SEISMIC DESIGN REGIONALIZATION MAPS
FOR THE UNITED STATES

by

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SYNOPSIS

Two maps give the geographical variation of effective peak acceleration EPA and effective peak velocity EPV. The map for EPA is based primarily upon a seismic risk study involving selection of source zones, seismicity parameters and attenuation laws. The map for EPV is a modification to the map for EPA. The probability that EPA and EPV will not be exceeded at any location during a 50-year period is estiamted as 80% to 95%. EPA and EPV are used as input to an equation for design base shear.

INTRODUCTION

This paper describes a portion of recommended nationally applicable seismic design provisions. These provisions have been produced by the Applied Technology Council, associated with the Structural Engineers Association of California, under contract with the National Bureau of Standards (NBS) with funding by NBS and the National Science Foundation Research Applied to National Needs Program, as part of the Cooperative Federal Program in Building Practices for Disaster Mitgation initiated in 1972 under the leadership of NBS.

The preparation of design regionalization maps is being carried out by a committee composed of the authors plus Drs. Jack Benjamin, John Foss, John Reed and John Wiggins. Such maps cannot be drawn without consideration of the totality of the recommended design provisions. Hence, some of the material presented in this paper represents input from other committees involved in the overall ATC effort, especially a Committee on Ground Motion Spectra chaired by Dr. H.B. Seed. The maps are not yet in final form, and this paper emphasizes basic principles and procedures and displays the maps as drawn at the time of this writing (June 1976).

POLICY DECISIONS

The proposed ground shaking hazard maps are based upon two policy decicions which are departures from past practice in the United States. First, the relation between design lateral forces and building period should take into account the distance from anticipated earthquake sources. To accomplish this objective it was necessary to use two ground motion parameters and hence to prepare two maps. Second, the probability of exceeding the design ground shaking should be roughly the same in all parts of the country. Zoning maps previously in use had been based upon a maximum ground shaking experienced

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during the historical period without consideration of the frequency with which such motions might occur.

GROUND MOTION PARAMETERS - EPA AND EPV

In the recommended provisions, the strength of ground shaking is represented by two parameters: effective peak acceleration (EPA) and effective peak velocity (EPV). In the provisions, these factors appear as parameters in an equation, given below, for design coefficient. However, to understand their origins one should think of them as normalizing factors for construction of smoothed elastic response spectra (6). EPA is proportional to spectral ordinates for natural periods in the range of 0.2 to 0.5 second, while EPV is proportional to spectral ordinates for a period of about 1 second (5). The constant of proportionality in both cases is 2.1 for 5% damping.

For any one ground motion, EPA and EPV would be chosen such that the resultant smooth response spectra are a reasonable fit to the actual spectra for periods longer than about 0.2 second. For motions of very short duration, EPA and EPV would be reduced to reflect the observed fact that only one or two cycles of motion cause little inelastic motion even if a structure yields. Thus, the EPA and EPV for a motion may be either greater or smaller than the peak ground acceleration and velocity. However, when the duration is very short and/or when very high frequencies appear in the ground motion, EPA may be significantly less than peak acceleration. On the other hand, EPV is generally greater than peak velocity at large distances from a major earthquake (5).

MAP FOR EPA

Fig. 3 is the recommended map for the contiguous 48 states. EPA is contoured, and interpolation between contours is appropriate. There may be locations inside of the 0.4g contour where higher values of EPA would be appropriate; however, contouring such small areas would amount to microzoning, and was beyond the scope of this effort.

A prime reference for the preparation of Fig. 3 was a map drawn by Algermissen and Perkins (2) using the principles of seismic risk zoning (1, 4). In the preparation of that map, seismic source areas were identified from historical seismicity and geology, and rates of occurrence and maximum credible magnitudes were established for each source area. Different attenuation laws were used west (8) and east (7) of the Rocky Mountains.

The Algermissen and Perkins map was modified through the judgement of the committee to reflect the most up-to-date thinking concerning active faults and seismic source areas. Suggestion were received from a panel of seismologists from different parts of the country.

MAP FOR EPV

Fig. 4 was constructed by modifying the map for EPA. First an EPA = 12 inches/sec was assigned to the contour for 0.4g on Fig. 3. This value of EPV together with an EPA = 0.4g define the standard shape of response spectra recommended by Dr. Seed's committee as applying for nearby earthquakes. A similar approach was used for all contours which are regional "highs" of EPA; for example, EPV was set at 3 inches/sec along the contour for EPA = 0.1g around the Appalachian Mountains and South Carolina in the southeastern part of the country.

Strong motion recordings from California were used to determine the distance required for EPV to halve with distance from a large earthquake (5). This distance is about 80 miles. Data on attenuation of Modified Mercalli Intensity indicated that velocity should continue to halve in about 80 mile intervals. Thus a contour spacing of about 80 miles was used around all regional "highs" in the west with the proviso that a contour for EPV should never fall inside the corresponding contour for EPA, etc.

For the east, data on attenuation of Modified Mercalli Intensity (3) indicated that within 100 miles of a large earhtquake attenuation was the same as in the west. Thereafter, however, the distance required for the velocity to halve nearly doubled. Hence, around the New Madrid "high" in the central United States, the first contour interval is about 80 miles while the next contour interval is 160 miles.

RISK ASSOCIATED WITH EPA AND EPV

The probability that the recommended EPA and EPV at a location will not be exceeded during a 50 year period is estimated to be roughly 90% - at least it is in the general range of 80 to 95%. Thus the ground motion envisioned for design, at any location, is not necessarily the most intense motion that can occur at the location. In this connection, several points must be emphasized. First, considering the significant cost of designing a structure for extreme ground motions, it is undesirable to require such a design unless there is a high probability that the extreme motion will occur or if there is a particularly severe penalty associated with failure or nonfunctioning of the structure. Second, a building properly designed for a particular ground motion will provide considerable protection to life safety during a more severe ground motion. Third, even if it were desirable to design for the extreme ground motion, it is impossible, at this time, to get agreement among experts as to the largest credible EPA and EPV. This is especially true for the less seismic portions of the country.

SEISMIC DESIGN COEFFICIENTS

The base shear to be used for design is given by $V = C_s W$ where W is the weight. The seismic design coefficient is:

$$C_s = \frac{1.2\ A_2\ G}{R\ T^{2/3}} \qquad (1)$$

but need not exceed $2.5A_1/R$ for stiff or deep soils nor $2A_1/R$ for soft soils. G is a soil profile factor, ranging from 1.0 for rock and shallow stiff soils to 1.5 for profiles with soft to medium stiff clays and soils. R is a response modification coefficient discussed in a companion paper by Newmark et al. T is related to the fundamental period of the building; the exponent on T reflects a need for conservatism in the design of flexible buildings. (The exponent on T, the G factor and the numerical coefffficient in Eq. (1) are still under study.) A_1 and A_2 are coefficients related to EPA and EPV as indicated in Figs. 3 and 4. To illustrate the use of Eq. (1) and Figs. 3 and 4, Fig. 1 gives values of A_1 and A_2 for several cities together with curves of C_sR for shallow stiff soil. Fig. 2 illustrates the possible effect of having different soil conditions within a specific city.

For possible use by code authorities, alternate versions of Figs. 3

and 4 are being prepared. On each map, the contours will be replaced by zones and the boundaries between zones will generally be drawn along county lines.

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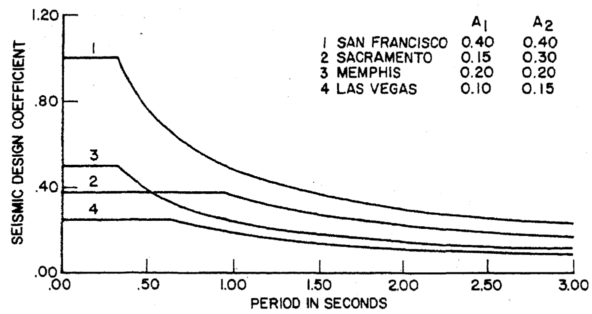
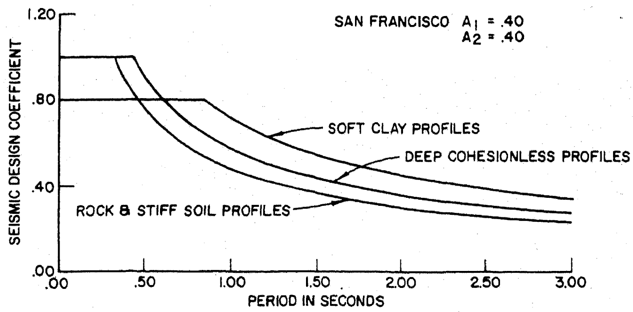
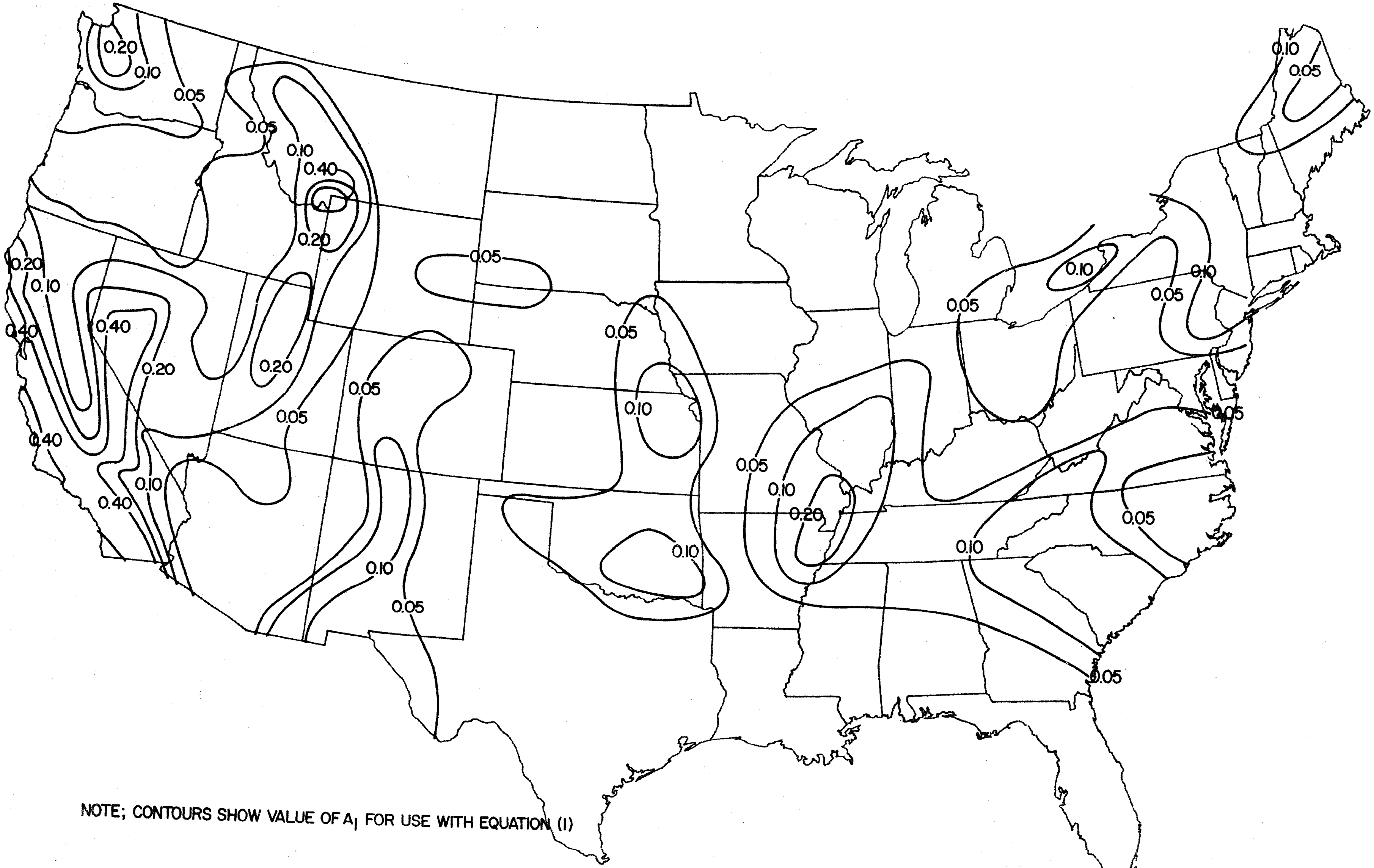


REPRESENTATIVE - DESIGN COEFFICIENT CURVES
FIG. 1



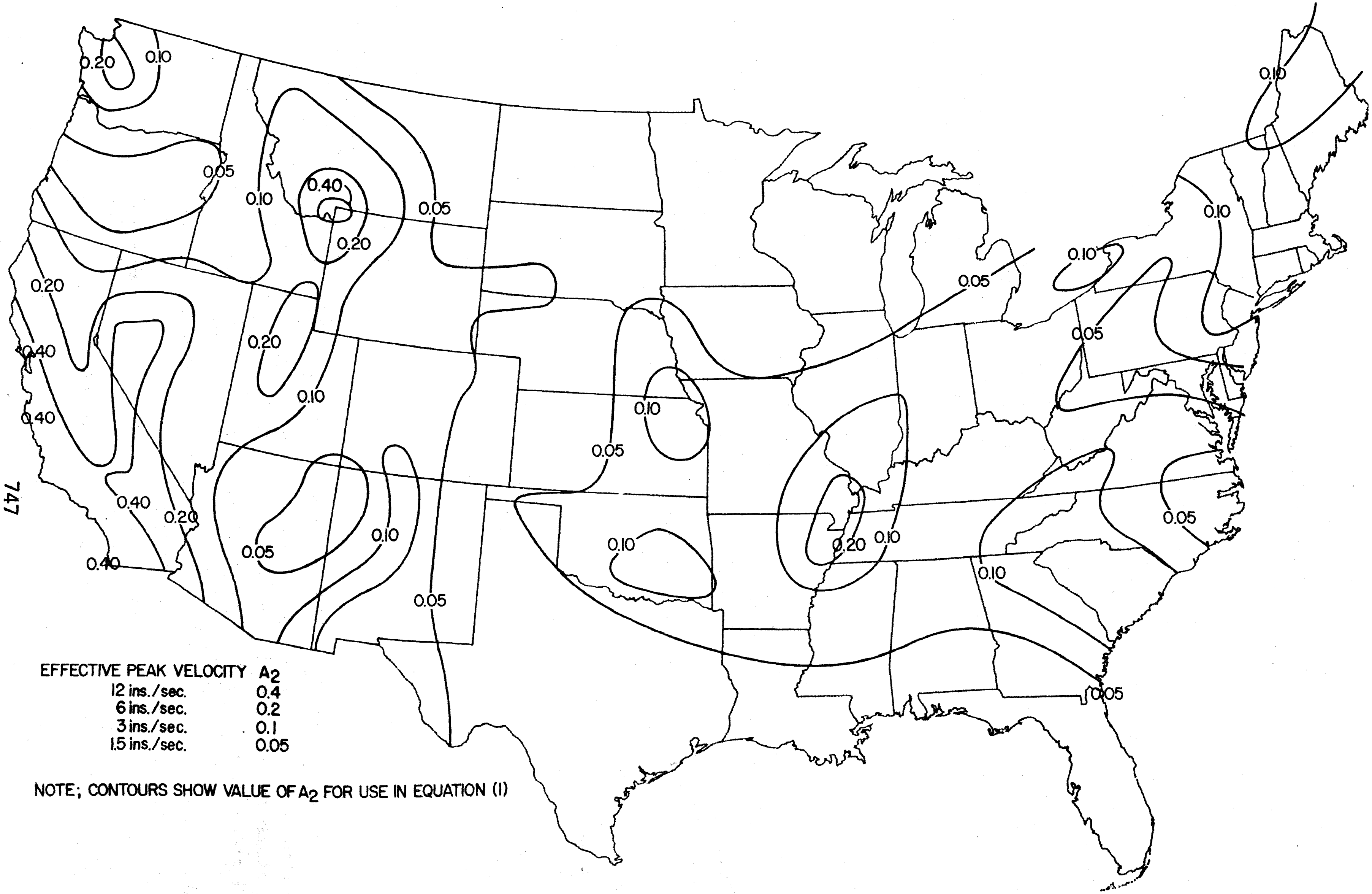
DESIGN COEFFICIENTS - FOR DIFFERENT SOIL CONDITIONS
FIG. 2



NOTE; CONTOURS SHOW VALUE OF A_I FOR USE WITH EQUATION (I)

EFFECTIVE PEAK ACCELERATION MAP

FIG. 3



EFFECTIVE PEAK VELOCITY	A_2
12 ins./sec.	0.4
6 ins./sec.	0.2
3 ins./sec.	0.1
1.5 ins./sec.	0.05

NOTE; CONTOURS SHOW VALUE OF A_2 FOR USE IN EQUATION (1)

EFFECTIVE PEAK VELOCITY MAP
FIG. 4

DISCUSSION

J.C. Stepp (U.S.A.)

Would you please define and discuss what is meant by "effective acceleration" in terms of its relationships to elastic response spectrum ?

K.L. Kaila (India)

The discussor have drawn the A - value and the b - value maps for the united states, (the slides for which have been shown) based on Kaila and Narain (1971) method. Here 'A' and 'b' are the constants in the earthquake regression relation $\log N = A - bM$, where N is the cummulative number of earthquakes with magnitude M and higher. The A and b - value maps prepared by us compare very well in their relative levels with effective peaks velocity A_2 in their map Fig. 4. The discussor had also had a chance to discuss with Dr. Perkins and group at USGS, Golden, Colorado our maps with the maps prepared by them. According to Dr. Perkins there is about 80 per cent agreement in the seismicity levels (A-values) as shown in our maps vis-a-vis relative levels of peak velocity and peak acceleration as shown in their maps, although the methods used in the preparation of the two sets of maps by them and we are totally different. What is the reaction to such a comparison by the authors of this paper ?

Author's closure

With regard to the question of Mr. Stepp, we wish to state that if we are interested only in structures which respond in a linear elastic manner, then there is a simple relation between effective acceleration and an elastic response spectrum. By definition, effective acceleration is 1/2.5 times the peak spectral response of a 5% damped mass-spring system.

However, when designing structures which are expected to become inelastic during a major shaking, the effect of duration must be considered. (I refer to an effect over and above the influence ofduration upon elastic response). If a motion with a very large peak acceleration involves only a few cycles, serious damage may not occur. On the other hand, a motion with much smaller peak acceleration but many cycles may bring about collapse. At the present, these considerations can only be incorporated into design by judgement. This effect is one of the reasons why effective accelerations in excess of 0.4g do not appear on the regionalization map given in the paper, and was also one of the factors considered when setting the minimum reinforcement and detailing requirements in the proposed design guide.

With regard to the question of Mr. Kaila, we wish to state that the source areas used by Algermissen and Perkins were developed largely on the basis of historical seismicity, supplemented where possible and appropriate by considerations of geology and tectonics. The algermissen-Perkins map for acceleration is thus greatly influenced by a parameter similar to your A-value. Hence it is not surprising that your map for the A-value shows many similarities but at the same time very important differences - to the Algermissen - Perkins map.