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16. Abstract (Limit: 200 words)
The impetus behind most earthquake engineering research is the application of the research results to the reduction of earthquake hazards through engineering design. Of primary importance is an understanding of the spectral characteristics of potentially damaging ground motions in all seismically active regions. Regional differences and local variations of ground motion are important, but the level of motion is significant only if it is potentially damaging to reasonably well designed structures or systems. Lower levels of motion are important only if interpretations based on them may be extrapolated to the higher, potentially damaging levels of ground motion. From the recurrence data and the average cost of instrumentation and its maintenance ($400 per year), the costs to obtain records with peak accelerations greater than specified levels have been estimated. For peak accelerations that are potentially damaging, the results imply that, except in the three most active areas, costs of the order of $10-20,000 per record must be anticipated in most areas of California. In areas less active than California, even higher costs must be anticipated. To maximize the benefit to be derived, it is clear that those studies that can be accomplished in the more active areas should be planned for those locations. Studies of local site conditions should be planned for Cape Mendocino, the San Benito Valley, and the Imperial Valley. Studies of low-rise buildings and freeway bridges also can be planned for these regions.

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The following discussion emphasizes the current capabilities and future needs in strong-motion instrumentation used as a research tool to solve significant problems in earthquake engineering. Some problems can be solved only from strong-motion data, and the solutions to other problems require verification that can be demonstrated only with strong-motion data. Significant strong-motion records from any one site are obtained infrequently and at considerable expense. Hence, careful planning is required to optimize the return of data for the investment required.

The impetus behind most earthquake engineering research is the application of the research results to the reduction of earthquake hazards through engineering design. Of primary importance in this research is an understanding of the spectral characteristics of potentially damaging ground motions in all seismically active regions. Regional differences and local variations of ground motion are important, but the level of motion is significant only if it is potentially damaging to reasonably well designed structures or systems. Lower levels of motion are important only if interpretations based on them may be extrapolated to the higher, potentially damaging levels of ground motion.

For many years, the stated engineering design philosophy has been that structures should survive frequently occurring levels of motion without damage and should survive the most extreme levels of motion without collapse. Design procedures, however, tend to emphasize the lateral forces associated with the frequently occurring levels of ground motion, not those that may cause damage. Furthermore, the performance of real structures during motions that cause significant damage is inadequately understood. A considerable amount of information on structural response at damaging levels can be obtained from laboratory and shake table tests, but confirmation of such results will be required from structures that are damaged in major earthquakes.

The types of studies that utilize strong-motion data may be classified as follows:

- Studies of the source mechanism.

- Studies of the spectral characteristics of strong ground motions and of the variations of these characteristics with the nature of the source, travel path, and local site conditions.

- Studies of soil failures through liquefaction or landslides.

- Studies of the response of representative types of structures and systems at potentially damaging levels of response and of the influence of the foundation conditions on this response.

- Studies of the response of equipment that is free-standing or mounted on structures.

Basic to all of these studies is the need to plan the instrument arrays so as to solve the important problems that can best be solved with strong-motion data from actual earthquakes. This requires an optimization of the location of networks and arrays and of the numbers and locations of instruments within arrays with the objective of obtaining data to evaluate analytical solutions for each specific problem.

Source mechanism studies represent a relatively recent use of the strong-motion data, and significant results have been achieved in determining source spectra and displacement characteristics from near-field records. A basic problem in source mechanism studies is that the instruments must be located "close" to the source of future events whose location and time of occurrence cannot be accurately predicted at the present time. Numerous instruments may have to be located in all significantly active areas in order to insure that the near-field records required to conduct source mechanism studies will be obtained.

Most of the significant strong-motion records obtained to date have been obtained in California, and the techniques for estimating the spectral characteristics and attenuation of strong ground motion are based largely on these records. Preliminary evaluations of the seismicity of other regions suggest that several other areas may provide as much data in the same time frame as some of the less active areas of California. Regional networks should be designed to obtain data on the differences in the spectral attenuation of ground motion in these regions. Numerous instruments may be required in each region if the spacing and location of the instruments in these networks are optimized relative to the nature of the source and in view of the anticipated amount of scatter in the attenuation data.

Local site effects include the influence of: 1) the amplification and filtering of motion by near-surface layers, 2) variations in the motion with depth even in the absence of noticeable layering, and 3) variations of ground motion over short distances. In none of these cases have adequate instrumentation arrays been designed and installed so as to obtain the data needed to verify the models that have been developed. General information about the influence of local site conditions on the spectral amplitudes of ground motion may be obtained from regional networks by placing instruments in different geologic settings or at sites with different soil conditions. More detailed studies will require an extensive instrumentation program including down-hole instruments. A few down-hole installations have provided data from low-level events, and a few more are being installed at the present, but meaningful data at potentially damaging levels of motion are nonexistant. Several three-dimensional instrumentation arrays should be installed in regions where the seismic activity is sufficiently high to insure an adequate return on the investment in instrumentation, its installation, and its maintenance. The location and spacing of instruments in these arrays need to be optimized with respect to the seismicity of the different regions, and the nature of the near-surface layering.

Instrumentation to study soil failures through liquefaction or landsliding is virtually nonexistant. These instruments can be incorporated into regional arrays if potential areas of soil failure are identified. Data from transducers placed in the area of potential soil failure as well as on nearby stable ground can be recorded remotely to obtain some meaningful data even though a soil failure occurs. Optimization of the spacing and location of transducers in areas of potential soil failure must await additional analytical studies of the problem. Extensive instrumentation for these studies should be installed only in highly active regions, however.

Although the San Fernando earthquake produced 60 sets of records of building response, most of these data are marginally significant. Only two buildings that incurred structural damage were instrumented, and only one of these was damaged significantly. On the other hand, data from at least twenty other buildings are of some importance in understanding the nonlinear behavior of typical buildings prior to the initiation of damage. No significant records have been obtained from any structures other than buildings. There are no cases in which instrumentation has been specifically designed to study soil-structure interaction, although two cases are known in which records have been obtained from buildings in which soil-structure interaction may have been an important factor. Optimization of the location of the instruments in each type of structure must be based on the dynamic characteristics of the particular structure. Allowing for the fact that many different types of structures are being instrumented for both operating and regulatory agencies, a total research program of instrumentation of representative types of structures should be optimized with respect to the seismicity of different regions and the relative importance of different types of structures.

Recurrence relations have been obtained from the strong-motion records obtained at installations that have been in place for about 40 years. In three cases (Ferndale, Hollister, and El Centro) the data are sufficient to provide statistically meaningful recurrence times for peak accelerations up to 100 cm/sec/sec, whereas in most cases the data are sufficient only to estimate the recurrence time at 10 cm/sec/sec. Of equal importance, however, is the fact that at several sites in "seismically active" areas, no estimate of recurrence could be made.

For example, no estimate could be made for Golden Gate Park, San Jose, Westwood, or Pasadena, although maximum accelerations of 100 cm/sec/sec have been recorded at each of these sites. Furthermore, although 12 records have been obtained at Helena, only three have been recorded since 1940 and none since 1960. These results are an indication of the serious difficulties that arise in any attempt to provide a rational plan to obtain the desired strong-motion data in a reasonable length of time.

From the recurrence data and the average cost of instrumentation and its maintenance ($400 per year), the costs to obtain records with peak accelerations greater than specified levels have been estimated. For peak accelerations that are potentially damaging, the results imply that, except in the three most active areas mentioned above, costs of the order of $10-20,000 per record must be anticipated in most areas of California. In areas less active than California, even higher costs must be anticipated.

The benefits that will be derived from the data also must be estimated to assess the proper significance of the costs. Obviously, the first set of data that will provide insight to some of the unanswered questions regarding the nature of the strong ground motions from earthquakes in the eastern parts of the United States will be of considerable value, whereas additional records at 50 cm/sec/sec obtained at any of the sites in California are of little added value. To maximize the benefit to be derived, it is clear that those studies that can be accomplished in the more active areas should be planned for those locations. Studies of local site conditions should be planned for Cape Mendocino (Ferndale), the San Benito Valley (Hollister), and the Imperial Valley (El Centro). Studies of low-rise buildings and freeway bridges also can be planned for these regions, whereas studies of high-rise buildings or dams can be conducted only in somewhat less active areas of California. A careful study of the seismicity of other regions must be made to determine the extent of instrumentation that is optimum in structures in those regions.