SEISMIC MICROZONATION

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SUMMARY

Seismic microzonation method using Uniform Risk Spectra[3,4] (URS) is reviewed and illustrated. It provides continuous probabilistic spectral amplitudes which can be used in design, in probabilistic estimation of response, or to generate synthetic accelerograms for non-linear analyses. The method does not require new or difficult steps to gather data and all required calculations can be performed on a personal computer.

INTRODUCTION

Earthquake resistant design provisions[1,6,9,13–17] contain information on the areal distribution of the horizontal force coefficient, and thus present maps showing how this coefficient varies geographically. These seismic zonation maps[1,6] typically do not show much detail and are ment to reflect the general distribution of the expected future earthquake shaking. Thus a large city or a metropolitan area may be covered by one constant value of the seismic design coefficient.

It has been recognized[1,9,13,14] by many earthquake engineers that the local soil and geologic conditions influence the level and nature of earthquake shaking and the degree of the observed damage.[17] Many code provisions[6] incorporate such effects into the shape of the design spectrum or allow further investigations to modify the average code coefficient and incorporate local areal variations reflecting the local site conditions. The extent of permitted departures from the average code amplitudes and the procedures recommended for estimating their flucations vary from one code to another.[6] In most currently employed methods these variations are determined from consideration of soil and geologic site conditions, which are assumed to "amplify" the average incident strong motion amplitudes.[9,13–15] The average amplitudes are determined from the maps of horizontal design coefficients, from assigned "representative" intensity for use in design (usually associated with different return periods), or from some amplitude controlling parameter (e.g. peak acceleration), determined via simplified seismic risk analysis.

The key assumption in the above approach is that the local soil and geologic conditions lead to amplification patterns which do not change from one earthquake shaking to the next, and that these patterns can be determined experimentally or by analysis of the local site conditions. In Japan, Kanai[8] and his co-workers investigated microtremors as possible source of excitation to "measure" the distribution of the local amplification patterns. Later studies of their analyses procedures and of the nature of microtremor waves,[2] and of the differences in their wave propagation paths relative to the paths of earthquake waves, have discouraged many investigators from further considering this approach.[35] So far no one has developed a satisfactory and physically justified method for using microtremor vibrations to characterize the patterns of amplification of ground motion during earthquakes. Observations of repeated strong motion shaking from different earthquake at the same recording station show large differences which depend on the angles of wave arrival, on the source mechanism of the earthquake, and on its proximity to the site. Simple analytical studies of wave scattering, focusing and diffraction, by soft soil and alluvial deposits show that the peaks of the spectral amplitudes of recorded motions at the ground surface can shift with changes in the incident angle of the arriving waves so much that he concept of "predominant period," as used in older microzonation studies,[8,14,18,19,36] can no longer be justified.

Some older proposals for microzonation methods included the local soil and local geologic site characteristics,[14,16] but more recent work tends to favor the local soil conditions only.[15] Our present understanding of the changes in strong motion amplitudes along the wave propagation path, from the source to the recording station, indicates that one must include both the soil and the geologic site conditions,[24–27] if correct average amplification is to be determined. This means that a larger volume (1 - 10 km) surrounding the site must be included in the analysis.[27] Typical soil investigations involve smaller (10 - 100 m) volume and include shallow soil properties only. Clearly the state-of-the-art microzonation mapping of the amplitudes of strong shaking may be complex and costly for an individual project and should involve entire cites and metropolitan areas.

The time involved in the development, in the implementation and in the long range benefits from proper use of physically sound microzonation maps in earthquake resistant design,[23] all suggest that it will take many years before the current individual, subjective and often incomplete or specialized microzonation studies, and the structures designed by the current procedures, are all surpassed and phased out. The future advanced society will have to overcome first the short term, often post facto, and the incremental improvements of earthquake design codes, before the full power of the multidimensional economic advantages are not only recognized, but also included in future microzonation procedures. Thus, at present, we can focus our attention on the physical aspects of this problem, hoping that through measurement and analysis at least sound principles can be developed for later inclusion into more integrated and general optimization framework.

MICROZONATION BASED ON U.R.S. METHOD

The method for preparing microzonation maps based on Uniform Risk Spectra (U.R.S.) has been discussed elsewhere in detail.[3,4,5,31,32,] Here only some general features and advantages of this approach will be summarized. The method is based on the computer program NEQRISK which computes U.R.S. for selected probabilities of exceedance, for a chosen duration of exposure (e.g. $Y = 50$ years), for a combination of random independent (Poisson) and literal (predicted) earthquake occurrence at sources which can be defined to reflect all the details of the faulting geometry surrounding the site. The seismic activity at all seismic sources can be described by the occurrence rates, versus magnitude or intensity, and in terms of the geological slip rates using time rate of change of the seismic moment.[32,34] When output is required in the form of acceleration time histories, the program NEQRISK is used to compute the Uniform Risk Fourier Amplitude Spectra, which then serve as input for computer program SYNACC, which calculates synthetic strong motion accelerations.[11,12,34] This program includes the site specific wave dispersion analysis and computes two horizontal, one vertical and two rotational (torsion and rocking) components of acceleration.

In the following we illustrate typical microzonation[10,21,26] maps computed via URS amplitudes and point out several advantages of this method. First, over an extended area of a large city, the seismic risk cannot be described by a constant (e.g. peak acceleration, or maximum intensity), unless all sources of earthquakes are at considerable distance (e.g. further than say 200 km). For example, Figure 1 illustrates the setting of the metropolitan Los Angeles area and shows the major qaternary faults in Southern California.[7,37] Earthquakes occurring at all these faults have been included in the calculation of microzonation maps illustrated in Figure 2. Even if the geologic and the soil media in this entire area were uniform, the microzonation maps would still indicate high and low amplitudes, which would be governed by the proximity, geometry and activity of all sources (faults) "contributing" strong motion amplitudes with different probabilities of exceeding spectral amplitudes at a site. In Los Angeles area, the seismic risk measured by the maximum site intensity or maximum "earthquake" that could shake a site,[23] slowly increases forwards northeast as one approaches the San Andreas fault, assumed to be the "major contributor" of earthquake events during the next $Y = 50$ years. Without San Andreas fault in this model the amplitudes of seismic risk, throughout Los Angeles, would be more variable and the amplitudes would reflect the proximity of a site to one or to several of the active faults in the model (Figure 1).

Second useful feature of the U.R.S. approach is that it incorporates the site soil and geologic conditions into the calculations directly. Figure 2 illustrates the Uniform Risk Pseudo Relative Velocity Spectra (in/sec) for oscillator periods $T = 0.04$, 0.34, 0.9 and 2.8 seconds, for probability of exceedance equal to 0.5 and for exposure during the next 50 years. The large amplitude elongated zone near the central part of the metropolitan area reflects the influence of the deep sedimentary basin ($\sim$ 30,00 feet) which tends to amplify more the longer period ground motion. A detailed manual with many such maps can be prepared[26] for probabilities of exceedance $p = 0.99$, 0.90. 0.50, 0.1 and 0.01, for example, and for amplitude scaling in terms of earthquake magnitude[28−30] or local intensity.[33,34] From such a manual, at any point in the area covered, one can construct U.R.S. of Pseudo Relative Velocity (PSV), for the above given probabilities of exceedance, to obtain the site specific URS of PSV amplitudes.

Third, the shape of the U.R.S. changes continuously as the site moves. This reflects changing contributions to the shaking amplitudes which come from faults at different distances, with different earthquake activity and for wave arrivals through different site soil and geology. Unless the risk is governed by the proximity of a fault where large earthquakes may occur, the shape of URS will usually be quite different from the shape of a response spectrum associated with one earthquake. The shape of U.R.S. will also reflect the relative proportion of small to large earthquakes occurring near a site, and the largest magnitude earthquake, $M_{\max}$, associated with one or several near sources.

Other details on URS microzonation maps, including conversion from horizontal to vertical components of ground motion, different scaling alternatives and forms of mapping can be found elsewhere.[10,23,26] The general methodology, definition and the methods of calculating URS have been available since 1977.[3,4]

In the above described microzonation method it is assumed that the objective is to determine the amplitudes of strong earthquake shaking in elastic and linear local site environment. These motions can be used as input to evaluate the liquefaction potential, landslide hazard, and various non-linear phenomena of response and their effects on distribution of structural damage, for example.

CONCLUSIONS

The purpose of this brief paper has been to review the current state of art in preparation of seismic zoning maps via U.R.S. method. This method enables one to incorporate many factors contributing to the seismic risk, in a balanced way, and to forecast the distribution of seismic risk for use in earthquake resistant design, using an independent Poisson sequence of earthquake events, earthquake prediction, or a combination of these two.

The calculations using NEQRISK and SYNACC computer programs can be performed on a small personal computer. The specification of earthquake sources, their geometry, number, and source activity, usually can be prepared from the existing seismicity and geologic data, by a coordinated group of geologists with total effort rarely exceeding a one man year. Following careful regional investigation of representative scaling and attenuation of recorded strong ground motion,[33,34] NEQRISK program can be modified to work with regionally representative empirical scaling functions for strong motion amplitudes.

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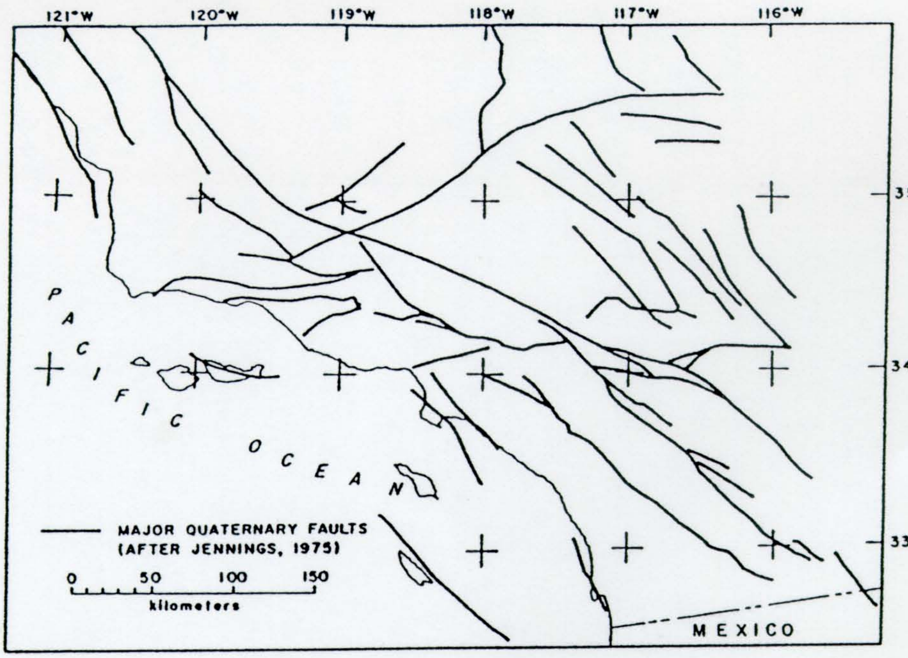

Figure 1

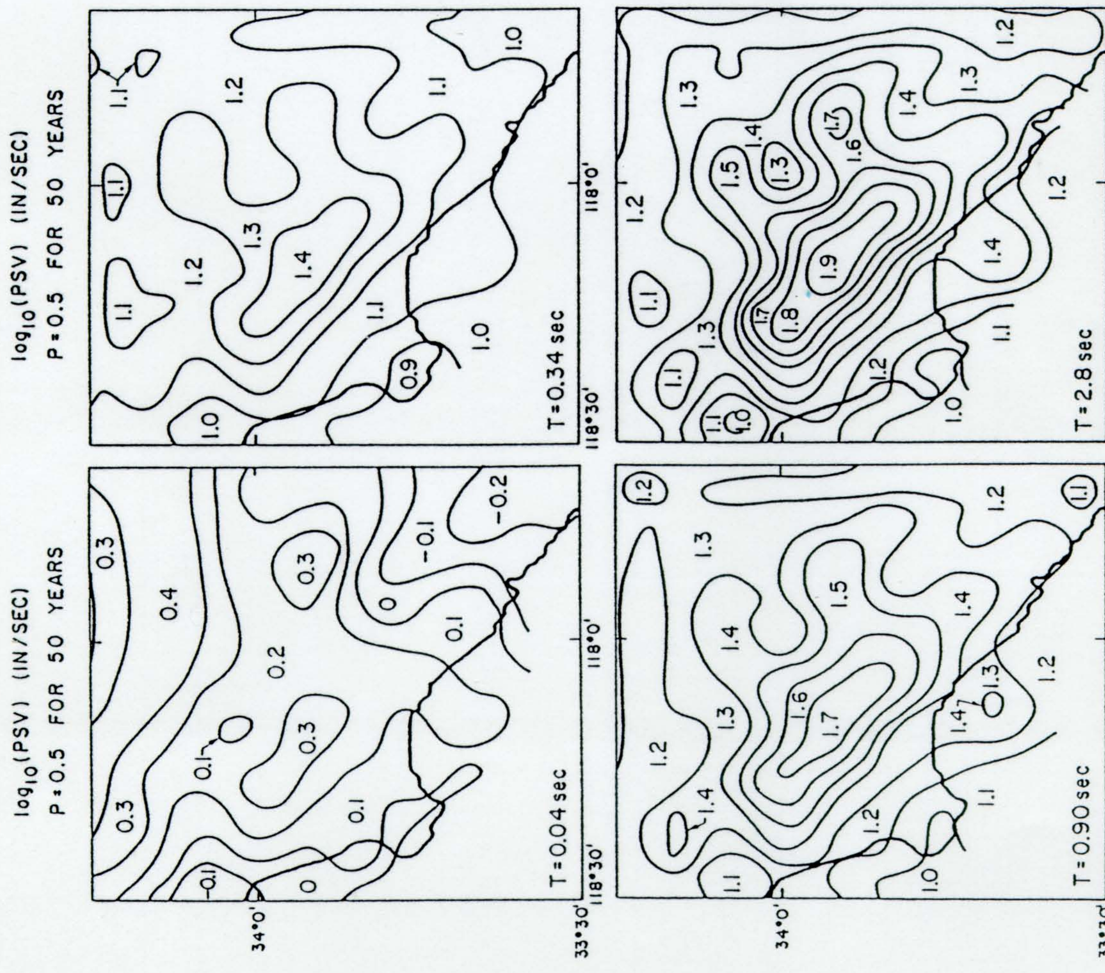

Figure 2