SIMULATION OF WIND RESPONSE OF TALL BUILDINGS USING COMPUTATIONAL FLUID DYNAMICS – A CASE STUDY

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ABSTRACT

High-rise buildings with unique architectural features has become popular in Sri Lanka in last few decades. Interaction of wind with buildings with complex geometry leads to a complex building-wind environment. However, all codes of practice and standards are only applicable for buildings with simple geometry and height limitations. Moreover, all wind codes mainly present static based calculation. Generally, the static analysis is suitable only for structures less than 50 m height. Therefore, the actual wind effect is difficult to assess by the wind loading codes, hence recommend using Computational Fluid Dynamics (CFD) models.

In this research, wind loads and its effects are calculated on a 31-storey high rise building utilizing three different international wind loading codes/standards, namely CP3 CHAPTER V-2:1972, BSEN 1991-4:2005 with SLS EN 1991-1-4:2019, AS/NZ 1170.2:2011 by encountering different factors and methods specified. The estimated forces are compared with each other since the different codes introduced different factors to estimate wind turbulent characteristics. Numerical Simulation has been carried out for the same building using RANS approach (Spalart-Allmaras). Comparison is carried out between the results obtained from simulation and code based calculations. This study has been used to evaluate the applicability / limitations of codes of practice via numerical simulation and identify the more suitable wind loading code. AS/NZS 1170.2:2011 is more suitable to evaluate the wind loads and their effects on tall buildings due to its advanced flow parameters. In addition, S-A turbulent model well performed in evaluating the complex building – wind environment accurately and different flow features such as vortices, wake formations etc. are clearly observed. The advantages of commercially available CFD software on complex fluid -structure problems has been discussed in terms of time, cost and accuracy of results opposed to other methods such as codes of practice and wind tunnel testing.

Specially dedicated to my beloved sister…..

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Abbreviation	Description
q_b	Basic velocity pressure (BSEN 1991-1-4:2005)
q_p	Peak velocity pressure (BSEN 1991-1-4:2005)
$\tilde{\upsilon}$	Spalart–Allmaras variable
Re_L	Reynolds Number based on your problem's characteristic length scale
$V_{des,\theta}$	Building orthogonal design wind speed (AS/NZS 1170.2:2011)
$V_{sit,\beta}$	Site Design wind speed (AS/NZS 1170.2:2011)
δ_{ij}	Kronecker delta
Δt	Small time step
Δy	distance of the first node from the wall
A	Altitude (BSEN 1991-1-4:2005)
A_{ref}	Reference area of individual surface (BSEN 1991-1-4:2005)
b	Width of the structure (BSEN 1991-1-4:2005)
B_s	Background factor (AS/NZS 1170.2:2011)
B_{sh}	Average breadth of the structure heights s and h (AS/NZS 1170.2:2011)
C_{alt}	Altitude correction factor (BSEN 1991-1-4:2005)
c_d	dilatational wave speed
C_{dir}	Directional factor (BSEN 1991-1-4:2005)
C_{dyn}	Dynamic response factor (AS/NZS 1170.2:2011)
C_e	Exposure factor (BSEN 1991-1-4:2005)
$C_{e,T}$	Exposure Correction factor (BSEN 1991-1-4:2005)
C_{fig}	Aerodynamic shape factor (AS/NZS 1170.2:2011)
$C_o(z)$	Orography factor (BSEN 1991-1-4:2005)
C_p	Pressure coefficient
$C_r(z)$	Roughness factor (BSEN 1991-1-4:2005)

$C_{r,T}(z)$	Roughness correction factor (BSEN 1991-1-4:2005)
C_sC_d	Structural factor (BSEN 1991-1-4:2005)
C_{season}	Seasonal factor (BSEN 1991-1-4:2005)
d	Distance from the closest surface
E	Young's modulus
E	Effective height 10 m above Y (CP3 Chapter V-2:1972)
E_t	(π/4) times the spectrum of turbulence (AS/NZS 1170.2:2011)
G	Gust Effect Factor
GLF	Gust Loading Factor
G_q	Gust Factor for wind Load Effect
g_R	Peak factor for the resonant response (AS/NZS 1170.2:2011)
g_v	Peak factor for the upwind velocity fluctuations(AS/NZS 1170.2:2011)
h	Height to top of the tower (AS/NZS 1170.2:2011)
H	Building height
h_{mk}	distance between m-th and k-th cells that lie near the fluid-structure interface
H_s	Height factor for the resonant response (AS/NZS 1170.2:2011)
I_h	Turbulent Intensity (AS/NZS 1170.2:2011)
K_a	Area reduction factor (AS/NZS 1170.2:2011)
$K_{c,e}$	Combination factor (AS/NZS 1170.2:2011)
K_l	Local pressure factor (AS/NZS 1170.2:2011)
K_p	Peak factor for the upwind velocity (BSEN 1991-1-4:2005)
K_p	Porous cladding reduction factor (AS/NZS 1170.2:2011)
k_r	terrain factor depending on the roughness length
L	flow characteristic length scale
L_h	A measure of the integral turbulence length scale
L_{min}	Smallest element dimension in the FEA mesh
M_d	Wind directional multiplier (AS/NZS 1170.2:2011)
M_s	Shielding Multiplier (AS/NZS 1170.2:2011)
M_t	Topographical Multiplier (AS/NZS 1170.2:2011)

$M_{z, cat}$	Terrain height Multiplier (AS/NZS 1170.2:2011)
N	Reduced frequency (non- dimensional) (AS/NZS 1170.2:2011)
n_a	First mode natural frequency of vibration of a structure in the along-wind direction in hertz. (AS/NZS 1170.2:2011)
P	Pressure
q	Dynamic pressure (CP3 Chapter V-2:1972)
R^2	Resonance Response Part (BSEN 1991-1-4:2005)
R_e	Reynold's number
$\mathrm{R_h}$, $\mathrm{R_b}$	Aerodynamic admittance (BSEN 1991-1-4:2005)
s	Height of the level which wind action effects are calculated (AS/NZS 1170.2:2011)
S	Size reduction factor (AS/NZS 1170.2:2011)
S_1	Topography factor CP3 Chapter V-2:1972)
S_2	Ground roughness, building size & height above ground factor (CP3 Chapter V-2:1972)
S_3	Statistical based factor (CP3 Chapter V-2:1972)
S_4	Directional factor (CP3 Chapter V-2:1972)
S_{ij}	Mean rate of strain tensor
U^*	Frictional velocity
V	Average wind speed
V	Basic wind speed
V'	Fluctuation wind speed
$V_{10, 3}$	3 *s* speed at 10 m height in open terrain category (CP3 Chapter V-2:1972)
$V_{10, 3}$	3 *s* speed at 10 m height in open terrain category (CP3 Chapter V-2:1972)
V_b	Basic wind velocity (BSEN 1991-1-4:2005)
$V_{b, map}$	Characteristic 10 minutes mean wind velocity before altitude correction (BSEN 1991-1-4:2005)
$V_{b,0}$	Fundamental value of basic wind speed (BSEN 1991-1-4:2005)
V_H	Wind speed at 'H' height (AS/NZS 1170.2:2011)
V_{Ht}	t *s* speed at height H in appropriate category (CP3 Chapter V-2:1972)

V_m	Mean wind velocity (BSEN 1991-1-4:2005)
V_{mk}	velocity of the fluid between those cells
V_R	Regional 3 s gust wind speed (AS/NZS 1170.2:2011)
V_s	Design wind speed
V_t	Wind velocity at any given instantaneous time'ṫ'
υ_t	Turbulent Eddy viscosity
W_e	Wind pressure on surface (BSEN 1991-1-4:2005)
Y	level corresponding to general roof top level or obstruction level(CP3 Chapter V-2:1972)
Y^+	non-dimensional distance between from the wall to first mesh node
z_0	Roughness length.
z_{max}	maximum height taken as 200 m
z_{min}	minimum height defined (BSEN 1991-1-4:2005)
α	Power law exponent (CP3 Chapter V-2:1972)
α	Lame constant
κ	Von Karman's constant
λ	Lame constant
ξ	Ratio of structural damping (AS/NZS 1170.2:2011)
S	Rotational tensor
ρ	Density of fluid

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