RESPONSE SPECTRA IN ALLUVIAL SOILS

by

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I. INTRODUCTION

Codes of practices of several countries [1] now recommend the use of response spectrum curves for aseismic design of structures. These response curves are generally smoothened to eliminate the peaks and troughs found in actual response spectrum curves. Housner[2] was the first to propose an average response spectrum and he also proposed normalising (multiplying) factors for eight actual time history accelerograms. Newmark and Rosenblueth[3,4] have proposed smoothened response spectrum curves in the form of tripartite plot and have indicated that in the low frequency range it tends to ground displacement and in the high frequency range it tends to ground acceleration. Blume[5] has also proposed smoothened response spectrum curves which could be applied to alluvial sites. The United States Atomic Energy Commission (USAEC)[6] has proposed smoothened response spectrum curves which have been normalised with respect to peak ground acceleration of 1.0 'g' where 'g' is the acceleration due to gravity.

Earlier it was felt that peak ground acceleration is a parameter which could describe the intensity of earthquake motion and empirical formulae were devised to predict ground acceleration in terms of magnitude of earthquake and distance from epicentre[7]. Now-a-days, other criteria like (i) peak ground velocity[4],

(ii) and non-dimensional parameter ad/v^2 (where a,v and d are respectively the peak ground acceleration, velocity and displacement) are used to describe the intensity of ground motion.

In this paper, acceleration response spectra, corresponding to five percent damping, obtained for fifty actually recorded time history accelerograms on alluvial sites have been analysed. The ordinates of the accelerograms have been normalised so that all the modified response spectra have been the same (i) peak ground acceleration (ii) peak ground velocity and (iii) ad/v^2 The envelope of the maxima and minima of the normalised spectra as well as an average of fifty spectra have been obtained for various cases.

A comparison of normalised average spectra indicates that a normalising factor of peak ground acceleration of 1.0 g corresponds to peak ground velocity of 150 cm/sec, and a value of ad/v^2 of 25. The USAEC spectra gives slightly larger values in the short period range and slightly smaller values in the intermediate, period range.

II. DATA USED FOR ANALYSIS

Earthquake Engineering Research Laboratory of California Institute of Technology[9, 8] have brought out an excellent compilation of actually recorded accelerograms mainly recorded in the Western part of U.S.A

Fifty of the records that were reported to be made on alluvial soil sites have been considered for analysis here. These are listed in Table 1. The acceleration response spectra of these fifty records corresponding to five per cent damping have been modified by use of suitable multiplying factors obtained by considering all the records have the same (i) peak ground acceleration of 1.0 'g' (ii) peak ground velocity of 100 cm/sec and (iii) non-dimensional parameter ad/v^2 of 10.

III. DISCUSSION OF RESULTS AND CONCLUSIONS

A simple average of all the fifty values of the normalised spectra corresponding to each period was evaluated. It was seen that the average response curves for different cases of normalisation correspond very nearly to each other if the following normalisation factor are used in the various cases, (i) a peak ground acceleration of 1.0 'g' (ii) a peak ground velocity of 150 cm/sec and (iii) ad/v^2 equal to 25.

Fig. 1 shows a plot of average response spectra. The USAEC spectra[6] is also shown in the same figure. It is seen that USAEC gives slightly higher values in the short period range and slightly lower values in the intermediate period range.

Using the revised values of normalisation (that is, average spectra nearly the same for the three criterion), maxima and minima values of the spectra for the fifty records have been obtained and shown in Figures 2 and 3. From Fig. 2 it could be seen that the normalisation corresponding to peak velocity gives the minimum value of the maxima envelope. The peak acceleration envelope is close to that of peak velocity. The ad/v^2 criteria gives very large values of maxima and if few records given in serial numbers 22, 26 and 44 are ignored (as shown in dotted curve of Fig.2) then the maxima looks reasonable. The records at the above serial numbers had unusually very low value of displacement as compared to other cases.

From Fig. 3 it could be seen that the peak acceleration criterion gives maximum value of the minima envelope. ad/v^2 criteria gives the lower value of minima envelope. Thus it could be seen that the scatter corresponding of ad/v^2 is largest and both peak acceleration and velocity criterion give nearly the same spread.

Fig. 4 shows a comparison of maxima, average and minima response curves corresponding to peak ground acceleration criterion. The average curve is more close to minima as compared to maxima indicating that a few records give unusual values. Using the three average spectra, a smoothend design spectra has been proposed by the authors. This design spectra is normalised with respect to (i) a peak ground acceleration 1.0 g(ii) a peak ground velocity of 150 cm/sec as well as (iii) a nondimensional factor ad/v^2 of 25. The average spectra is also compared with the USAEC response spectra. The USAEC spectra given slightly larger values in the short period range and slightly smaller values in the intermediate period range.

Records at serial numbers 4,33,38 and 46 satisfy all the three criterion of peak acceleration, peak velocity and ad/v^2 (In these the ratio of $\frac{a}{g} \simeq \frac{v}{150} \simeq \frac{ad}{25}$). Records at serial numbers 2,3,4,6,7,13,14,15,22,26,27, 30,33,37,38,40 and 46 satisfy acceleration and ad/v^2 criterion and records at serial numbers 4,20,28,33,38, 46 and 48 satisfy velocity and ad/v^2 criterion. Since there is relatively more error in the determination of ground displacement 'd' the criterion of ad/v^2 gives a greater scatter as compared to acceleration and velocity criterion.

IV. ACKNOWLEDGEMENTS

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TABLE - 1

Sl No.	Station	Date	Comp.	Mag-nitude	Peak Accl.	Peak vel.	ad/v^2
1.	El-Centro	5-18-40	S	6.3	341.7	33.4	3.34
2.	El-Centro	5-18-40	W	6.3	210.1	36.9	3.06
3.	Pasadena	7-21-52	S	7.7	46.5	6.2	3.26
4.	Pasadena	7-21-52	W	7.7	52.1	9.1	1.82
5.	Taft	7-21-52	N21E	7.7	152.7	15.7	4.15
6.	Santa Barbara	7-21-52	N42E	7.7	87.8	11.8	2.9
7.	Santa Barbara	7-21-52	S48E	7.7	128.6	19.3	2.0
8.	Hollywood St.Basement	7-21-52	E	7.7	43.5	9.4	2.9
9.	Hollywood St.PE Lot	7-21-52	E	7.7	41.2	8.9	3.32
10.	Eureca	12-21-54	N11W	6.6	164.5	31.6	3.04
11.	Eureca	12-21-54	N79E	6.6	252.7	29.4	4.12
12.	Ferndale	12-21-54	N44E	-	155.7	35.6	1.74
13.	Ferndale	12-21-54	N46E	-	197.3	26.0	2.8
14.	El-Centro	2-9-56	S	-	32.4	4.0	4.86
15.	El-Centro	2-9-56	W	-	50.1	7.0	4.2
16.	San-Francisco S.P.Build.Base	3-22-57	N45W	5.3	44.9	5.0	2.5
17.	Hollister	4-8-61	S01W	5.6	63.4	7.8	2.91
18.	Hollister	4-9-61	N89W	5.6	175.7	17.1	2.28
19.	El-Centro	4-8-68	S	6.5	127.8	25.8	2.34
20.	El-Centro	4-8-68	W	6.5	56.3	14.7	2.86
21.	Vernon Calif.	3-10-33	N08E	6.3	130.6	28.7	2.46
22.	El-Centro Calif.	12-30-34	N	6.5	156.8	20.5	1.56
23.	El-Centro Calif.	4-13-49	S02W	7.1	66.5	8.2	2.37
24.	Seattle Wash	4-13-49	N88W	7.1	65.9	7.9	2.85
25.	Taft Calif	1-12-54	N21E	5.9	63.9	5.9	3.23
26.	Cholame Shandon Calif.No.2	6-27-66	N63E	5.6	479.6	77.9	2.07
27.	Cholame Shandon Calif.No.12	6-27-66	N50E	5.6	52.1	7.0	4.36

TABLE-1

28.	Orion BLUD	2-9-71	N00W	6.6	250.0	30.0	4.14
29.	Orion Build.	2-9-71	S90W	6.6	131.7	23.9	3.19
30.	Hollywood Storage	"	N90E	6.6	143.2	19.4	5.16
31.	Hollywood Storage	"	S00W	6.6	167.3	16.5	4.915
32.	Wilshire Build. Basement	"	S00W	6.6	146.7	18.1	4.61
33.	Wilshire Build. Basement	"	S90W	6.6	155.7	22.1	4.112
34.	Hollywood Build. Basement	"	N00E	6.6	81.2	12.6	4.14
35.	Hollywood Build. Basement	"	N90E	6.6	98.0	13.3	3.988
36.	Wilshire Build. Basement	"	N75W	6.6	82.2	20.9	2.76
37.	Wilshire Build. Basement	"	N15W	6.6	115.0	21.5	2.94
38.	Wilshire Build. Subbasement	"	N00E	6.6	133.8	22.3	3.07
39.	Wilshire Build. Subbasement	"	S90W	6.6	111.8	18.6	3.742
40.	6th Street Basement	"	S00W	6.6	158.2	18.4	4.20
41.	Vernon,CMD Build.	"	N83W	6.6	104.6	17.5	5.054
42.	Vernon,CMD Build.	"	S07W	6.6	80.5	15.1	3.812
43.	East Broadways M.S.Building	"	S70E	6.6	265.7	30.8	3.108
44.	East Broadways M.S.Building	"	S20W	6.6	209.1	23.5	2.[illegible]
45.	South Olive Street Street,St.level	"	S53E	6.6	131.9	20.8	4.42
46.	South Olive Street Street level	"	S37W	6.6	139.0	20.7	3.76
47.	North Robertson BLVD Sub basement	"	S88E	6.6	96.2	16.8	3.612
48.	-do-	"	S02W	6.6	89.9	17.9	3.168
49.	Pumping Plant Pearblossom	"	N00E	6.6	85.2	8.5	2.476
50.	Vola Reactor Lab.	"	S00N	6.6	83.1	8.3	4.825

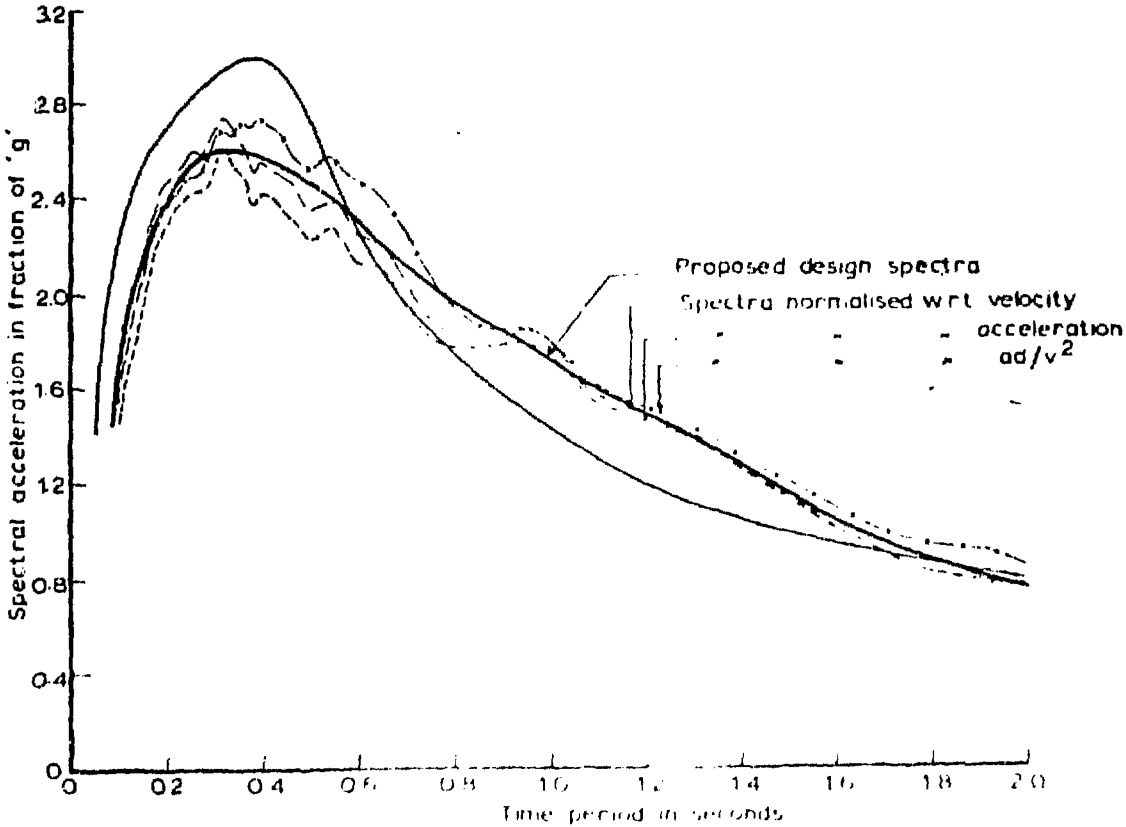

FIG 1 AVERAGE RESPONSE SPECTRA

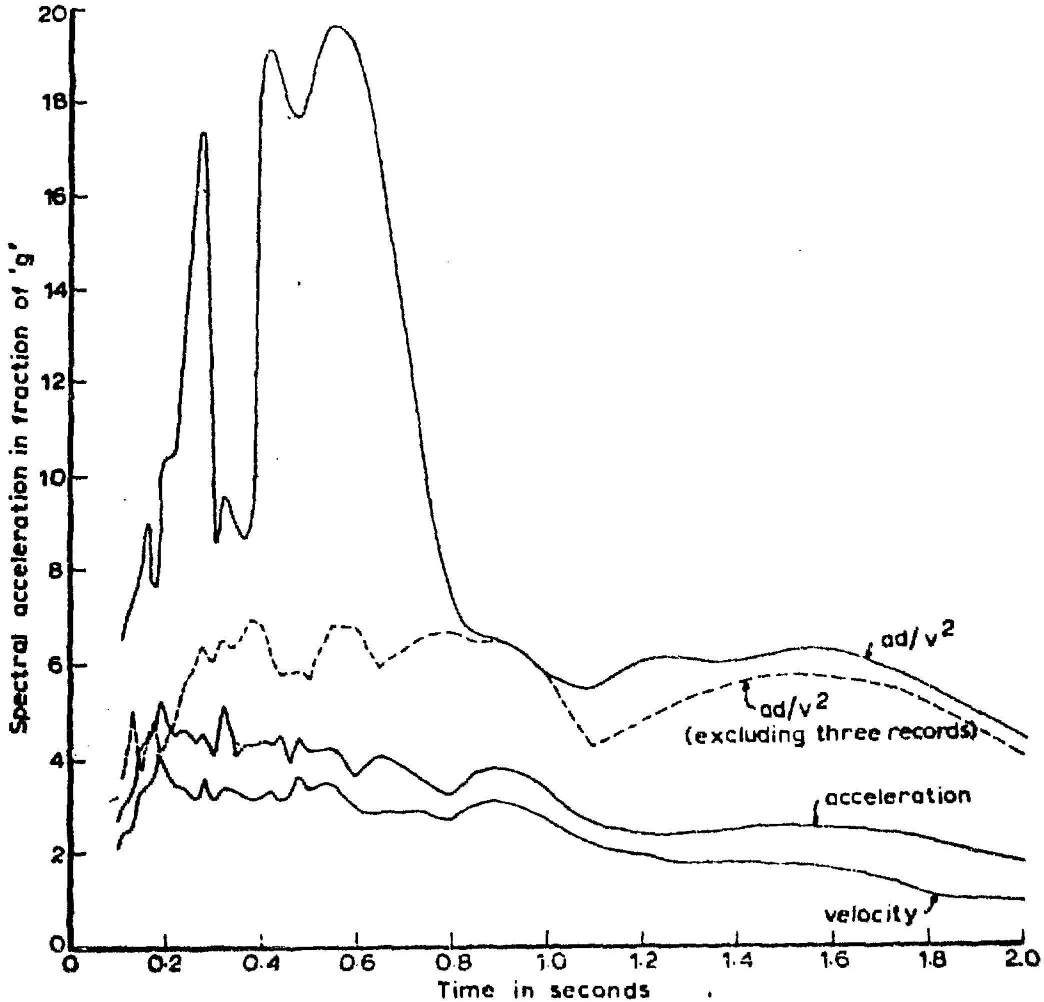

FIG 2 _ENVELOPE OF MAXIMUM RESPONSE SPECTRA

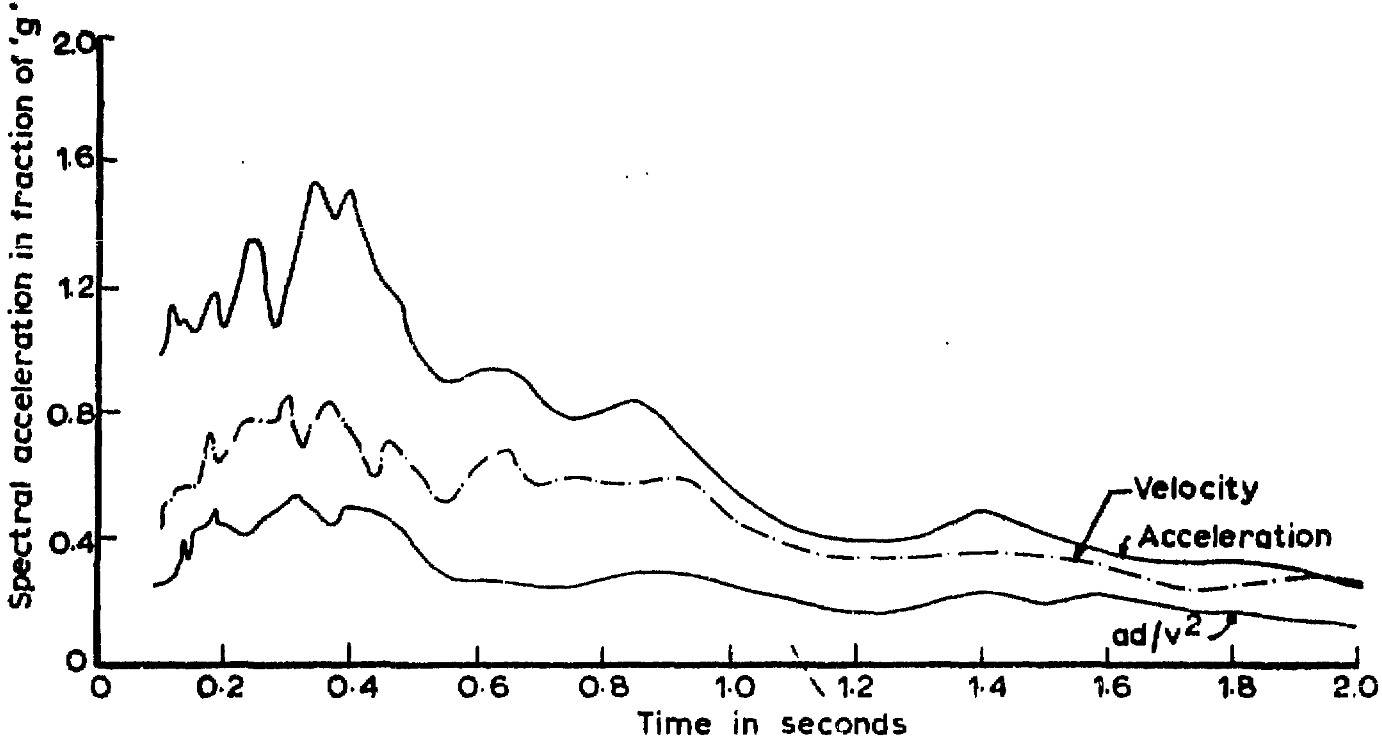

FIG 3 _ENVELOPE OF MINIMUM RESPONSE SPECTRA

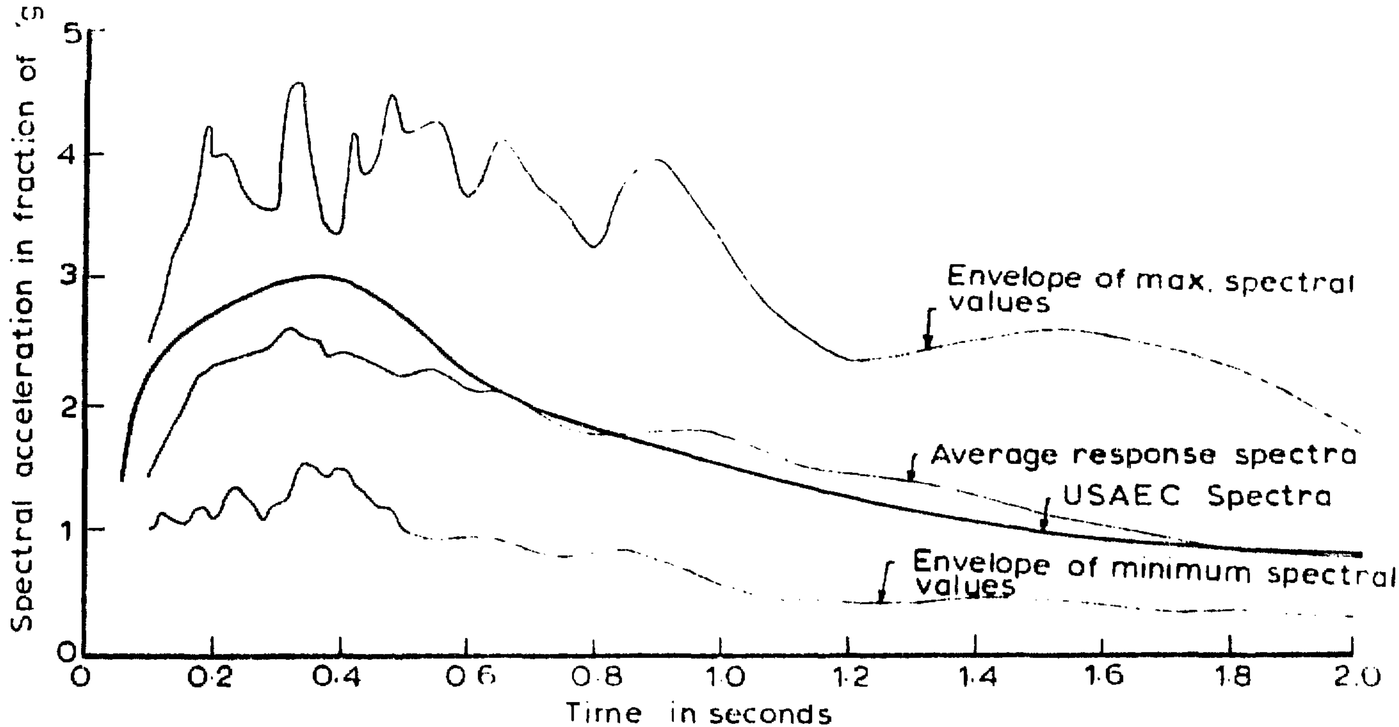

FIG. 4 _COMPARISON OF MAXIMA, AVERAGE, MINIMA RESPONSE CURVES CORRESPONDING TO PEAK ACCELERATION