

**Summary
of
Lesson Two
Lateral Forces
(Kaplan 2006)**

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Definitions

chinooks: windstorms on eastern slopes of Rockies

Santa Anas: windstorms in Southern California

revolving cup anemometer: measures wind speed

fastest mile speed: used in building design. The time it takes a column of air one mile long to pass the anemometer. Wind data standardized at height of 10 meters or 33 feet. Used on contour maps from UBC. Adjusted to provide mean reoccurrence interval of 50 years (2% probability).

special wind regions: areas on contour map having far different wind speeds than surrounding areas. Wind speeds determined by local records.

stagnation pressure: direct wind pressure in lbs. per square foot on a vertical surface.

suction: negative pressure or uplift from drag

drag forces: caused by friction when wind passes over building. Drag acts in direction of wind.

Response of Buildings to Winds Loads

Buildings respond to wind in the following fashion:

- 1) Direct pressure on windward side
- 2) Negative pressure on leeward side
- 3) Uplift pressure on roof from drag & internal pressure
- 4) Negative pressure on sides from drag & internal pressure
- 5) Increased pressure at corners and eaves
- 6) Vibration due to gusts
- 7) Greater wind pressure at increased heights due to less friction.

Stagnation pressure (direct wind pressure)--This is related to fastest mile velocity in mph and measured in lbs. per square foot by the following formula:

$$p = 0.00256V^2$$

Doubling wind velocity causes a fourfold increase in wind pressure.

Wind pressure on building is affected by the following:

- 1) Height due to friction from the ground
- 2) Terrain of area surrounding building
- 3) Size and shape of building

Code Requirements (1994 UBC)

UBC uses a static analysis method to simulate actual varying wind forces and determined by the following formula:

$$p = C_e C_q q_s I$$

which are determined as follows.

C_e Factor--This is based on UBC Table 16-G and accounts for the height of the building, the exposure (terrain) at the buildings site and an increase for gusting affect.

Site exposure is classified by Exposure B, C, or D and defined as follows:

*Exposure B: At least 20% of ground level area extending one mile or more from the site has surface irregularities (buildings, forest, etc.)

*Exposure C: In any quadrant 1/2 mile or more from the site, the terrain is generally flat and open.

*Exposure D: The most severe with wind speeds of 80 mph or greater and terrain this is flat and unobstructed facing large bodies of water over one mile or more relative to any quadrant of the building site.

This expose extends inward from the shoreline $1/4$ mile or 10 times the building height (whichever is greater).

C_q Factor--This is the a pressure coefficient for the structure or portion of the building under consideration and is based on UBC Table 16-H.

There are two methods for determining wind pressures to be used in design:

*Method 1 (Normal Force Method): This can be used for any building (required for gabled rigid frames).

This method assumes all wind pressures perpendicular to external surfaces are acting simultaneously. Height in accordance to UBC Table 16-G is taken into account.

*Method 2 (Projected Area Method): The wind pressures on the projected horizontal and vertical areas are determined and assumed to be acting simultaneously. This method is limited to buildings less than 200 ft. in height, excluding gabled rigid frames.

q_s Factor--This is the wind stagnation pressure at a standard height of 10 meters (33 feet) determined from the basic wind speed at that height. Conversion by way of the stagnation wind pressure formula is shown on UBC Table 16-F

I Factor--This is the importance factor and similar to that used in earthquake design. The importance is based on the occupancy category of the building and is either 1.0 or 1.15. The higher value is for essential and hazardous buildings and assumes a mean reoccurrence interval of 100 years.

Lateral Load Resisting Systems

The lateral load resisting systems are the same as in seismic design (MRF's, shear walls, braced frames, tubular), but the type of system does not affect the magnitude of the wind load. Ductility is less important in wind design than seismic design due to the following:

- *Seismic assumes stress in inelastic range beyond yield point
- *Wind assumes stresses to occur in inelastic range

Overturning

As with earthquake design, buildings must be designed to resist overturning moments from wind forces. Since wind forces act in one direction for a longer period than seismic forces, the dead load resisting moment must be **1.5 times** the wind overturning moment.

The wind overturning moment may not exceed $2/3$ of the dead load resisting moment unless the building is anchored to resist excess moment.

Example:

- 1) Figure overturning moment
- 2) Figure dead load resisting moment
- 3) Factor of safety: dead load resisting moment \div overturning moment ≥ 1.5

If the building is properly anchored, the foundation may be used to figure dead load resisting moment.

Deflection and Drift

Deflection or drift must be minimalized to prevent damage to brittle building elements and minimize discomfort to the building's occupants.

Drift between adjacent stories is limited to around 0.0025 times the building height. This is half what is allowed for seismic forces since wind loads occur more often.

Diaphragms, Collectors and Torsion

Wind forces are transferred from vertical resisting elements to diaphragms in the same manner as earthquake forces. Collectors can be used in wind design in the same fashion as for earthquake design.

Torsion from wind loads occurs in a rigid diaphragm in a manner similar to torsion from seismic loads. Accidental torsion is generally not considered in wind design.

Elements and Components of Structures

The same basic formula used for design of the lateral force resisting system is used for wind pressures on elements and components of a building.

$$p = C_e C_q q_s I$$

However, wind pressures over the surface of a building can vary greatly, and building discontinuities can cause high suctions or negative pressures. UBC Table 16-H provides higher values for the C_q factor in the design of elements, components, and discontinuities.

Combined Vertical and Horizontal Forces

UBC requires all building components be designed for the following load combinations:

- 1) Dead + floor live load + wind
- 2) Dead + floor live load + wind + snow/2
- 3) Dead + floor live load + snow + wind/2

Roof live load and seismic load are not considered to be acting at the same time as wind load. Only 1/2 of wind or snow is considered in #2 and #3 since it is unlikely they will have maximum values at the same time.