Equivalent wind Static Load Analysis on Tall Structures

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Abstract— Structures are classified into two types rigid and flexible, our part of the study is on tall structures which are more flexible and are susceptible to the vibrations which are caused or induced by wind forces. In the analysis and design of high rise buildings estimation of wind loads and their inter story drifts are the two important things to be considered for the reason that there should be safe living of the inhabitants. Inter storey drift can be controlled through suitable structural system. The present study involves the study of calculation of wind displacements and its inter storey drifts using equivalent static analysis for forty storey building and results are compared with respect to various wind speeds .Also analysis is carried out for static and gust pressure comparision,as well as base shear calculations. Structure is analyzed using fem analysis with wind load calculated by static method as per IS-875partIII 1987 with and without shear walls.

***Key words*:** wind, displacement, drift, frequency, base shear.

I. INTRODUCTION

Wind in a structural engineers point of view is defined as lateral load which causes increase in greater moments and forces at the base of the building and also we are familiar that, In most of the developing countries around the world the cities are been growing at very faster rates, leading to a common feature in the growth of vertical buildings, because horizontal expansion has reached the saturation point. Which is also leading to adequacy of land in metro cities that is why it is must and should for a structural engineer to know about tall buildings and the effect of wind loads on it.

Therefore the building plan has to be designed in a symmetrical about the axes so that centre of lateral stiffness and mass coincides on each other so that wind forces which are acting on centre of the mass of the floor diaphragm which is resisted by the buildings at the centre rigidity by its stiffened members.

In case of static structure the flow only interacts with external body of the building, similarly when structures are very stiff deflections under wind load will not be significant therefore structure is said to be “static”

A. Loading System

Dead Load: All permanent constructions of the structure form the dead loads. The dead load comprises of the weights of walls, partitions floor finishes, false ceilings, false floors and the other permanent constructions in the buildings. The dead load loads may be calculated from the dimensions of various members and their unit weights. the unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m” and 25 kN/m” respectively.

B. Live Load

Imposed load is produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, load due to impact and vibration and dust loads. Imposed loads do not include loads due to wind, seismic activity, snow, and loads imposed due to temperature changes to which the structure will be subjected to, creep and shrinkage of the structure, the differential settlements to which the structure may undergo.

C. Wind load

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 meters above ground.

Fig. 1: Pedestrian discomfort. A simple task such as crossing a plaza may become extremely unpleasant during winter months in cold climates

II. CALCULATION OF WIND LOAD

Wind load is calculated based on two different methods a) Static method and b) Gust factor method.

A. Static method

The basic wind speed Vb of a region correspond to certain reference conditions as highlighted in the earlier section, and shall be modified to include the effects of risk level, terrain roughness, height, structure size and local topography to obtain design wind speed, Vz in m/s at height z for the chosen structure as given below

Vz = Vbk1 k2 k3; Where Vz = Design wind speed (in m/s) at height z

Pz = 0.6Vz2

Vb = Basic wind speed for the site (33m/s,39m/s,44m/s,47m/s)

k1 = Probability factor or risk coefficient with return periods (1.06,1.07,1.07,1.08)

1) k2 = Factor for the combined effects of terrain (ground roughness) height and size of the component on structure. Table-2, Terrain category3, Class B- from IS 875 Part III- 1987)

k3 = Factor for local topography (hills, valleys, cliffs, etc.)

The following table shows Static pressures calculated using IS: 875 (Part III)

2) Modelling details

Our plan consists of 40 storey building with 13 Number of bracings with the spacing 6meters each The comparative study for modeling is for various Wind zones with and without shear wall.

3) Analysis of building for variation

Category 3 - terrain with numerous closely spaced obstructions having the size of building structures up to 10m in height with or without a few isolated tall structures.

4) Wind data

Wind Zone: Basic wind speed 33,39,44,47 m/s
Terrain Category : III
Class of Building : B
Topography : Flat

Wind speeds, design wind pressure, loads to the building are calculated using standard IS codes.

III. Building Description

A multi storey building of 40 storey which is been planned in different stages ,accordingly it consists of 15 storeys in the first stage ,again 15 number of storeys in the second stage with the elimination of 3braces at outer periphery, similarly the thord stage consists of 10 storeys with elimination of 5braces at periphery of the building plan as shown in figure1,figure 2,figure 3 and elevation of the building plan.

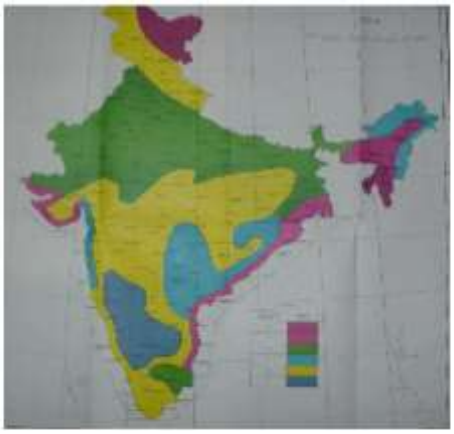

Fig. 1:

IV. Pressure Coefficients

The pressure coefficients are always given for a particular surface or part of the surface of a building. The wind load acting normal to a surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient (C,) and the design wind pressure at the height of the surface from the ground. The average values of these pressure coefficients for some building shapes Average values of pressure coefficients are given for critical wind directions in one or more quadrants. In order to determine the maximum wind load on the building, the total load should be calculated for each of the critical directions shown from all quadrants. Where considerable variation of pressure occurs over a surface, it has been subdivided and mean pressure coefficients given for each of its several parts.

Then the wind load, F, acting in a direction normal to the individual structural element or Cladding unit is:

F= (Cpe – Cpi) A Pd

Where,

Cpe = external pressure coefficient,

Cpi = internal pressure- coefficient,

A = surface area of structural or cladding unit, and

Pd = design wind pressure elements) Individual cladding units including glazing and their fixings.

pressures	Cpe	Cpi
Upto 15 storey	0.7	-0.25
16-30 storey	0.8	-0.25
31-40 storey	0.9	-1.25

Table. 1:

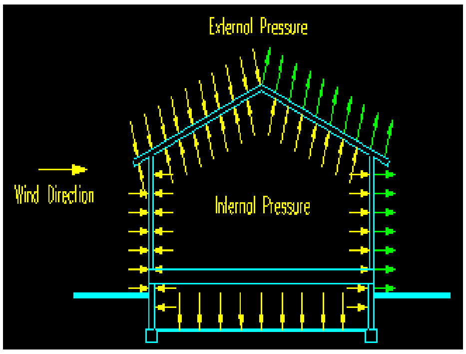

Fig. 2:

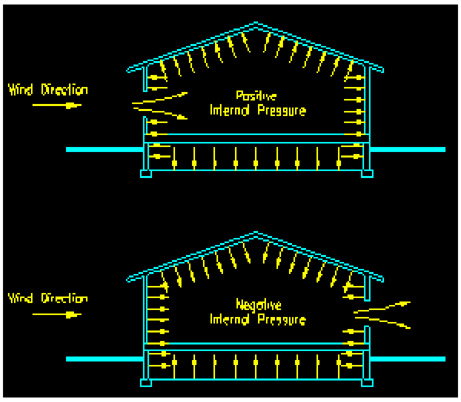

Fig. 3:

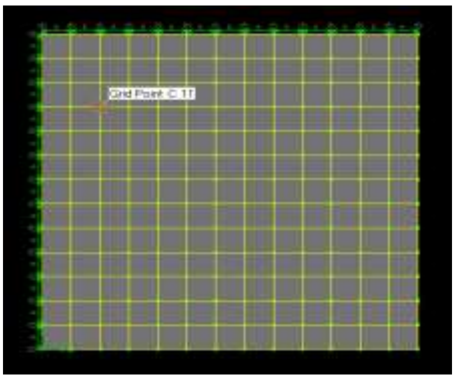

Fig. 4: plan Model at stage 1

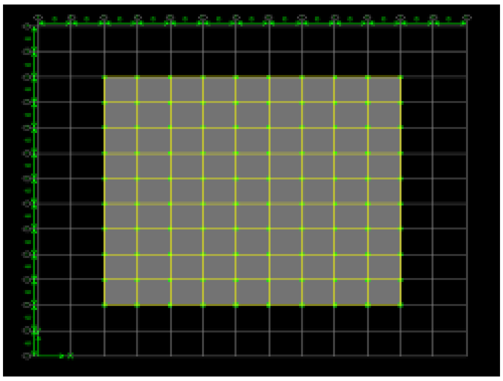

Fig. 5: plan Model at stage 2

Bracing details	6mx13m
No of bracing lines along plan length	13
No of bracing lines along plan width	13
Spacing of braces	6
Floor to floor height	3.5m
Total no. of floors	40
Floors in first stage Floors in second stage Floors in third stage	15 15 10
Beam details(M30)	300mmX600mm
Column details: at first stage(M40) At second stage(M30) At third stage(M30)	600mmX600mm 600mmX600mm 500mmX500mm
Thickness of slab	150mm
live load Floor finish	4Kn/m^2 3Kn/m^2

Table. 2:

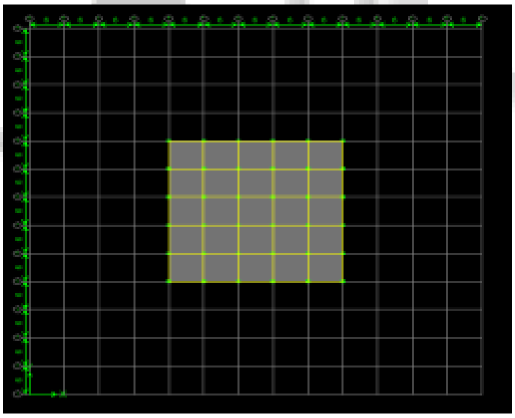

Fig. 6: Plan Model at stage 3

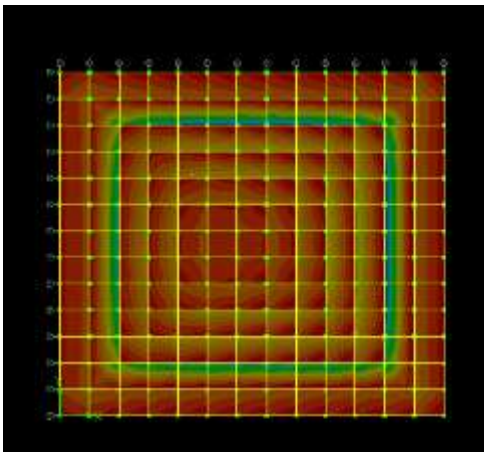

Fig. 7: Max stress in the plan

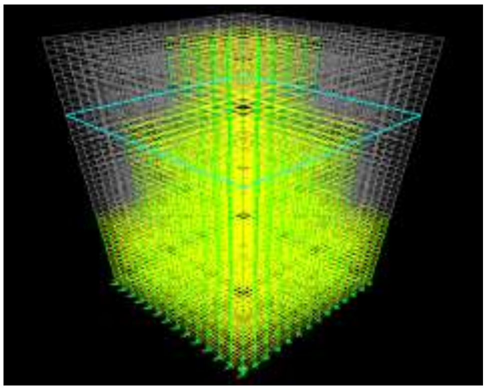

Fig. 8: Elevation (3D model)

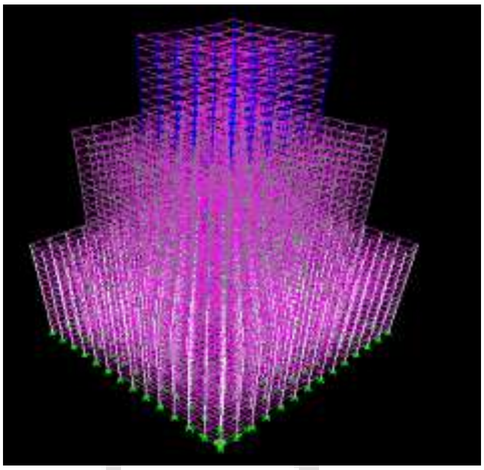

Fig. 9:

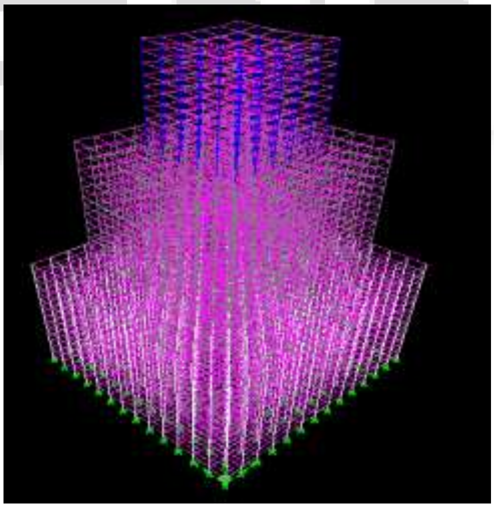

Fig. 10: Deformed shape

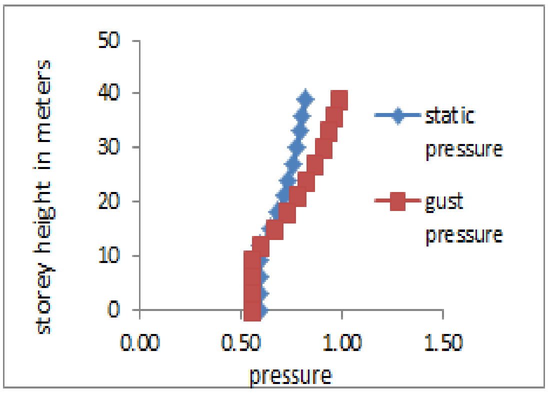

Fig. 11: Variation of static and gust pressure with height

level	elev	k2	vz	static pz
1	39	1.057	36.97	0.82
2	36	1.048	36.66	0.81
3	33	1.039	36.34	0.79
4	30	1.030	36.03	0.78
5	27	1.015	35.50	0.76
6	24	1.000	34.98	0.73
7	21	0.985	34.46	0.71
8	18	0.964	33.72	0.68
9	15	0.940	32.88	0.65
10	12	0.904	31.62	0.60
11	9	0.904	31.62	0.60
12	6	0.904	31.62	0.60
13	3	0.904	31.62	0.60
14	0	0.904	31.62	0.60

Table. 3:

level	elev	k2	vz	gust pz
1	39	0.667	23.33	0.98
2	36	0.658	23.02	0.95
3	33	0.649	22.70	0.93
4	30	0.640	22.39	0.90
5	27	0.625	21.86	0.86
6	24	0.610	21.34	0.82
7	21	0.595	20.81	0.78
8	18	0.574	20.08	0.73
9	15	0.550	19.24	0.67
10	12	0.520	18.19	0.60
11	9	0.500	17.49	0.55
12	6	0.500	17.49	0.55
13	3	0.500	17.49	0.55
14	0	0.500	17.49	0.55

Table. 4:

V. SHEAR WALLS

Shear walls are plane elements made up of reinforced concrete thin walls having length and thickness providing lateral stiffness. The shear and overall flexural deformations are design constraints, along with the stress levels, axial and bending. Concrete shear walls may be cast in place or pre-cast. Pre-cast panel walls are also used within a concrete or steel frame to provide lateral resistance. The ductile shear walls used in earthquake resistant design have to be detailed carefully. Coupling beams should have diagonal reinforcement to develop shear resistance. Steel shear walls are also used sometimes, by connecting them to framework by welding or high strength bolts. Masonry shear walls are also used, with solid walls and grouted cavity masonry to carry shears and moments, with reinforcements encased.

VI. LATERAL DISPLACEMENT IN EQUIVALENTSTATIC METHOD

Wind speeds	Model at 40th floor	Model at 30th floor	Model at 20th floor	Model at 15th floor	Model at 10th floor	Model at 1st floor
33m/s	0.0627	0.0443	0.0299	0.0204	0.0145	0.009
39m/s	0.0892	0.063	0.426	0.0290	0.0207	0.0013
44m/s	0.1157	0.0817	0.0552	0.0377	0.0268	0.0016
47m/s	0.1320	0.0932	0.063	0.043	0.306	0.0019

Table. 5: Variation of maximum lateral displacement in meters at different heights for different wind speeds in wx direction with shear wall

Wind speed	Model at 40th floor	Model at 30th floor	Model at 20th floor	Model at 15th floor	Model at 10th floor	Model at 1st floor
33m/s	0.0427	0.0318	0.0200	0.0137	0.0084	0.0003
39m/s	0.0607	0.0452	0.0285	0.0195	0.0119	0.0005
44m/s	0.0788	0.0587	0.0369	0.0253	0.0155	0.0006
47m/s	0.0877	0.0663	0.0418	0.0287	0.0172	0.0005

Table. 5: shows the variation of maximum lateral displacement for different models at different wind speeds(Equivalent static method in X-direction with and without shear wall).

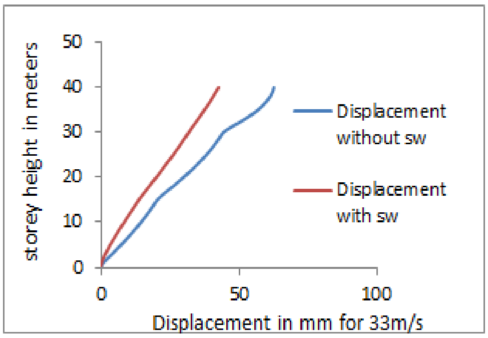

Fig. 12(a):

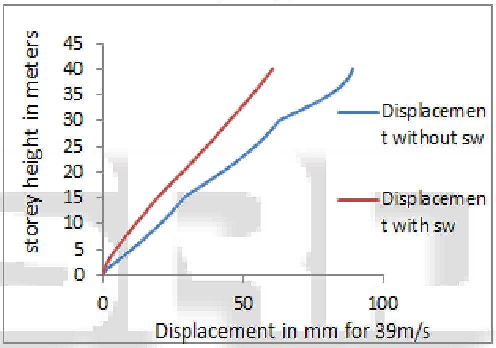

Fig. 12(b):

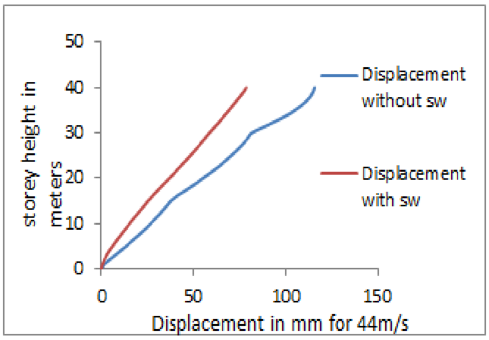

Fig. 12(c):

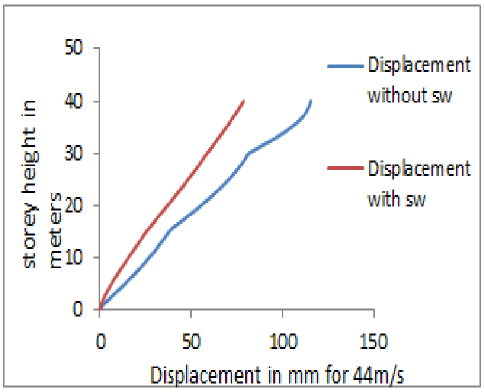

Fig. 12(d):

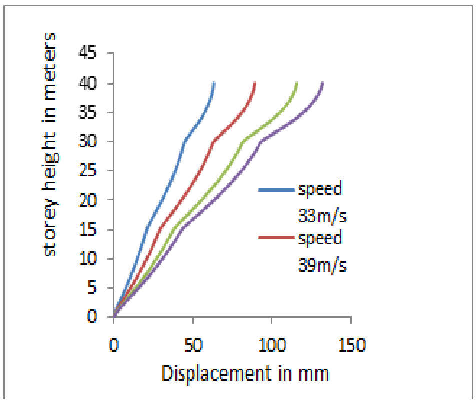

Fig. 12(e):

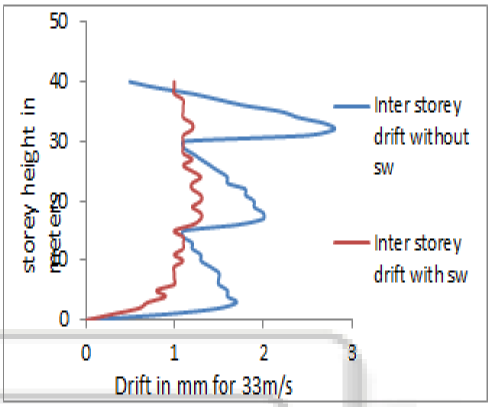

Fig. 12(f):

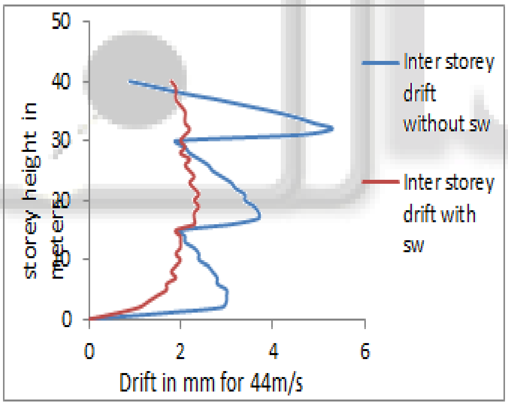

Fig. 12(g):

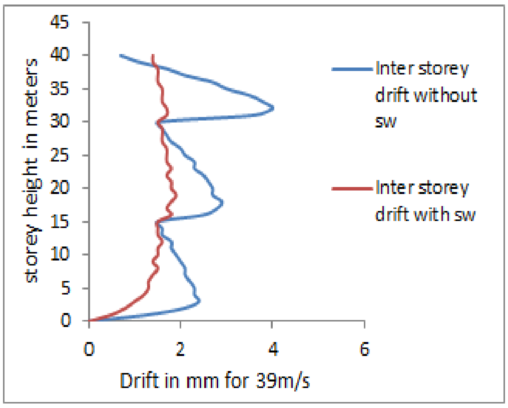

Fig. 12(h):

Fig. 12(a,b,c,d,e,f,g,h): Combined effect of displacement for different wind zones without shear wall

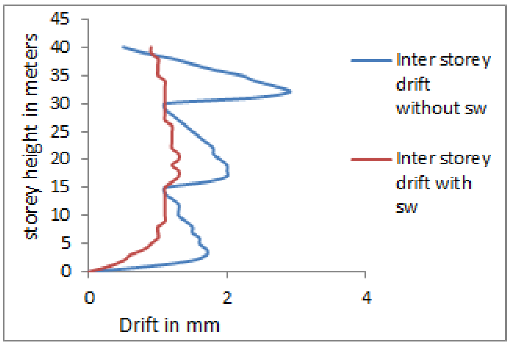

Fig. 13(a):

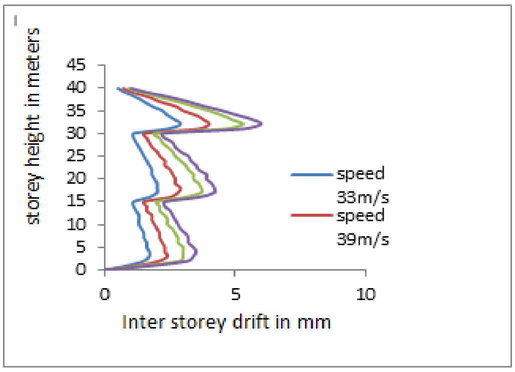

Fig. 13(b):

Fig. 13(a,b): Combined effect of inter storey drift for different wind zones without shear wall

VII. COMFORT

Concerning comfort, some tall buildings may experience vibrating sway, which is the back and forth movement of a building due to wind loads. Such sway can lead to cracking in the concrete and further weakening of the structure due to fatigue, if the sway is considerably strong and frequent. This sway may also cause the users of the building to experience motion sickness which causes nausea.

A building with uncomfortable movements may even be uninhabitable. An engineer can hinder these effects through creating an aerodynamic structure which is less affected by the winds, through designing the structure with attention to strengthening against sway and There exists a certain frequency range that is uncomfortable for people. Most people feel the affects of motion sickness in the frequency range 0.1 - 1.0 Hz. Calculations should be made to determine the structures eigen frequencies, transverse and lateral, and damping should be applied when necessary.

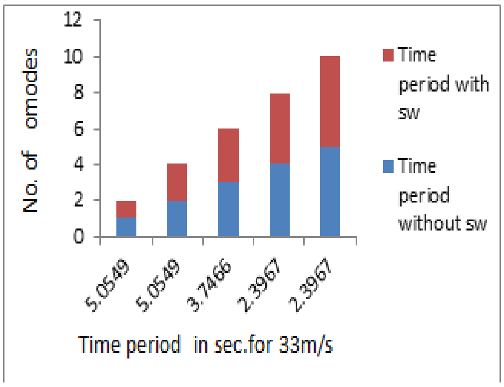

Fig. 14:

VIII. Subsystems and Components

The subsystems or components of the tall building structural systems are essentially the following.

- Floor systems
- Vertical Load Resisting Systems
- Lateral Load Resisting Systems
- Connections

The most commonly used structural system are broadly defined as follows.

- Moment Resisting Frames
- Shear Wall-Frame Systems
- Shear Truss-Outrigger Braced Systems
- Framed-Tubes
- Tube-in-Tube Systems with interior columns
- Bundled Tubes
- Truss Tubes without interior columns
- Modular Tubes

The structural system should be able to carry different types of loads, such as gravity, lateral, temperature, blast and impact loads. The drift of the tower should be kept within limits, such as H/500.

Some premium for wind is often required. Buildings within about 13 to 14 stories tall, this is often possible. The one third increase allowed in the allowable stresses may be just sufficient to carry wind. Buildings in the 20 to 50 story range, this is not always possible. The structural engineer is required to use innovative schemes like shear wall-frame, shear truss-frame and framed tubes and outrigger braced systems. This premium for wind is often minimized by an optimum design of beams and columns and floor systems to match given stress limits and drift

Wind displacements

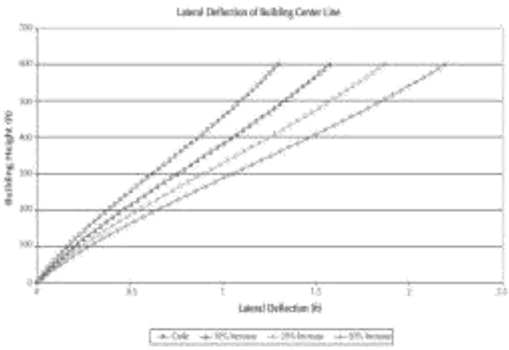

Fig. 15: Long-term global warming and climate change mayincrease wind loads, whichmay have negative effects on the performance of existing tall structures

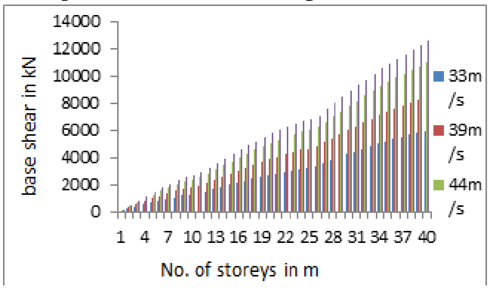

Fig. 16

IX. Fire

The design consideration for fire prevention and protection, smoke control fire-fighting and escape are beyond the scope of a book on building structures. However, since fire appears to be far the most common extreme situation that will cause damage in structures, it must be a primary consideration in the design process.

A knowledge of the temperature gradient across the member and the degree of restraint afforded by the supports and surroundings structure, enables the stress in the member to be evaluated. Particularly the elastic modules or stiffness and strength, may deteriorate rapidly as the temperature rises, and the resistance to loads is greatly reduced. For example the yield stress of mild steel at a temperature of 700o C is only some 10-20% of its value at room temperature. Over the same temperature range the elastic models drops by around 40-50%. The critical temperature at which large deflections are collapse occurs will thus depend on the materials used, the nature of the structure and the loading conditions

X. Conclusions

1) There is increase in lateral displacement values as governing wind speed increases.
2) By providing shear wall lateral displacement decreases geadually.
3) Also from other studies provision of frame system like: Moment Resisting Frames ,Shear Wall-Frame Systems , Shear Truss-Outrigger Braced Systems ,Tube-in-Tube Systems with interior columns Truss Tubes without interior columns Modular Tubes lateral displacement at higher speeds can also be controlled.
4) Tall commercial buildings are primarily a response to the demand by business activities to be as close to each other.
5) Design drift index limits that have been used in different countries range from0.001 to 0.005. To put this in respective, a maximum horizontal top deflection of between 0.1 and 0.5m (6 to 20 in.) would be allowed in a 33-story 100-m(300-ft) high building, or alternatively a relative deflection of 3 to 15 mm (0.12 to 0.6 in.) over a story height of 3 m (10 Ft.).
6) It is most important thing to fulfill the human comfort criteria.
7) We have to consider fire resisting capacity of the building because with the increase of temperature strength of the building comes down
8) A Comparative Study on RCC Structure with and without Shear Wall ,P. V. Sumanth Chowdary1 Senthil Pandian. M2
9) Behaviour of multistoried building under the effect of wind load Assistant Professor, Department of Civil Engineering, P.R.M.I.T.&R, Badnera, Amravati.

References

[1] Wind and earthquake engineering by taranath
[2] Wind load effects and equivalent static wind loads of tall buildings based on synchronous pressure measurements Guoqing Huang, Xinzhong Chen_ Wind

Science and Engineering Research Center, Department of Civil and Environmental Engineering, Texas Tech University, Lubbock, TX 79409, USA Received 20 September 2006; received in revised form 9 January 2007; accepted 10 January 2007.
[3] Study of Structural RC Shear Wall System in a 56-Story RC Tall Building O. Esmaili1 S. Epackachi2 M. Samadzad3 and S.R. Mirghaderi4.
[4] Stability of Tall Buildings by David Gustafsson & Joseph Hehir.
[5] Influence of diagonal braces in RCC multi-storied frames under wind loads: A case study Suresh P1, Panduranga Rao B2, Kalyana Rama J.S3
[6] A parametric study of multy storey RC building with horizontal irregularity,Himanshu Gaur1, R.K Goliya2, Krishna Murari3, Dr. A. K Mullick4.
[7] Estimation Of Design Wind Forces for aTall Building Based on Wind Tunnel Study A Anjana Susan John1* And S Selvi Rajan2.

