Illinois Power Company

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U-0611
L30-83(03-10)L

Docket No. 50-461 March 10, 1983

Director of Nuclear Reactor Regulation
Attention: Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Reference: NRC letter A. Schwencer to G. Wuller, IP dated January 12, 1983, "Request for Further Clarification on the Soil Amplification Issue".

Subject: Clinton Power Station Unit 1
SER Outstanding Issue #3 (NUREG-0853)

Dear Mr. Schwencer:

This is in reply to the referenced letter and the request by Mr. G. Giese-Koch in the telephone conference with NRC, IP and S&L on March 1. Enclosed is the document entitled, "Response to NRC Request for Further Clarification on the Soil Amplification Issue." Figure 4 of our response gives the additional information verbally requested by Mr. Giese-Koch in the March 1 telephone conversation.

We believe that this clarification information is adequate to close SER outstanding issue #3 in the next SER supplement. Your concurrence of issue resolution is kindly requested.

Sincerely,

G. E. Wuller

G. E. Wuller
Supervisor-Licensing
Nuclear Station Engineering

GEW/jmm

enclosure

cc: Dr. H. Abelson, NRC Clinton Project Manager
Mr. G. V. Giese-Koch, NRC GB
Mr. B. N. Jagannath, NRC HGEB
Mr. H. H. Livermore, NRC Resident Inspector
Illinois Department of Nuclear Safety

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RESPONSE TO NRC REQUEST FOR FURTHER CLARIFICATION ON THE SOIL AMPLIFICATION ISSUE

NRC Request

In a letter (Reference 1) dated January 12, 1983, the NRC staff requested IPC to provide further clarification on the soil amplification issue. The letter stated:

> "However, the staff has noted that the "weighted average" amplification peaks are considerably lower than the peaks on the "mean soil property" amplifications curve (Figure 1). In the case of the amplification factors obtained from the SHAKE program, the "weighted average" peaks fall outside (below) the range of peaks predicted by the range of soil properties (upper/lower bound) assumed for the site (Figure 2). In past safety reviews the NRC has recommended a conservative approach in enveloping the effects of soil amplification if uncertainities existed.
>
> Therefore, we request that you discuss the resulting fluctuations in the theoretical soil design spectrum caused by assuming a range of soil properties. Subsequently you should justify, statistically or otherwise, the use of the weighting procedure referred to earlier in this letter in light of past NRC positions....."

Background

For seismic reevaluation of the Clinton Project a time history consistent with a 0.2g RG 1.60 spectra was used (Reference 2). The response spectrum of this time history is presented in Figure 32 (labeled as Design Basis Time History Spectra) site specific response spectrum report (Reference 3).

To show that this design basis time history is a conservative representation of the expected ground motions for a 5.8 m_b earthquake at the Clinton site, an 84th percentile site specific response spectrum was developed using near field earthquake motion recorded at similar sites for earthquake magnitude of 5.8 ± 0.5 m_b.

Figure 32 of Reference 3 compared the 84th percentile site specific response spectrum thus developed, to the design basis time history spectrum. It was concluded from this comparison that the design basis time history is a conservative representation of the expected ground motion at the Clinton site for a 5.8 m_b earthquake.

Since the available information regarding the depth of rock-soil interface at many recording stations used for the Clinton site specific spectrum study was limited, the effect of the soil-rock velocity contrast (at 200-feet depth) on the site specific spectrum was further evaluated. Conservative soil amplification curves were obtained using three sets of soil properties presented in Table 220.15-1 of Reference 2 and reproduced here in Table 1 for ready reference. A weighted average of these three amplification curves was obtained by assigning 25%, 50% and 25% weights to upper, mean and lower bound soil properties respectively. Then the 84th percentile 5% damped response spectra amplification curve corresponding to the weighted Fourier amplification curve was computed. Finally, applying these spectral amplifications to the average of the 84th percentile 5.8 m_b rock spectrum generated by LLL/TERA and TVA, the theoretical ground response spectrum at the Clinton site was developed. It was shown that the design time history spectrum essentially envelopes this theoretical ground response spectrum (see Figure 37 of Reference 3).

Statistical Analysis

The Clinton site specific response spectrum was developed at an 84th percentile level consistent with the Regulatory Guide 1.60 philosophy. In developing the theoretical ground response spectrum to evaluate the effect of the rock-soil velocity contrast, a heuristic approach (weighting procedure) was taken in the treatment of the soil properties without resorting to a detailed statistical treatment. However, the procedure to develop the theoretical ground spectrum described in the previous paragraph yielded a better than 84th percentile ground response spectrum because the

84th percentile rock spectrum was amplified by the 84th percentile soil response spectrum amplification curve. The 25%, 50% and 25% weighting factors for the upper, mean and lower bound soil properties, respectively, was based on the fact that for the design earthquake, the soil properties are more likely to be the mean properties than upper or lower bound properties. Use of 84th percentile response spectra amplification factors based on the envelop of the Fourier amplification factor for upper, mean and lower bound soil properties would be overly conservative and would yield ground response spectrum well above the 84th percentile level.

In response to the latest request for clarification, we have performed a more detailed statistical analysis to show that the design time history spectrum essentially envelops the 84th percentile ground response spectrum obtained from the theoretical soil amplification and the LLL/TERA and TVA 5.8 m_b rock spectra.

The statistical analysis accounts for the effect of variability in soil shear modulus on the surface response spectrum by a more formal statistical treatment, without assigning specific weights to the upper-bound, mean and lower-bound soil properties identified in Table 1. The following steps were undertaken to perform the evaluation:

Step 1

The coefficient of variation of shear modulus at each of the four soil layers shown in Table 1 was calculated using the triaxial test data shown in Figures 220.15-2 through 220.15-5 of Reference 2. These calculations used the data for values of shear strain in the range from $2x10^{-2}$ to $2x10^{-1}$ percent. The shear strain induced by strong earthquakes is expected to be in this range (see Figure 220.15-6 of Reference 2). Table 2 lists the coefficients of variation thus determined for each layer.

Step 2

It is assumed that the shear modulus in each layer is independent of moduli in other layers and it is a lognormal random variable. The values of shear modulus listed for the mean soil property in Table 1 for four layers were considered to represent the mean values of the shear moduli of the soil profile. Using this information and the corresponding coefficient of variation from Table 2, ten sets of shear moduli were randomly generated to represent the range of possible soil property variation. Table 3 lists these 10 simulated shear modulus profiles.

Step 3

The SHAKE Program (Reference 4) was used to compute the response spectrum amplification factors for each of the 10 simulated soil profiles by applying 14 different rock motions (shown in Table 4) and computing the resulting ground response spectrum. At each frequency, f, this procedure yielded 10x14=140 realizations of response spectrum amplification factor. The mean value and coefficient variation of the response spectrum amplification factor, A(f) were then calculated from the simulation results and are presented in Table 5. The 14 rock motions listed in Table 4 are all the rock motions available through the California Institute of Technology with maximum ground acceleration between 0.05 and 0.5g.

For the Clinton site specific spectra report, (Reference 3), the response spectrum amplification factors were computed by Dr. Vanmarcke using a random vibration approach. For the present statistical evaluation the services of Dr. Vanmarcke were not available in a timely manner and the alternate SHAKE program procedure was used. To establish the validity of the SHAKE procedure a mean plus one standard deviation amplification curve was generated for upper bound, mean and lower bound soil property (Table 1) using the fourteen different rock motions (Table 4) and computing the ground surface spectra resulting from these rock motions. The mean plus one standard deviation amplification curve was generated for each soil property using the fourteen sets of amplification factors. The weighted average of the mean plus one sigma response spectrum amplification was obtained by assigning 25%, 50% and 25% weights to upper, mean and lower bound soil properties. Figure 1 compares the 84th percentile response spectrum amplification factors obtained from the SHAKE procedure to the corresponding amplification factors obtained by Dr. Vanmarcke using random vibration method. It can be observed that the two procedures yield very similar results with the SHAKE procedure giving slightly more conservative results at higher frequencies.

Figure 2 compares the 84th percentile response spectrum amplification curve obtained by the use of the weighting procedure and the 84th percentile response spectrum amplification curve obtained from a more detailed statistical analysis. It can be observed that the two curves are in good agreement, thus justifying the weighting procedure used in Reference 3.

Step 4

The mean and the coefficient of variation of the LLL/TERA and TVA 5.8 magnitude rock site spectra were obtained from the mean and the 84th percentile spectra presented in References 5 and 6.

Step 5

Using response spectra and amplification statistics from Step 3 and the rock response spectra statistics from Step 4, the 84th percentile value of the ground response spectrum was determined using both LLL/TERA and TVA rock spectra. Figure 3 shows the average of the 84th percentile surface spectra thus determined. This spectrum is compared to the design basis time history spectrum. This comparison shows that with very minor exceptions at very limited range of periods the 84th percentile surface spectra are less than those used for design. Therefore an explicit and formal consideration of reasonable variation in soil properties leads to surface spectra at the Clinton site which are less than the spectra used in design.

Note also, that the spectrum of the present analysis is in close agreement with the ground surface spectrum obtained by Weston after considering soil amplification (Reference 3, Figure 37).

Figure 4 presents the comparison of the Clinton design time history spectrum to the theoretical surface spectrum obtained by multiplying the average of the 84th percentile 5.8 magnitude rock site spectrum developed by TVA and LLL by the 84th percentile soil response spectrum amplification factors obtained in Step 3 above. It can be observed from the figure that the design spectrum envelopes the theoretical surface spectrum at all frequencies significant to the systems and structure design.

References

1. Letter from A. Schwencer of the NRC Staff to George Wuller of IPC, dated January 12, 1983, Subject: Request for Further Clarification on the Soil Amplification Issue - Clinton Power Station, Units 1 and 2.

2. Illinois Power Company Letter No. U-0374 from J. Geier to J. R. Miller; Nuclear Regulatory Commission dated December 3, 1981.

3. "Site Specific Response Spectra Clinton Power Station -Unit 1 of Illinois Power Company", Revision 1, May 1982, prepared for Sargent & Lundy by Weston Geophysical Corporation.

4. SHAKE, Soil Layer Properties and Response for Earthquake Motions (09.7.119-3.3). S&L modified program written by J. Lysmer and P. B. Schnabel of the University of California, Berkeley which computes response in a horizontally layered semi-infinite system subjected to vertically traveling shear waves based on the continuous solution of the shear wave equation.

5. TERA Corporation, "Seismic Hazard Analysis", Report NUREG/CR-1582, August 1980.

6. Tennessee Valley Authority, Division of Engineering Design, "Justification of the Seismic Design Criteria Used for the Sequoyah, Watts Bar and Bellefonte Nuclear Power Plants - Phase II,", August 1978.

Table 1 Dynamic Soil Properties Used for the Soil Amplificaton Study*

Soil Layer Number	Layer Depth (ft)	Weight Density (k/ft^3)	Poisson's Ratio	Damping Ratio	SOIL SHEAR MODULUS (KSF)		
					Upper Bound	Mean	Lower Bound
1	20.	0.132	0.40	0.084	6063.	4547.	3032.
2	105.	0.150	0.35	0.101	7000.	5250.	3500.
3	10.	0.134	0.35	0.059	5500.	4125.	2750.
4	75.	0.145	0.40	0.089	5500.	4125.	2750.
5	Half Space	0.159	0.29	0.000	300000.	300000.	300000.

*Same as Table 220.15-1 of Reference 2.

TABLE 2 COEFFICIENT OF VARIATION OF SOIL SHEAR MODULUS

	Layer	Coefficient of Variation
1.	Structural Fill	0.36
2.	Illinoian Till	0.98
3.	Lacustrine Deposit	0.25
4.	Pre-Illinoian Deposit	0.57

TABLE 3: Values of Simulated G for Different Soil Layers

	Soil Shear Modulus (KSF)			
Simulation #	Layer #1	Layer #2	Layer #3	Layer #4
1	5559	4565	4710	3737
2	6816	1195	3512	2508
3	3319	8749	4286	6502
4	3220	9160	3927	3955
5	5417	8341	4015	1824
6	2488	10368	3516	4548
7	5711	716	4150	3760
8	4437	2951	4295	5259
9	7929	5429	5213	3221
10	4142	1968	5260	7880

TABLE 4 Earthquakes Used to Determine Spectral Amplification Factors

Earthquake	Date/Time	Recording Station	Magnitude	Epicentral Distance (km)	Instrument Orientation	Maximum Acceleration (g)
Helena, Montana	10-31-35/1138 MST	Caroll College	6.0	7	S00W S90W	.146 .145
Eureka, California	12-21-54/1156 PST	Eureka Federal Building	6.5	25	N11W N79E	.168 .258
San Francisco, California	3-22/57/1144 PST	Golden Gate Park	5.3	13	N10E S80E	.084 .105
Parkfield, California	6-27-66/2026 PST	Temblor	5.5	7	N65W S25W	.270 .348
Parkfield, California	6-27-66/2026 PST	Chalame-Shandron, Array No. 5	5.5	6	N05W N85E	.355 .434
San Fernando, California	2-9-71/0600 PST	Castiac Old Ridge Route	6.6	30	N21E N69W	.316 .271
San Fernando, California	2-9-71/0600 PST	Pacoima Dam, After Shock at 104.6 sec	3.0-5.0	9	574W 516E	.112 .115

Table 5 Response Spectra Amplification Factors: Mean and Standard Deviation

Frequency	Mean	SD	Frequency	Mean	SD
.20	1.23	.18	4.20	1.11	.22
.30	1.35	.30	4.41	1.09	.22
.40	1.46	.34	4.61	1.08	.23
.50	1.69	.40	4.81	1.08	.24
.60	1.81	.52	5.00	1.07	.25
.70	2.15	.68	5.24	1.05	.22
.80	2.29	.63	5.49	1.05	.24
.90	2.38	.47	5.75	1.01	.21
1.00	2.31	.46	5.99	1.00	.21
1.10	2.31	.54	6.25	1.00	.22
1.20	2.29	.56	6.49	.98	.24
1.30	2.16	.58	6.76	.94	.23
1.40	2.01	.55	6.99	.92	.25
1.50	1.82	.45	7.25	.91	.27
1.60	1.64	.38	7.52	.90	.27
1.70	1.50	.36	7.75	.92	.28
1.80	1.36	.36	8.00	.93	.29
1.90	1.30	.36	8.47	.96	.28
2.00	1.28	.36	9.01	.92	.25
2.10	1.25	.36	9.52	.86	.23
2.20	1.23	.35	10.00	.86	.23
2.30	1.21	.34	10.53	.87	.23
2.40	1.16	.31	10.99	.91	.26
2.50	1.13	.30	11.49	.91	.26
2.60	1.11	.29	12.05	.93	.27
2.70	1.10	.29	12.50	.94	.29
2.80	1.10	.29	12.99	.94	.28
2.90	1.12	.30	13.51	.95	.29
3.00	1.13	.30	14.08	.97	.30
3.15	1.14	.30	14.49	.96	.31
3.30	1.14	.29	14.93	.95	.32
3.45	1.15	.28	15.87	.96	.32
3.60	1.14	.25	16.95	.96	.34
3.80	1.14	.22	18.18	.98	.36
4.00	1.14	.23	20.00	.96	.34

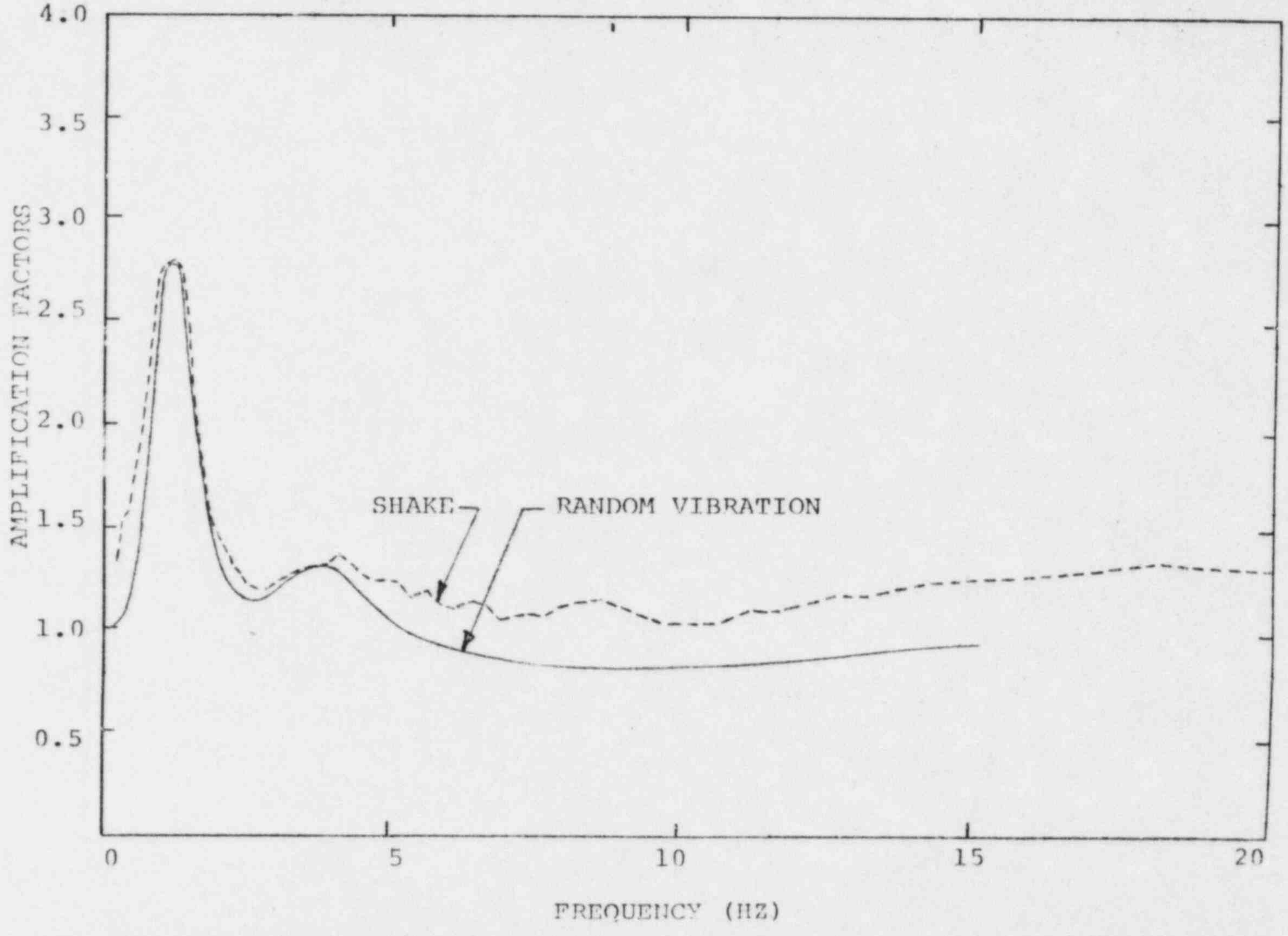

Figure 1: Comparison of Weighted Response Spectrum Amplification Curves Using SHAKE Procedure and Random Vibration Method

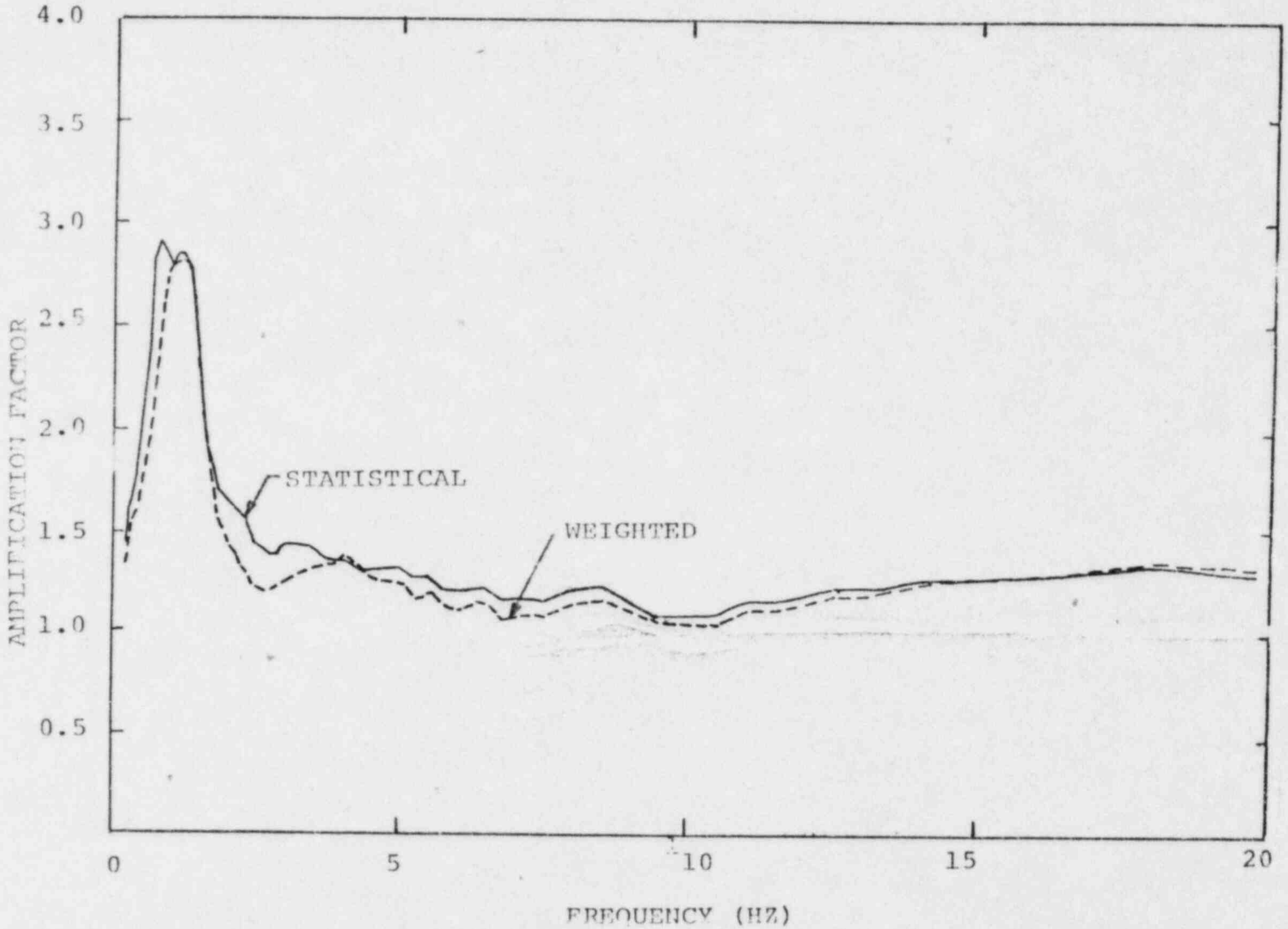

Figure 2: Comparison of the 84th Percentile Response Spectrum Amplification Curves Using the Weighting Procedure and from Statistical Analysis (Both from SHAKE)

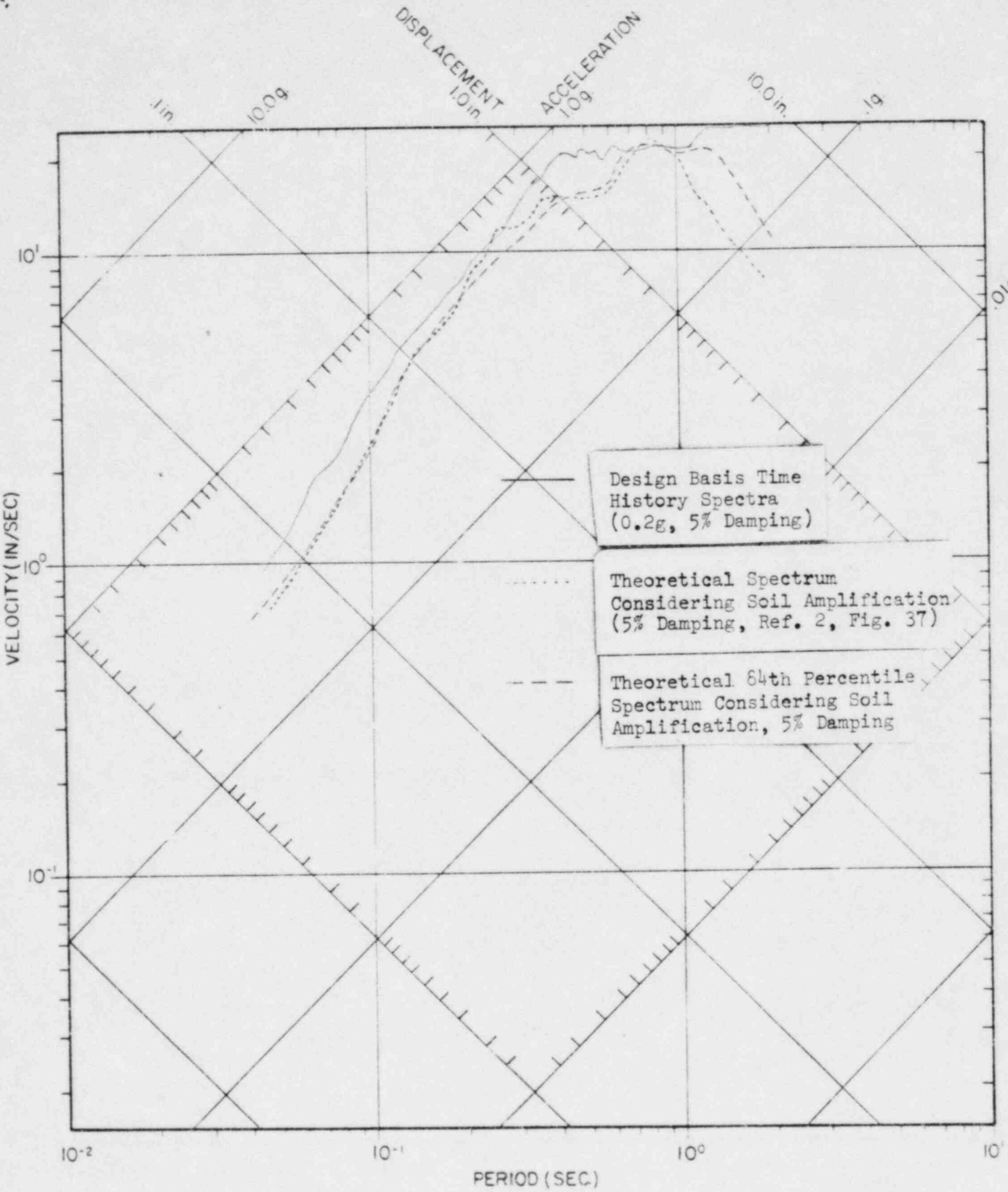

Figure 3: Comparison of Design Basis Time History Spectrum to Theoretical Spectra Considering Soil Amplification

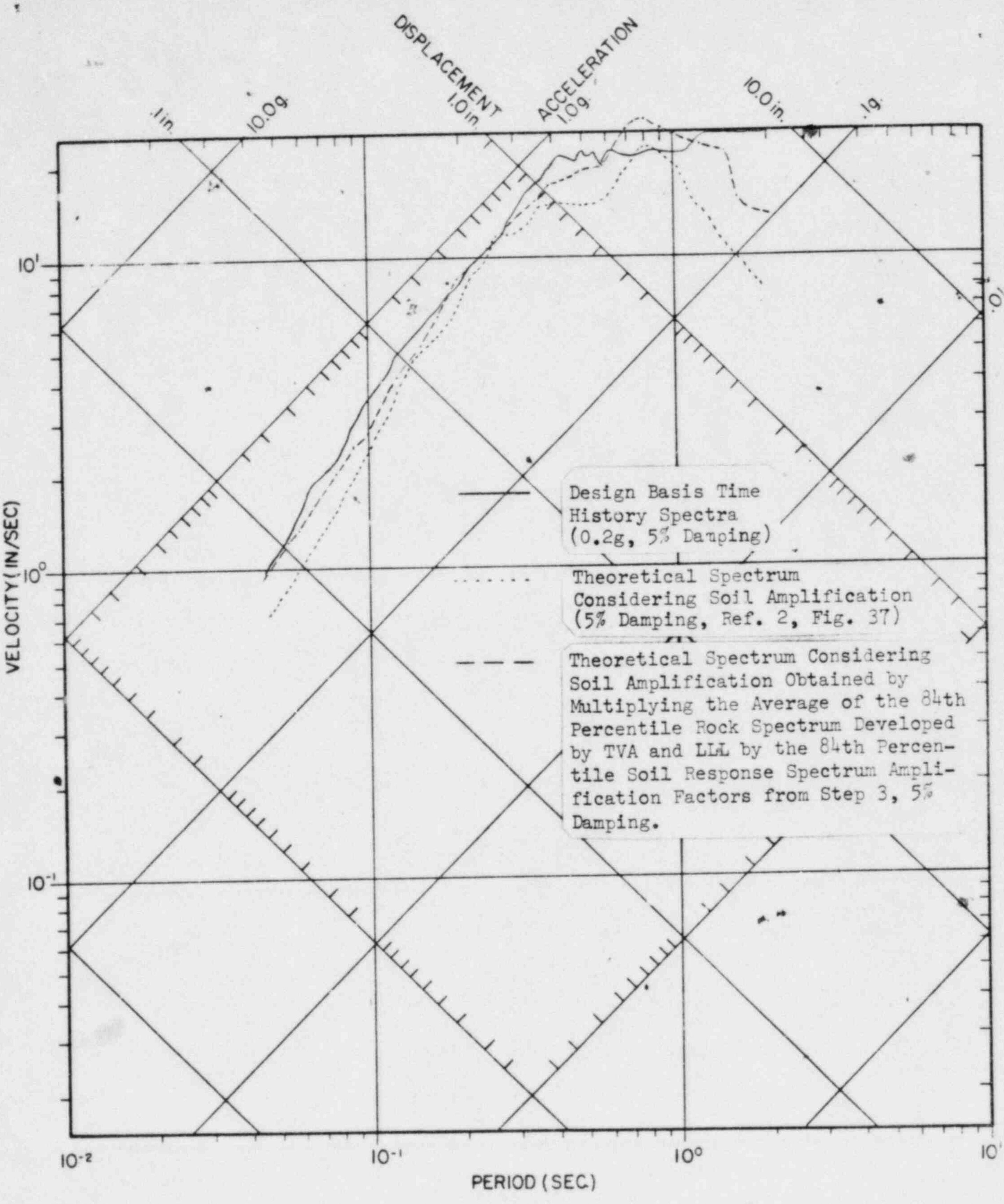

Figure 4: Comparison of Design Basis Time History Spectrum to Theoretical Spectra Considering Soil Amplification