ORTHOGONAL EFFECTS IN RESPONSE SPECTRA SEISMIC ANALYSIS

A well designed structure should be capable of resisting earthquake motions equally from all possible directions. An option in some existing design codes for buildings and bridges requires that members be designed for *100 percent of the prescribed seismic forces in one direction plus 30 percent of the prescribed forces in the perpendicular direction*. Other codes require the use of 40 percent rather than 30 percent. However, they give no indication on how the directions are to be detemined for complex structures.

For response spectra analyses, it has been shown that the *design of elements for 100 percent of the prescribed seismic forces in one direction plus 30 or 40 percent of the prescribed forces applied in the perpendicular direction* is dependent on the user's selection of the reference system. In a recent publication [1], it was demonstrated that for structures which are rectangular and have clearly defined principal directions, these *percentage* rules yield approximately the same results as the SRSS method for directional combinations. These commonly used *percentage combination rules* are empirical and can underestimate the design forces in certain members for some directions of excitation.

The referenced paper details an alternate method in which an SRSS combination of two 100-percent spectra analyses, with respect to any user defined orthogonal axes, is used. This method will produce design forces which are not a function of the reference system and results in a structural design which has equal resistance to seismic motions from all directions.

The theory in the paper is based on the assumption that motions which take place during an earthquake have one principal direction. Or, that during a finite period of time, around the time of the occurrence of the maximum ground acceleration, a principal direction exists. For most structures this direction is not known and, for most geographical locations, cannot be estimated. Therefore, the only rational earthquake design criterion is that the structure must resist an earthquake of a given magnitude in any possible direction. In addition to the motion in the principal direction, there is a probability that motions normal to that direction will occur simultaneously. Also, it is valid to assume that these normal motions are statistically independent because of the complex nature of three-dimensional wave propagation. An example is presented which illustrates that the percentage methods can produce nonsymmetric results for a symmetric structure.

The SRSS method of combining directional effects is based on fundamental principles of random vibrations; therefore, the SRSS method of combining the effects of orthogonal input spectra has been incorporated in the SAP90 and ETABS computer programs.

1. "A Clarification of the Orthogonal Effects in a Three-Dimensional Seismic Analysis", E.L. Wilson, I. Suharwardy and A. Habibullah, *EERI EARTHQUAKE SPECTRA*, Vol. 11, No. 4, Nov. 1995. Readers who wish to receive a copy of this paper may fax or e-mail their request to CSI.

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