Effect of wind on structure.

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Wind produces three different types of effects on structure:static,dynamic and aerodynamic.The response of load depends on type of structure.When the structure deflects in response to wind load then the dynamic and aerodynamic effects should be analysed in addition to static effect.Sound knowledge of fluid and structural mechanics helps in understanding of details of interaction between wind flow and civil engineering structures or buildings

Flexible slender structures and structural elements are subjected to wind induced along and across the direction of wind. When considering the response of a tall building to wind gusts, both along-wind and across-wind responses must be considered. These arise from different the former being primarily due to buffeting effects caused by turbulence; the latter being primarily due to alternate-side vortex shedding. The cross-wind response may be of particular importance because it is likely to exceed along-wind accelerations if the building is slender about both axes.

Any building or structure which does not satisfy either of the above two criteria shall be examined for dynamic effects of wind.:

a) Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0. and

b) Buildings and closed structures whose natural frequency in the first mode is less than 1 Hz.

Wind induced oscillation

There are three forms of wind induced motion as follows:-

a) Galloping - Galloping is transverse oscillations of some structures due to the development of aerodynamic forces which are in phase with the motion. It is characterized by the progressively increasing amplitude of transverse vibration with increase of wind speed. Non circular cross section are more susceptible to this type of oscillation

b) Flutter - Flutter is unstable oscillatory motion of a structure due to coupling between aerodynamic force and elastic deformation of the structure. Perhaps the' most common form is oscillatory motion due to combined bending and torsion. Long span suspension bridge decks or any member of a structure with large values of d/t (where d is the depth of a structure or structural member parallel to wind stream and t is the least lateral dimension of a member) are prone to low speed flutter.

3)Ovalling **:** This walled structures with open ends at one or both ends such as oil storage tanks,and natural draught cooling towers in which the ratio of the diameter of minimum lateral dimension to the wall thickness is of the order of 100 or more, are prone to ovalling oscillations.These oscillations are characterized by periodic radial deformation of the hollow structure.

The dynamic component which essentially causes the oscillation of structure is generated due to three reasons:-

1)Gust

The wind velocity at any location vary considerably with time.In addition to a steady wind there are effects of gusts which last for few seconds.and yields a more realistic assessment of wind load.In practice the peak gust are likely to be observed over an average time of 3.5 to 15 secs depending on location and size of structure..The intensity of gusts is also related to the duration of gusts that affects structures.Larger structure will be affected more by gust of larger duration and thus subjected to smaller pressure compared to smaller structure.

The gust effect factor accounts for additional dynamic amplification of loading in the along-wind direction due to wind turbulence and structure interaction. It does not include allowances for across-wind loading effects, vortex shedding,instability due to galloping or flutter, or dynamic torsional effects. Buildings susceptible to these effects should be designed using wind tunnel results.

This factor accounts for the increase in the mean wind loads due to the following factors:

• Random wind gusts acting for short durations over entire or part of structure.

• Fluctuating pressures induced in the wake of a structure, including vortex shedding forces.

• Fluctuating forces induced by the motion of a structure.

2)Vortex Shedding

When wind acts on a bluff body forces and moments in three mutually perpendicular direction are generated- out of which three are translation and three rotation.For civil and structures the force and moment corresponding to the vertical axis (lift and yawing moment) are of little significance. Therefore the flow of wind is considered two-dimensional consisting of along wind response and transverse wind response.

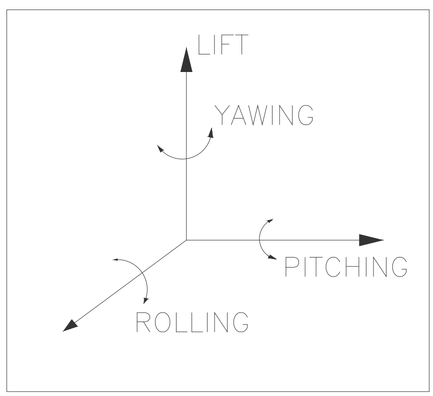

FIGURE 1

Along wind response refer to drag forces, and transverse wind is the term used to describe crosswind. The crosswind response causing motion in a plane perpendicular to the direction of wind typically dominates over the along-wind response for tall buildings.

Consider a prismatic building subjected to a smooth wind flow.The originally parallel upwind streamlines are displaced on either side of the building due to boundary layer separation.This results in spiral vortices being shed periodically from the sides into the downstream flow of wind creating a low pressure zone due to shedding of eddies called the wake. When the vortices are shed accross wind component are generated in the transverse direction.

At low wind speeds, since the shedding occurs at the same instant on either side of the building, there is no tendency for the building to vibrate in the transverse direction. It is therefore subject to along-wind oscillations parallel to the wind direction. At higher speeds, the vortices are shed alternately, first from one and then from the other side. When this occurs, there is an force in the along-wind direction as before, but in addition, there is an force in the transverse direction.. This type of shedding, which gives rise to structural vibrations in the flow direction as well as in the transverse direction, is called vortex shedding.The frequency of shedding depends mainly on shape and size of the structure,velocity of flow and to a lesser degree on surface roughness,turbulence of flow.

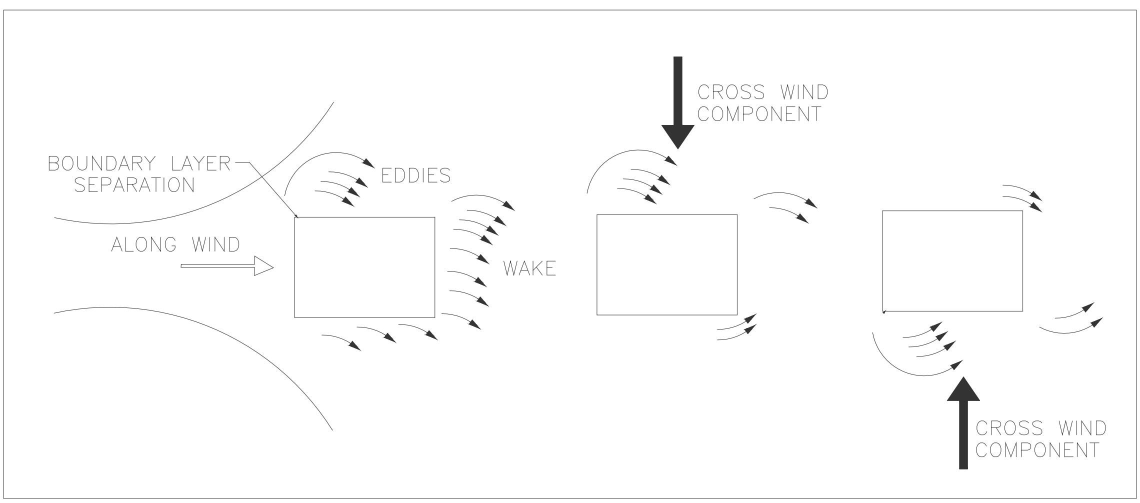

FIGURE 2 :VORTEX SHEDDING PHENOMENON

For slender structure, the shedding frequency ή shall be determined by the following formula:

$$ή = SVd / b$$

where
S = Strouhal number,
Vd = design wind velocity, and
b = breadth of a structure or structural members in the horizontal plane normal to the wind direction

a) Circular Structures - For structures circular in cross-section:

S = 0.20 for bVz not greater than 7,
and
= 0.25 for bVz, greater than 7.

b) Rectangular Structures - For structures of rectangular cross-section:

S = 0.15 for all values of b Vz

Where Vz = Design wind speed

3) Buffeting

A downwind structure could oscillate due to vortex sheeding of adjacent structure

Reference:

1) S.N. Manohar, Tall Chimneys – Design and Construction, Tata McGraw-Hill, 1985

2)P C Varghese**,** Advanced Reinforced Concrete Design, Prentice-hall Of India,2005

3) Bungale s. Taranath**,**Wind and earthquake resistant buildings, Marcel dekker,2005

4) IS 875 : Part 3 : 1987 Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures - Part 3 : Wind Loads