Code feature section

ASSESSMENT OF EARTHQUAKE RESPONSE FROM MODAL ANALYSIS

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The writer has always had reservations about accepting the result of direct integration of floor forces from a digitalised earthquake record, where no attempt is made to first separate out the various modes and then to recombine them in a controlled manner. To take an extreme example, in one earthquake the first mode response may be in exact phase opposition to a higher mode response, at the instant when both modes have risen to maximum amplitude. In another earthquake of similar magnitude and duration but with a slightly different pattern of movement, the modal responses could be of the same magnitude as in the previous earthquake, but the first mode response could be exactly in phase with a higher mode response at the instant when both modes have risen to maximum amplitude. Obviously, a building designed to resist the integration of floor forces in the first earthquake may not be safe in the second earthquake. It appears to be far sounder design to consider the modes separately, and then to decide on a basis for combining them which will take reasonable account of all possible phase relationships between modes on a statistical basis By so doing, the designer is providing for a whole family of similar earthquakes, rather than the one earthquake of which he happens to have a record.

An interesting article by R. Shepherd (1) in the September 1969 issue of the Bulletin cites one building where "root-sum-square" calculations of storey forces gave misleading results, and hence a direct integration procedure was used instead. For the reasons set out above, the writer feels that calculation of the respective floor forces, followed by combining of modes on a probability basis, would still form a sounder basis for design and would provide for a wider range of earthquakes. The important point is of course, that the combining of modes must be done on a logical basis and not, just by blindly following a "root-sum-square" rule.

In principle the approach would appear to be as follows. For each floor, the first mode and second mode forces would be calculated separately. Then a series of phase differences between the first and second modes would be assumed. The phase difference would represent the fraction of the second mode period by which the second mode maximum was ahead of or behind the first mode maximum in time, and could be given a number of alternative values ranging from zero up to half of the second mode period. For each assumed value, the resultant forces on all floors could be added together algebraically - i.e. <u>taking account of whether the force was positive or negative in direction</u>.

This would give design shears for every alternative value of phase difference. Then, from the results for all phase differences, a set of shears could be calculated which would give a 90% probability that combination of first and second modes with random phase differences would not exceed the calculated values.

In actual application of the above principle it would not be necessary to calculate the values for alternative differences. The phase difference which would give the 90% probability could usually be determined immediately, and only one set of resultant storey shears would consequently have to be calculated. The ratio of the maximum possible values to the 90% probability values could also be calculated for the designer's consideration.

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(1) R. Shepherd "Some Limitations of Modal Analysis in Seismic Design." Bulletin of the N.Z. Society for Earthquake Engineering, September 1969.