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Notes and Comment

DESTRUCTIVE ACTION by vibrations in structures amplified by resonance is something concerning which engineers appear destined to learn much that will add to the store of useful knowledge both in designing and protecting buildings, bridges, dams and other structures. In the layman's mind resonance is a term associated only with sound. It is conceived as the sympathetic response of a still object set in motion by another in vibration, resulting from the fact that both possess the same pitch or tune, as popularly demonstrated by one tuning fork, producing a certain tone, causing another apart from it to respond when set in vibration. Practical application of this simple principle of resonance is illustrated in musical instruments.

But resonance is an attribute, or whatever you may choose to call it, of any rhythmical motion, however it may be produced or whatever may be the result. Its destructive effect, as recognized in the study of earthquakes in recent years, lies in its power to amplify, when the rhythm is sustained in a definite period of oscillation for an appreciable time. Rhythmical motion may be produced not only by earth waves, but also by wave action or surge of water or air or any other fluid element; or it may be produced by revolution of a flattened car wheel or the whirling of an unbalanced object. The result is vibration with varying periods of oscillation. Resonance is never manifest, however, except that an object having the same period of oscillation as the source of its motion lies somewhere in its path.

This principle has been utilized in the construction of a machine which is now being used to obtain data regarding the vibration of buildings and structures, and even the ground, by the Seismological Division of the U. S. Coast and Geodetic Survey, which has undertaken a program of strong-motion seismological investigations in California, the purpose of which is to obtain data and information to assist engineers to design buildings and structures to most successfully resist seismic movements. Results obtained have already demonstrated that data may be obtained, sufficiently definite and accurate, to furnish the basis for intelligent study of stresses set up in buildings by vibration. Up to this time all such calculations have been predicated on theoretical assumptions. While these assumptions are believed to be reasonable, nevertheless it will be a matter of much importance and also great satisfaction to engineers to have available data upon which they can confidently rely.

Records secured by specially designed instruments in the operation of this vibrating machine are described and explained by Franklin P. Ulrich, chief of the California Seismological program in Engineering-News Record, issue of November 14, 1935. These records have made it possible to chart force curves and amplitude periods obtained by experiments in more than three hundred buildings and structures of various types, including bridges, piers, water tanks, dams, etc. It has also been possible to plot deflection curves for the fundamental and second mode of vibration and to determine the approximate centers of rotation for two torsional modes. To the layman this may not mean much but to engineers it has great significance because it will materially aid them in securing the most effective structural design to resist lateral forces, such as are produced in earthquakes.

The vibrating machine used in these experiments was designed by Prof. L. S. Jacobsen of Stanford University, and John A. Blume a graduate student in structural engineering, to simulate earthquake motions. It consists of three 30-inch rotating steel discs which are unbalanced by attaching to them lead plates. The forces developed vary with the speed of rotation and the proportion of unbalance. Two discs are placed below and one above the axis on which the forces set up are transmitted to the structure, the weights being so arranged that only horizontal forces are developed, the vertical forces being neutralized by an even balance between the upper and lower discs. The amplitude of the vibrations produced range from 0.1 to 1.0 second. Results obtained with this machine will determine the advisability of constructing a larger one, but for present investigations the range of the machine is adequate.

Vibrations set up in a structure by the machine are recorded by instruments in the same manner as those caused by a seismic shock. With the discs speeded up to 600 revolutions per minute the machine runs from three to six minutes before coming to rest. When resonance is produced by coincidence of the period of vibrations of the machine with the fundamental period of the structure or with that of any portion of it the resonance effect is indicated on the record by an increase in the amplitude of the oscillations. Experiments have illustrated, Mr. Ulrich states, that a very small disturbing force can set up large vibrations when the period of the force is in resonance with the fundamental period of the structure, as demonstrated when the machine revolved at a period of 1.20 second and the disturbing force was only 54 pounds per square inch.

That the scientific study of earthquake forces and motions which has been instituted will hasten the practical and effective solution of problems involved in proper structural design to resist them is not doubted. There is the possibility also that it will open up new fields of research which may promote more effective control of nature's forces to make many different types of structures safe against damage or destruction when subject to forces other than those produced by seismic movements. A better understanding of this simple phenomenon, called resonance, may also help to explain many things in connection with structural dynamics that have on occasions baffled engineers.