SEISMICITY AND SITE EFFECTS ON EARTHQUAKE RISK

by

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SYNOPSIS

An earthquake risk model that incorporates a bayesian estimate of seismicity and an amplification factor for local site conditions is developed and applied to the Los Angeles, California area. Recency of faulting is used as a criteria for assigning activity rates to faults with no "historic" record of earthquake epicenters. Shear-wave velocity profiles are used to characterize local site conditions. 100-year expected peak velocities are computed by combining the above models with probability and statistical models of earthquake occurrence.

INTRODUCTION

Decisions of the routing of aqueducts, transportation, and electric power transmission systems in seismically active regions should incorporate a consideration of the risk of seismic shaking along the various possible routes. In regions such as California, where the seismic regime and areal geology are comparatively well understood, it is useful for this purpose to display the seismic risk of the region on maps. This paper outlines a methodology for estimating these risks, and applies the method to a part of the Los Angeles area. Risk, as it is used throughout this paper, is defined as the probability that a ground motion index (such as peak velocity) will be exceeded within a certain period of time for a specified design life.

The main features of the present paper are the utilization of a bayesian-type seismicity model and the incorporation of a quantitative site effects model. The former represents an attempt to utilize geologic data, such as recency of faulting, to estimate the activity of major faults having no "historic" earthquake epicenters associated with them. The site amplification model includes the effect of local site conditions on the intensity of seismic shaking. As a result, a site classification scheme, based on the utilization of shear-wave velocity profiles, is presented and is incorporated into the analysis of risk.

SEISMICITY

Since the historic record of earthquake occurrences in Southern

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California is of relatively short length and subject to large uncertainty (2), it was decided to use both historic seismicity data as well as regional tectonics to assess the activity of the major faults of the region.

Thirty-five faults within a 200-kilometer radius of the study zone were selected as potential sources of future earthquakes, Fig. 1. The faults were grouped into three classifications based on their known recency of activity and surface faulting (1): these being active (A), potentially active of high potential (HP), and potentially active of low potential (LP). A fourth group classified as inactive (IA) by the A.E.G. criteria was excluded from consideration. This classification is believed to give a reasonable indication of the relative amounts of seismic activity that can be expected in the future (4).

The historical seismicity of the 200-kilometer region surrounding the site was determined from available catalogs of Southern California earthquakes occurring from 1812 through 1975. Based on this data, the recurrence curve for the region was found to be,

$$\mathrm{Log}_{10}N = 5.34 - 1.0M \tag{1}$$

where N is the number of events per year occurring within the region having Richter magnitude M or greater. The San Jacinto Fault was the only fault for which enough historical data was available to establish a recurrence curve. This curve, established for a narrow zone surrounding a 266-kilometer segment of the fault is given by,

$$\mathrm{Log}_{10}N = 3.82 - 0.79M \tag{2}$$

The lack of adequate historical activity to establish recurrence curves for the remaining faults requires some sort of "bayesian" assessment of their activity rates. In this respect it was assumed that each fault classification could be characterized by a constant activity rate per unit length of fault. This, of course, excludes the San Jacinto Fault whose activity is given by Eq. (2). Active faults were assigned an activity rate per unit length based on the historic seismicity of the region, Eq. (1), less the seismicity associated with the San Jacinto Fault. This conservatively assigns all of the past historic activity to those known active faults. HP-type and LP-type faults were arbitrarily assigned activity rates per unit length of 1/2 and 1/6 times that of the active faults. The values of 1/2 and 1/6 represent preliminary estimates and should be revised accordingly as research warrants. The b-value, or slope of the recurrence curve, for each fault classification was given a value of -1.0 as established for the region as a whole.

LOCAL SITE CONDITIONS

An important concern to those estimating earthquake risk is the effect of local site conditions on expected earthquake ground motions. In the past only limited correlations between qualitative site classifications and various instrumental indices have been found. Recently, however, a new classification system was introduced which uses a quantitative representation of site properties to characterize site effects (3). The technique consists of fitting parabolic functions through shear-wave velocity profiles using the following equation,

$$V_s = Kd^{0.37} \qquad (3)$$

where V_s is shear wave propagation velocity (ft/sec); d is depth (ft); and K is a constant. Therefore, the dependence of velocity on depth can be established by the value of K.

Using K to represent a measure of site properties, multiple regression (3) were performed using ground motion index data provided by the 1971 San Fernando earthquake. From this analysis, a strong correlation was found between peak particle velocity, V (cm/sec), and K. This relationship, as a function of hypocentral distance R in kilometers, is given below and in Fig. 2,

$$V = e^{4.69}K^{.33}R^{-1.05} \qquad (4)$$

Correlations utilizing peak acceleration and peak displacement exhibited little dependence on K. In order to incorporate magnitude into the analysis, Eq. (4) was multiplied by $e^{1.2(m-6.4)}$.

Equations similar to Eq. (4) were also established for two types of rock: Sedimentary and Basement Rock. These equations, however, do not incorporate K-values.

PROBABILITY DISTRIBUTION

The joint probability distribution utilized to represent the occurrence of earthquakes in time, magnitude and space was a Gumbel Type II extreme value distribution. This distribution, transformed to give the distribution of maximum annual peak velocity using Eq. (4), is given by,

$$P(V>v) = 1-e^{-t/T} \qquad (5)$$

where $P(V>v)$ is the probability that peak velocity is exceeded (i.e. risk) in t years; t is the design life of the structure under consideration, and T is the return period. For specified values of risk, design life and return period, the design peak velocity can be computed by an iterative solution of Eq. (5).

For the purpose of this study, the following parameters were used; T = 100 years, t = 50 years, and risk = 0.39.

EXAMPLE

To illustrate the methodology, an example is presented using a part of the Los Angeles area. The Basement and Sedimentary rock estimates of 100-year peak velocities is given in Fig. 3. Geographically, the rock sites are located in the top portion of the study area. In general, the velocities exhibit little variation within each of the two rock groups.

The soil site estimates of velocity in Fig. 3, however, have been computed using a reference K-value of 400. Because of this, the variation in values can be attributed totally to effective fault distances. Note that the largest value of velocities lie diagonally on a line from the lower right-hand corner to the upper left-hand corner of Fig. 3. This trend is due to the presence of the Newport-Inglewood fault.

Since the 100-year velocities for the soil sites were computed using a reference K-value, a velocity coefficient is used to obtain the site-dependent velocities. This coefficient, C_v, is computed from the following equation,

$$C_v = (K/400)^{.37} \tag{6}$$

where K represents the soil parameter determined from the shear-wave velocity profile. The base soil velocity, V_{400} is then multiplied by this coefficient to obtain the expected velocity, V_k, for the site.

By incorporating C_v, the site velocities, V_k, for the three sites are found to vary from 33 to 45 cm/sec. The original base velocities, however, only span a 3 cm/sec range. The rock velocities range from 13 cm/sec for Basement Rock to 27 cm/sec for Sedimentary Rock. Therefore, for this example, K-value and rock type have a greater effect on the areal distribution of velocity than does the seismicity of the region.

CONCLUSION

A method of computing the 100-year design ground motion for a site is presented and applied to a portion of the Los Angeles area. The important features of the method include 1) a bayesian assessment of fault activity rates and 2) a quantitative assessment of site effects. For the relatively small study area used in this paper, it was observed that site conditions had a much greater effect on the 100-year velocities than did the regional seismicity. However, with the inclusion of a larger study area, the effect of seismicity would be expected to become more significant.

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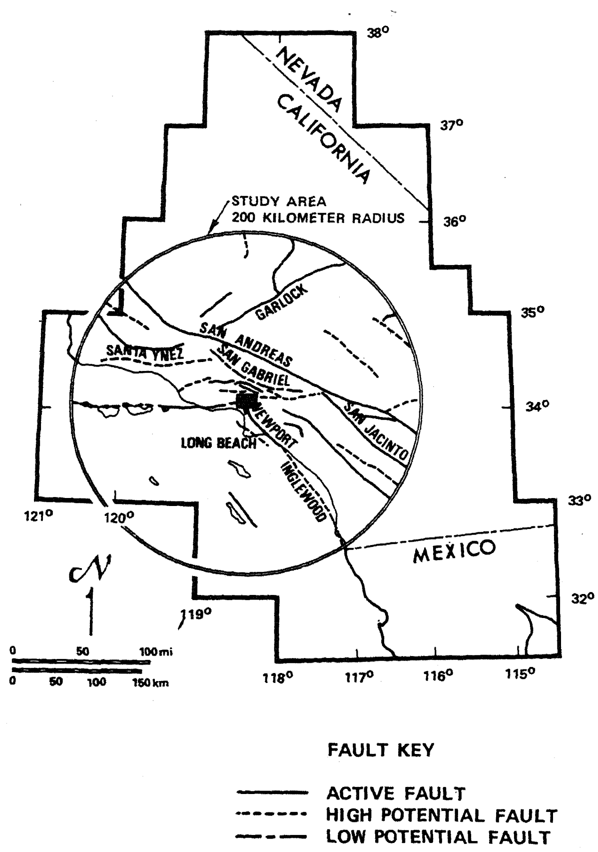

Figure 1. Base Fault Map for Southern California.

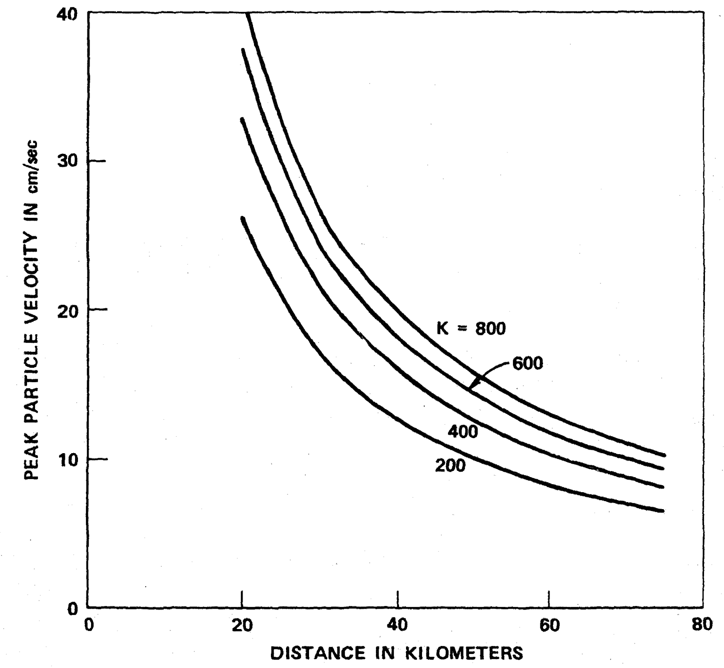

Figure 2. Multiple Regression of Peak Velocity on Hypocentral Distance and K-Valve.

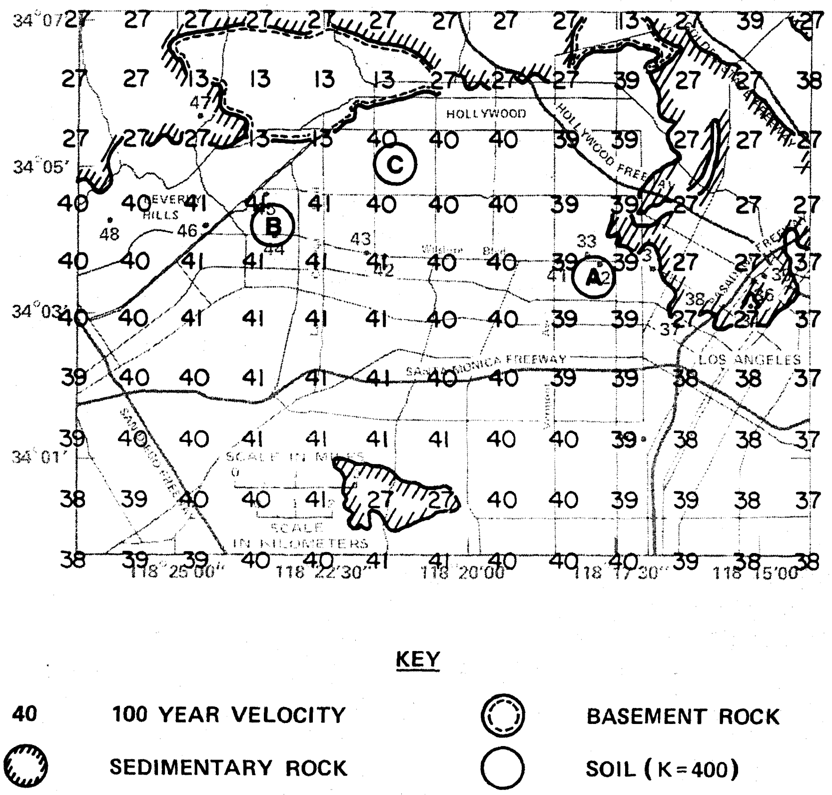

Figure 3. 100—Year Velocity Base Map for Central Los Angeles.

TABLE 1
COMPUTATION OF 100-YEAR PEAK VELOCITY

SITE	LOCATION	K-VALUE	V_{400} (cm/sec)	C_v	V_k (cm/sec)	M.M.I.
A	616 S. NORMANDIE, L.A.	603	39	1.15	45	IX
B	435 OAKHURST, BEVERLY HILLS	429	41	1.02	42	IX
C	1100 HIGHLAND, HOLLYWOOD	231	40	0.83	33	VIII–IX