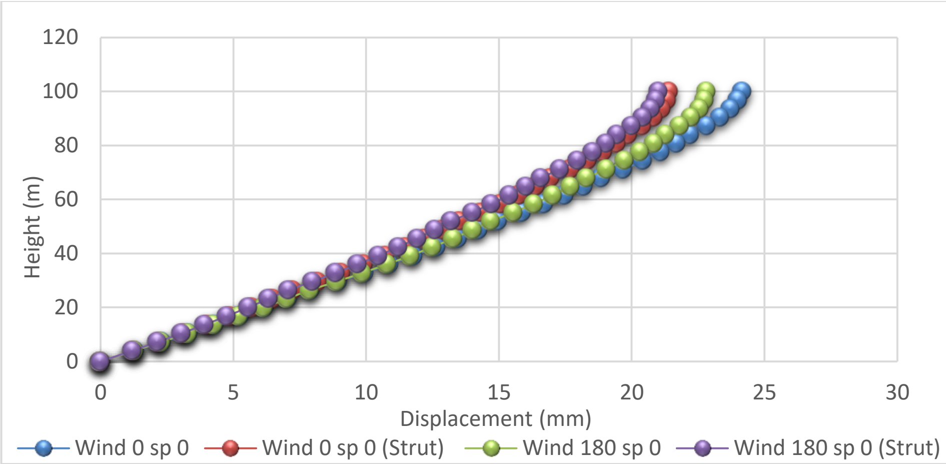


Figure 16: Displacement vs. Height for wind angle cases for column 2 of building under interference with 0 mm spacing condition.

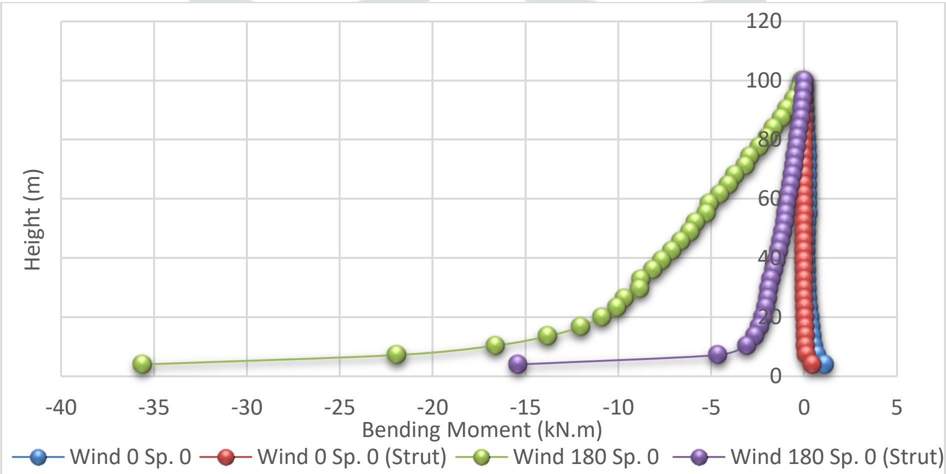


Figure 17: Bending moment vs. Height for wind angle cases for column 2 of building under interference with 0 mm spacing condition.

- It is seen from figures that variation in axial forces are almost negligible in both isolated and interference cases for all the columns. This axial force consists of weight of column and slab of each floor and from results it is clear that it is not affected by change in wind loads. Also due to diagonal strut axial force is decreases by 5 to 7% for wind 0 & 3 to 5 % for wind 180-degree case.
- Bending moment (BM) is zero at the top and maximum at the base While axial force is maximum at base and minimum at top. Due to diagonal strut bending moment is decreases by 80 to 85 % wind 0 and 70 to 80 % wind 180-degree case.
- Maximum resultant displacement is around 24 mm in column 2. Resultant displacement is decreases due to effect of diagonal strut is up to 10 to 12% in both wind 0 & wind 180-degree cases.

IV CONCLUSIONS

Effect of wind for irregular plan building with different wind angles and interference of building causes major damages to the building. Also ignoring masonry infill wall in later load analysis lead to damages to building. In this study, the irregular plan T shape building with considering wind angels 0° and 180° with isolated and wind angels 0° with interference of same building with 0 mm spacing. Then wind pressure coefficient from wind tunnel experiment Ahlawat (2015) is directly applied on beam column joint. Masonry wall is modelling as equivalent diagonal strut. Compare the variation in internal stresses like axial force, bending moment and displacement with and without diagonal strut. Conclusion drawn from the analysis are shown below:

- It is seen from graphs axial forces have no effect of interference and its value remains same in all of the cases.
- Due to effect of diagonal strut axial force has been decreased by 7 to 10 % in all cases.
- By using diagonal strut, the displacement has been decreased by up to 10 to 15 % for all for all cases.
- 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 1 and 2 are less.

- Due to diagonal strut the bending moment has been decreased by 70 to 80 % in all the isolated and interference cases.
- It is, therefore, concluded that it is important to consider interference conditions while designing tall buildings for wind loads.
- It is noted after results that masonry wall by considering diagonal strut reduces effect of lateral load like wind loads.

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