OBSERVING AND MEASURING SWAY IN A TALL BUILDING

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A very comprehensive study of wind forces extending over a five year period of observation on the Empire State Building is reported in the Proceedings of the American Society of Civil Engineers, September, 1938. It seemed of interest to compare the results of a similar study on a fifteen story building with those on one hundred and two stories. Although our study was begun only two months ago the data collected lead to several interesting and confirming results.

The building in which the observations reported were made is Mundelein College for Women, located on Sheridan Road at Devon Avenue in Chicago. The total height above the street level is 208 feet. Above the fourth floor there is symmetry along one axis extending north and south. Structurally this building consists of reinforced concrete construction, the outer walls of which are covered with limestone. The partitions are of tile and plaster and the floors of concrete, pan construction. Much of this material is not elastic and does not follow Hooke's law. As a result when it is subjected to loads, the building shows a slight amount of plastic action; that is, when it is deflected by a horizontal force it will not return exactly to a definite fixed position.

The story height, the length of the resisting walls, the number of windows, the type of masonry, the sequence in which the different stories were built and the temperature—all affect the damping resistance, and these variables make it impossible to predict what the ratios of resistance will be in any given building. After many high winds the wall resistance probably diminishes.

For these reasons engineers design for elastic resistance only. Even there the variables are so many, and so many approximate assumptions are necessary that their best design figures are plus or minus ten per-cent. Their aim is to so frame the building that under the maximum "twenty-year-wind" in the most effective direction the yield point of the elastic materials will not be exceeded.

The buildings in the vicinity of the structure are of varying heights ranging from low two story residences to seventeen story apartment buildings. A study of the character of the obstructions which, it was easily seen, were of the type that would disturb the air currents, was undertaken for a radius of four blocks. North and northwest, south and southwest are the directions of greatest obstruction. The entire east side is exposed to the Lake and the west side has but one building as tall as seven stories.

Two methods of taking observations were used. In one the dial on the four-cup anemometer and the direction of the wind were read just before and just after the deflection readings. The average velocity was taken and not the maximum. In the other half hour deflection readings were automatically recorded on a single recording sheet for a period of eight hours each day. These cluster points were interpreted on the basis of average deflection and average anemometer readings which were taken hourly during the corresponding day.

A pendulum hanging from a point between the eighth and ninth floors with a 110 lb. bob poised over a recording table was adjusted to a chosen zero point at the centre of a graduated circle directed toward the compass points. A sheet of polar coordinate paper was placed between the tungsten point on the lower surface of the bob and a copper plate on the recording table. For one type of observation the automatic timing device closed the circuit every half hour, and a perforation was made in the polar coordinate paper. For the other, a new sheet of polar co-ordinate paper was slipped into the gap and properly orientated, the switch manipulated manually, and the reading taken.

By either method the deflection for wind velocity up to 20 miles per hour did not exceed 0.15 inches with the lower limit at 0.08 inches. At no time did the deflection reading return to the chosen zero point. The data reported herein are those of the movement of the ninth floor relative to a point 120 feet below, the lateral movement of which is doubtless small and may be neglected.

In effect, the building has two distinct movements. It deflects from the vertical and it vibrates with a definite period, similar to the prongs of a tuning fork when struck. A steady wind causes deflections only, whereas a gusty wind will set up vibrations with amplitudes that vary with the strength and character of the storm.

To study the vibration of the building a transit instrument was set up in the pendulum shaft and sighted on a target on the top of the shaft. Up to the present the amplitude of vibration has been too small to be detected. As the pendulum did not record movements of its support that are not of greater duration than the period of its swing, which is 11.92 seconds, the building vibrations are not recorded by the bob, but their mean position is determined by it.

Observation of the air currents around the structure were made on April 25, at 3 o'clock in the afternoon during a seven mile per hour wind blowing from the east. A rubber balloon was tied to a long thread and sent out from several predetermined points near corners on the 4th, 8th, and 14th stories. These data show that the flow of air is greatly disturbed by the building in a manner far from simple.

The following conclusions directly confirm those of the study made on the Empire State Building:

(1) The distribution of the wind pressure on a tall building is very complicated and irregular; the air currents having broken up by the surrounding structures and by the building itself.

(2) The action of the building under horizontal loads is plastic as well as elastic, with the result that strains and deflections are not proportional to the forces that produce them.