Indian National Report on Wind Effects on Structures, APEC 2010

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Indian Society for Wind Engineering (ISWE)

Indian Society of Wind Engineering (ISWE) was established in 1993 and at present the total membership is 468. The main activities of ISWE are organization of a National Conference on Wind Engineering (once in two years) and publishing a bi-annual Journal on Wind Engineering. Information on the society are available on website www.iswe.co.in.

The Society provides a necessary forum

(a) to the individuals and institutions connected with, or, interested in industrial aerodynamics.
(b) for exchange of ideas for the advancement and dissemination of knowledge in the field of Wind Engineering.
(c) to promote research and development work in the field of Wind Engineering.
(d) for arranging seminars, symposia, workshop, training course etc. and
(e) to recognize excellence of research and application in Wind Engineering by instituting awards and prizes

With the rapid growth of infrastructure in India and the need for greater involvement of wind engineering, the society wishes to expand its activities. As one of the steps towards the above objective, and realizing the importance of adopting a Multi Hazard Approach, ISWE plans to undertake a workshop cum training program. The activity is intended for designers, engineers, researchers and professionals on the topic of "Seismic and Wind Resistant Design of Building Structures" followed by an "International Advance School in Wind Engineering". The experts with in India and outside India shall be delivering lectures on a well structured course. This activity is jointly organized by CBRI and ISWE. The advance course is supported by ***Global Centre of Excellence, Tokyo Polytechnic University, Japan***. The course is planned in Delhi during 3~8 December 2010.

Important Milestone in R & D Activities of Wind Engineering in India

- 1985- First Asia Pacific Symposium on Wind Engineering (APSOWE) at Roorkee
- 1985- Indo-US Workshop on Wind Disaster Mitigation at SERC, Chennai
- 1986- SERC UNCHS Workshop on Cyclone Disaster Mitigation at SERC, Chennai
- **1993- Establishment of Indian Society for Wind Engg. (ISWE) Roorkee.**
- 1995- Ninth International Conference on Wind Engg. (9^{th} ICWE), Delhi
- 1992-1995- SERC_UNDP Project on Engg. Of Structural for Mitigation Damage due to Cyclone at SERC, Chennai
- 1996-1997- Action Plan_ 2 Phase of above UNDP Project on Wind Engineering at SERC, Chennai
- 1999- TCDC International Conference on Disaster Mitigation at SERC, Chennai
- From 2001 to 2009 ISWE organized 5 National Conference on Wind Engineering all over India every alternate year. The latest one was in Surat (Gujarat) from 4^{th} to 6^{th} Nov., 2009.

<u>Institutions actively involved in R & D activities of Wind Engineering in India</u>
(in alphabetical order)

1. Anna University, Chennai
2. Central Building Research Institute (CBRI), Roorkee
3. Central Road Research Institute (CRRI), New Delhi
4. Indian institute of Science (IISc), Bangalore
5. Indian Institute of Technology, Kanpur
6. Indian Institute of Technology, Kharagpur
7. Indian Institute of Technology, Madras
8. Indian Institute of Technology, Roorkee
9. National Aerospace Laboratories, Bangalore
10. National Institute of Technology of Nagpur. (VNIT)
11. National Institute of Technology of Surat. (SVNIT)
12. Structural Engineering Research Centre (SERC), Chennai
13. Thapar University, Patiala
14. Vellore Institute of Technology, Vellore

Major work in the recent past of the following Institutes is included:

1. SERC Chennai
2. IIT Roorkee
3. IIT Kanpur
4. CBRI Roorkee

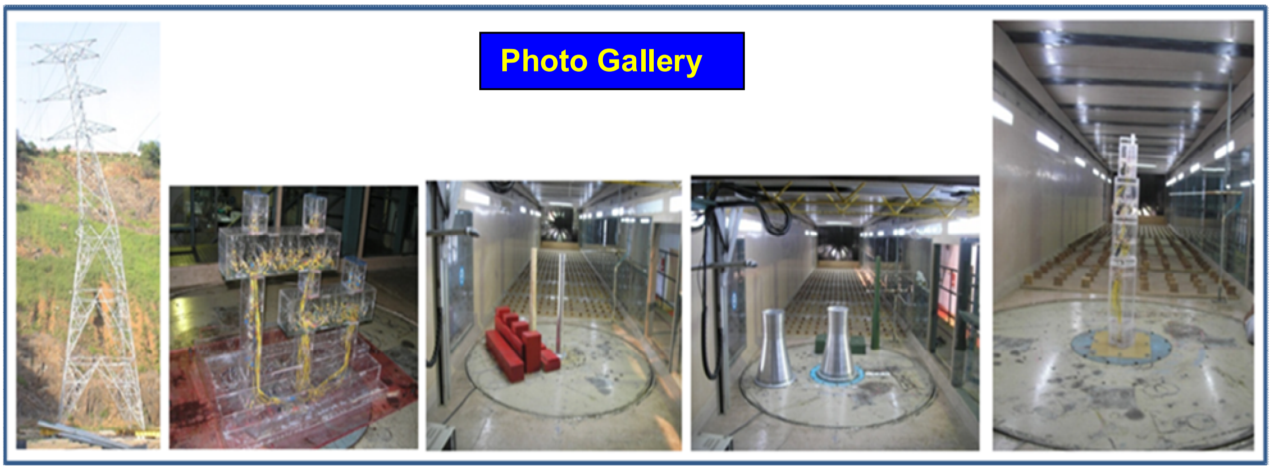
1. Structural Engineering Research Centre (SERC), Chennai

The R&D activities in the following areas are actively carried out:

- Interference effects (Cooling towers, chimneys, prisms)
- Pressure measurements (Tall buildings, bridge pylons, etc.)
- Sectional models (static / dynamic) Bridge cross-sections
- Dynamic response of wind turbine blades
- Computational fluid dynamics

The major recent contributions/achievements of SERC in the area of Wind Engg are listed below:

- Contributions to Indian standards on Wind Loads IS: 875 (Part-3 1987 And IS : 15498 2004).
- SERC is a research partner in the National Millennium Technology Leadership Initiative project for development of low-cost Wind tunnel through non conventional energy.



2. Indian Institute of Technology Roorkee (IITR)

Wind Tunnel Facilities-

- An Open Circuit Atmospheric Boundary Layer Wind Tunnel: Cross section 2.1m x 2.0m with a test section of 15m length and wind speed 18m/s.

- Closed Circuit Wind Tunnel, X- Section 1.3×0.85×8.2m, Wind speed range 2~20m/s

The various fields where research activities in the recent past have been conducted are:

i. Effect of Architectural Features on Wind Load in Buildings
ii. Wind Loads on Canopy Roofs
iii. Wind Effects On Tall Buildings with Peculiar Shapes
iv. Design of Gable Roof Building for Wind-Identification of Sensitive Parameters

i. Effect of Architectural Features (Aspect Ratio, Roof Angle, Overhang and Boundary Wall) on Wind Load in Buildings

Commonly available single story gable roof buildings without any openings have been considered. Buildings with two different roof angles, 25^o and 10^o, with and without overhang have been chosen. Height (H) and width (B) of gable buildings are 3.25 m and 3.75 m and length (L) of the buildings 7.5 m and 22.5 m have been considered.

- It has been observed that with an increase of distance between building and boundary wall, there is first a significant decrease in the magnitude of negative mean pressure coefficients (suction) on overhang, and shows maximum positive values when boundary wall is at two times the height of building wall; further increase in the distance tapers off the effect of boundary wall.
- It is found that, for isolated condition the value of design pressure coefficients (suction) increase to some extent for buildings with L/B = 6 as compared to that of the building with L/B = 2. In presence of boundary wall, suction on different zones of roof decreases maximum when boundary wall distance is three times the heights of building walls. Further increase in the distance of boundary wall from the building tapers off the effect on pressure variation.
- It has been observed that the design wind pressure on wall surface of building with overhang increases considerably compared to that of the building without overhang. In the presence of the boundary wall, maximum reduction for positive pressure is found when the spacing of boundary wall is 1H to 1.5H of building wall. Negative pressure values for the building wall reduce significantly when wall position is at three times the height of building wall.

ii. Wind Loads on Canopy Roofs

The canopy roof buildings having length, width and eaves height 12m, 6m and 3m respectively are selected for the study. The buildings are considered to be situated in sub-urban terrain (power law index-0.143, turbulent intensity 0.9%).

In all four models with varying roof slopes i.e. 0^o, 10^o, 20^o and 30^o were fabricated to study the effect of roof slopes. The experiments were conducted in closed circuit wind tunnel having x-section 1.3×0.85m size, length 8.2m and varying wind speed in the range of 2 to 20 m/s. Canopy roof models with different parameters (i.e. with change in roof slope, blockage and interference conditions) were tested in the wind tunnel in free stream wind velocity of 15 m/sec by changing different wind incident angles.

Mean, rms, maximum and minimum wind pressures on the upper surface and lower roof surface of the roof models were measured in order to study the effect of different wind incident angles (0^o, 15^o, 30^o, 45^o, 60^o, 75^o and 90^o) on wind pressure distribution.

With the help of experimentally available data. ANN analysis was made to correlate the various parameters with one another. Using CFD analysis considering the same parameter as used in the experimental study, the wind flow pattern and pressure values on the roof surface were compared with experimentally obtained wind loads.

The following are the main findings of this research work-

a).The high positive pressure coefficient for canopy roof of 30^o slope occurs at wind incident angle close to 75^o.

b).Near the corner the canopy roof is under high suction at acute wind incident angles i.e.0^o< Ø >20^o. After this pressure values decrease.

c).The canopy roof with 50% and 75% blockage on one side, experiences high-suction pressure at wind incident angle 15^o, 75^o, 285^o and 315^o.

d).The interference effect is maximum at 45^o wind incident angle.

iii. Wind Effects on Tall Buildings with Peculiar Shapes

In the present study, three different building plans namely square, octagonal, circular and their composite shapes (square to octagonal and square to circular) with various height are considered both theoretically as well as experimentally. In experimental study, the rigid models of tall buildings were tested in closed circuit wind tunnel in order to measure the mean and fluctuating pressures at various points on different surfaces.

The effect of various geometric and flow parameters such as uniform plan, composite plan and height ratio, wind incidence angle etc. on wind pressure distribution were studied.

The buildings having length, width and total height 30m, 30m and 150m respectively were selected for the study. Only height ratio was changed for composite plan building keeping the above dimension same. The buildings were considered to be situated in sub-urban terrain (power law index-0.143, turbulent intensity 0.9%). Each model had been tested under six different wind incident angles namely 0^o, 15^o, 30^o, 45^o, 60^o, 75^o.

It is found from the study that the suction values varied widely on the parallel side faces of uniform square and octagonal building with changing wind incident angle. The variation in suction value is around 3 times the minimum value at 15^o wind incident. Significant variation has been observed around the junction level of composite buildings. Comparatively greater pressure occurs just above the junction of the building due to separation of the wind flow.

After obtaining wind pressures experimentally and then the horizontal forces at each nodal point, the buildings are analyzed by software package STAAD Pro. Mean response including moments, shear forces and displacements are obtained under various wind angles.

It is seen from the response study that twisting moment at the junction of out-side central column of the composite building is very large as compared to upper and lower value. Even it varies from 2 to16 times. At the junction level, horizontal structural member (beam) carries more shear force and moments compared to others. Optimum tip displacement is noticed in 50% height square and 50%height circular plan shape building at 0^o angle of attack.

iv. ***Design of Gable Roof Building for Identification of Sensitive Wind Parameters***

The objectives of the study are

1. Identify the factors which make a difference in the evaluation of the wind pressures and compare them for the different wind codes.

2. Carry out comparative study of Indian and other International wind codes (especially from Asia Pacific regions) regarding wind pressures and to evaluate the quantity of steel used in truss members when analyzed for wind loads.

Wind Pressures on Gable Building

International Wind Codes	IS:875 Part3,1987	AIJ-2004	AS/NZS 1170.2:2002
Wind Pressure (N/m^2)	$706.717 \times C_P$	$524.79 \times Cp$	$502.9 \times C_{Pe}$ or $628 \times Cp_i$

$Cp = Cp_e - Cp_i$, Cp_e is external pressure coefficient and Cp_i is internal pressure coefficient and Cp is total pressure coefficient.

The sensitive parameters are-

1. Roof Angle
2. Openings
3. Building Aspect Ratio
4. Wind Incidence Angle
5. Different Truss Configurations

3. Indian Institute of Technology Kanpur (IITK)

National Wind Tunnel Facility (NWTF), a state-of-the-art 3 m x 2.25 m closed circuit wind tunnel, with considerable associated equipment and instrumentation, is established at IIT Kanpur in 1999, capable of testing at wind speed up to 80 m/sec.

- Wind Tunnel Model Study for Chimney for 6x135MW Power Project.
- Wind tunnel testing of aero elastic model for single flue steel Chimney.
- Wind Tunnel Testing of the Aero-elastic model for Triple Flue Chimney.
- Wind Tunnel study on rigid model of 81 storey residential Tower.
- Wind Tunnel Study on rigid model of 1-Gstadium Sports complex testing at NWTF.
- Wind tunnel model test for NDCT of Aravali & Bhusawal Thermal power project.
- Wind Tunnel Study of Chimney & NDCT for 2x507.5 MW.

4. Central Building Research Institute (CBRI) Roorkee

A low speed open circuit wind tunnel is being used in CBRI of research projects related to buildings. The cross section of the tunnel is 2.4m x 1.8m and is capable of testing at wind speed up to 40Kmph.

Different Research Works being pursued at present are as follows:

i. Programme of up-gradation of existing wind tunnel facility and strengthening of wind research group
ii. Study on Wind-Induced Interference on Tall Buildings
iii. Study on prediction of wind environment for pedestrians comfort at different combination of buildings arrangement.
iv. Development of architectural design of building roofs for cyclone prone areas.

Study on Wind-Induced Interference on Tall Buildings

An exhaustive literature survey on the interference effect of tall buildings has been carried out and 56 research papers starting from 1970s have been studied. Different parameters e.g. geometries, turbulence intensities, power law index, orientation and wind incidence angle, terrain conditions, number of interfering buildings, etc. have been studied. Different researchers have chosen different parameters for quantifying interference. From comfort and safety point of view the two parameters i.e. accelerations and the base forces are most important. Only a few papers have studied accelerations. Furthermore hardly any studies have been carried out with possible codification as an objective. For that a more systematic approach is required. Most studies have chosen square building for studying the effect of interference whereas the oncoming trend is to have fairly oblong rectangular or even non-rectilinear plan shapes Interference effects in such buildings is still to be studied in greater details.

The proposed study aims to first define the most appropriate basis for quantifying the effect of interference, and determine these for a set of two tall buildings interfering with each other through literature survey, theoretical study and wind tunnel measurements.

Proposed Building Parameters

- Principal Building = 240*60*20 m
- Interfering Building = 240*60*20 m
- Slenderness Ratio: $H/\sqrt{A}$ = 6.928

- Model Ratio = 1:400
- Dimension Ratio = 12:3:1
- Model Type = HFFB
- Terrain Type = Open/Sub-Urban
- Study (Measurements) = Moments and Accelerations

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