TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

400 Chestnut Street Tower II

February 3, 1982

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Chief
Licensing Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Ms. Adensam:

In the Matter of the Application of	)	Docket Nos. 50-390
Tennessee Valley Authority	)	50-391

Enclosed for NRC review is information concerning material and geometric damping at Watts Bar Nuclear Plant. This information should resolve open item 9 of the draft Safety Analysis Report.

If you have any questions concerning this matter, please get in touch with D. P. Ormsby at FTS 858-2682.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Regulation and Safety

Sworn to and subscribed before me
this 3rd day of Feb. 1982

Paulette H. White
Notary Public
My Commission Expires 9-5-84

Enclosure
cc: U.S. Nuclear Regulatory Commission (Enclosure)
Region II
Attn: Mr. James P. O'Reilly, Regional Administrator
101 Marietta Street, Suite 3100
Atlanta, Georgia 30303

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ENCLOSURE

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2
MATERIAL AND GEOMETRIC DAMPING

QUESTION

In response to Question 362.33 the applicant has indicated that for the seismic analyses a soil damping ratio of 10 percent was used for the soil deposit underneath the structures and the primary motion was translatory rigid body motion. The staff requires that applicant must provide values of the material damping and geometric damping used in the SSI analysis in the various modes of vibration of the foundation of structures for the OBE and SSE conditions.

RESPONSE

Material and Geometric Damping Used in SSI Analysis

The soil-supported and pile supported Category I structures were analyzed as follows.

Structure	Support	Analysis Technique
Diesel-Generator Building	Soil	Lumped Mass Modal Analysis with Equivalent Soil Springs
Waste-Packaging Area	Soil	Lumped Mass Modal Analysis with Equivalent Soil Springs
Condensate Demineralizer Waste Evaporator (CDWE) Building	Piles	Lumped Mass Modal Analysis with Equivalent Soil Springs and Finite Element Analysis (LUSH*)
Refueling Water Storage Tank	Soil	Lumped Mass Modal Analysis with Equivalent Soil Springs and Finite Element Analysis (FLUSH**)

*Computer Program for Complex Response Analysis of Soil-Structure Systems by J. Lysmer, T. Udaka, H. B. Seed, and R. Hwang, April 1974.
**Computer Program for Approximate 3-D Analysis of Soil-Structure Interaction Problems by J. Lysmer, T. Udaka, C. F. Tsai, and H. B. Seed, November 1975

Details of the analysis methods are given elsewhere. Refer to WBN FSAR Section 3.7.2.1.2 for the lumped mass modal analysis and to the referenced reports for the LUSH and FLUSH analysis.

The damping provided by the supporting soil is accounted for differently in each of the three analysis techniques listed.

In the LUSH and FLUSH finite element analyses, a material damping value is assigned to the individual soil elements. In the LUSH analysis of the CDWE Building, a constant material damping factor of 10 percent of critical was used for the soil elements. This was a supplemental and confirmation analysis to the soil spring analysis and was performed only for the SSE case. In the FLUSH analysis of the refueling water storage tank, strain dependent soil properties were used. The so-called "Seed Sand" material property curves were used. This relationship is given in Table 1. A maximum element material damping value of 15 percent of critical was calculated during the refueling water storage tank analysis.

In the lumped mass modal analysis method, soil damping is incorporated in two stages. First, the top of ground acceleration time history is determined by amplifying the top of rock acceleration time history through the soil. Second, the response of the lumped mass modal representing the structure and soil is determined. This procedure is described briefly as follows and shown schematically in figure 1.

The design earthquake for the site is defined as a top of rock motion. This motion must be convolved through the soil to determine a top of ground motion. This is accomplished by considering the soil as an elastic medium and making a dynamic analysis of a slice of unit thickness considering only horizontal shearing resistance of the soil. This results in a simple "shear beam" analysis of the soil deposit. Constant material properties are used. A soil damping value of 10 percent of critical is used in this stage of the analysis for OBE and SSE conditions. Typically the top of ground acceleration is about three times the top of rock acceleration. For the Diesel Generator Building, the maximum horizontal ground surface acceleration is 0.27 g based on 0.09 g horizontal rock acceleration for the OBE condition. For the waste packaging area, the maximum horizontal ground acceleration is 0.27 g based on a 0.09 g horizontal rock acceleration for the OBE condition. The resulting top of ground spectra are shown in figure 2. For the CDWE Building the maximum horizontal ground acceleration is 0.66 g based on a 0.18 g horizontal rock acceleration for the SSE condition. Similar results can be obtained using the computer code SHAKE.

Secondly, a lumped mass modal representing the structure and foundation springs representing the soil is determined. The response of this model to the top of ground motion is calculated. The damping ratio used in the system response analysis depends on whether the soil or structure dominates the system's motion in a given mode. If the portion of the model representing the structure is dominant, then the applicable damping value for structural materials listed in Table 3.7-2 of the WBN FSAR is used. If the portion of the model representing the soil (soil springs) is dominant, then a lumped damping value that simulates the soil mass damping is used. As explained in section 10.5 of <u>Vibrations of Soils and Foundations</u> by Richart, Hall, and Woods, the lumped damping parameter should include both the effects of geometrical damping and material damping.

Table 2 lists both (1) the available geometric and material damping values of the soil mass and (2) the damping value used in design for the various modes of vibration of the foundations of Category I structures. The geometric damping values in Table 2 were calculated in accordance with section 7.7 of Richart. The material damping values are based on literature data for soils in the strain ranges expected during OBE and SSE conditions.

Table 1 - Strain-compatible Soil Properties**

Effective Shear Strain γ_{eff} (%)	log (γ_{eff})	Shear Modulus Reduction Factor*		Fraction of Critical Damping (%)	
		Clay	Sand	Clay	Sand
$\leq 1. \times 10^{-4}$	-4.0	1.000	1.000	2.50	0.50
3.16×10^{-4}	-3.5	0.913	0.984	2.50	0.80
1.00×10^{-3}	-3.0	0.761	0.934	2.50	1.70
3.16×10^{-3}	-2.5	0.565	0.826	3.50	3.20
1.00×10^{-2}	-2.0	0.400	0.656	4.75	5.60
3.16×10^{-2}	-1.5	0.261	0.443	6.50	10.0
1.00×10^{-1}	-1.0	0.152	0.246	9.25	15.5
0.316	-0.5	0.076	0.115	13.8	21.0
1.00	0.	0.037	0.049	20.0	24.6
3.16	0.5	0.013	0.049	26.0	24.6
$\geq$10.00	1.0	0.004	0.049	29.0	24.6

*This is the factor which has to be applied to the shear modulus at low shear strain amplitudes (here defined as 10^{-4} percent) to obtain the modulus at higher strain levels.

**Excerpt from FLUSH by John Lysmer, et al.

Table 2. Damping for Lumped Mass Modal Analysis

Structure	Mode No.	Predominate Motion	Damping (percent of critical) Available Geometrical	Material	Value used for Design	Remarks
Diesel Generator Building	1	Hor. Translation of Foundation	60	10	10	AEC Limit
	2	Rocking and Hor. Translation of Foundation	30	10	10	AEC Limit
	3	Primary Bldg. Deformation	--	5	10	*
Waste Packaging Building	1	Rocking and Hor. Translation of Foundation	20	10	10	AEC Limit
	2	Horizontal Translation of Foundation	20	10	10	AEC Limit
	3	Primary Bldg. Deformation	--	5	10	*
CDWE Building	1	Hor. Translation and Rocking of Foundation	Not calculated	5	5	
	2	Rocking and Hor. Translation of Foundation		5	5	
	3	Vertical		5	5	
Refueling Water Storage Tank	1	Horizontal Translation of Foundation	Not calculated	10	10	

*Simplification of using the same damping value as the first and second modes is based on minor contribution to system response of third mode.

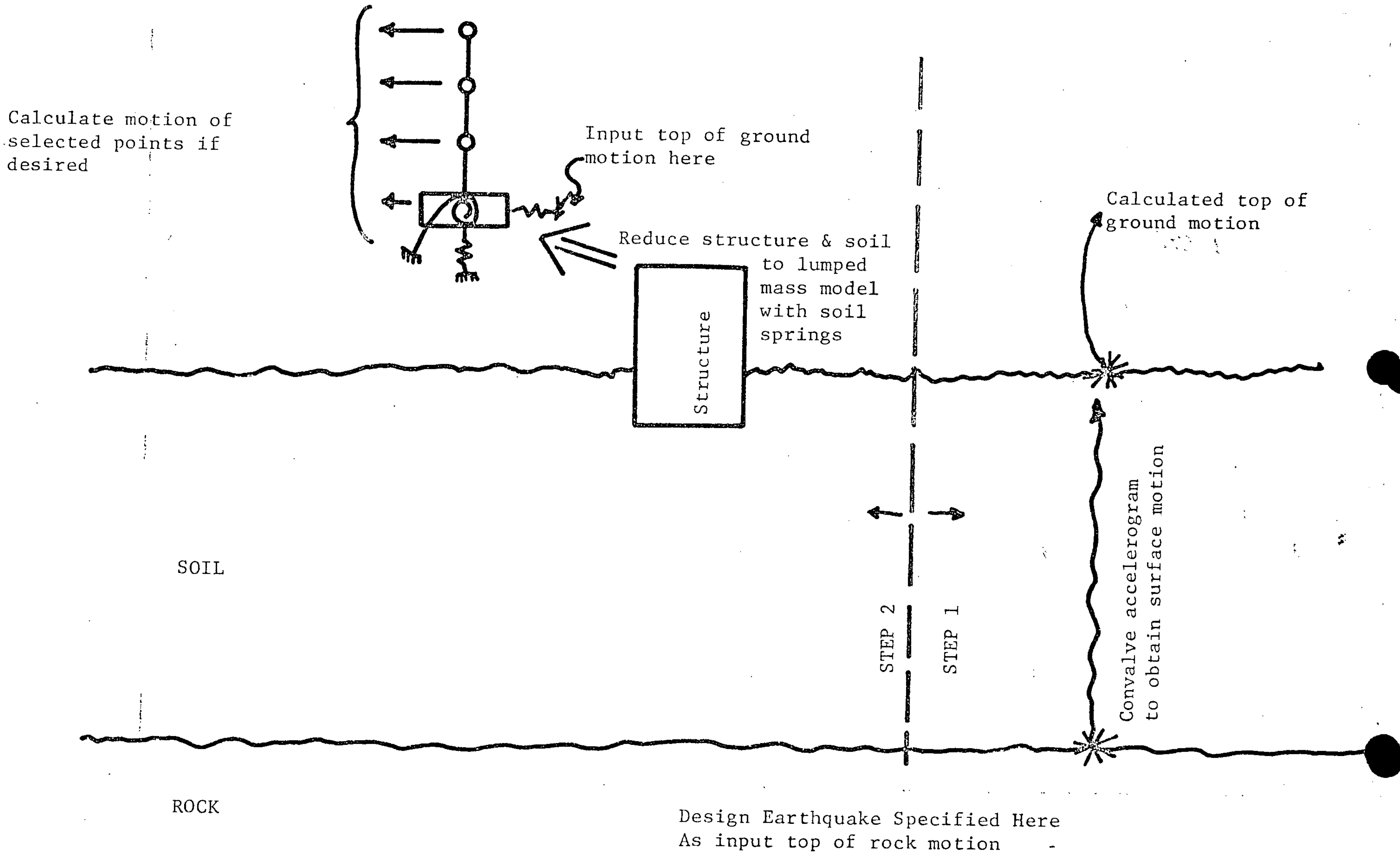

FIGURE 1 Schematic of Lumped Mass Model Analysis

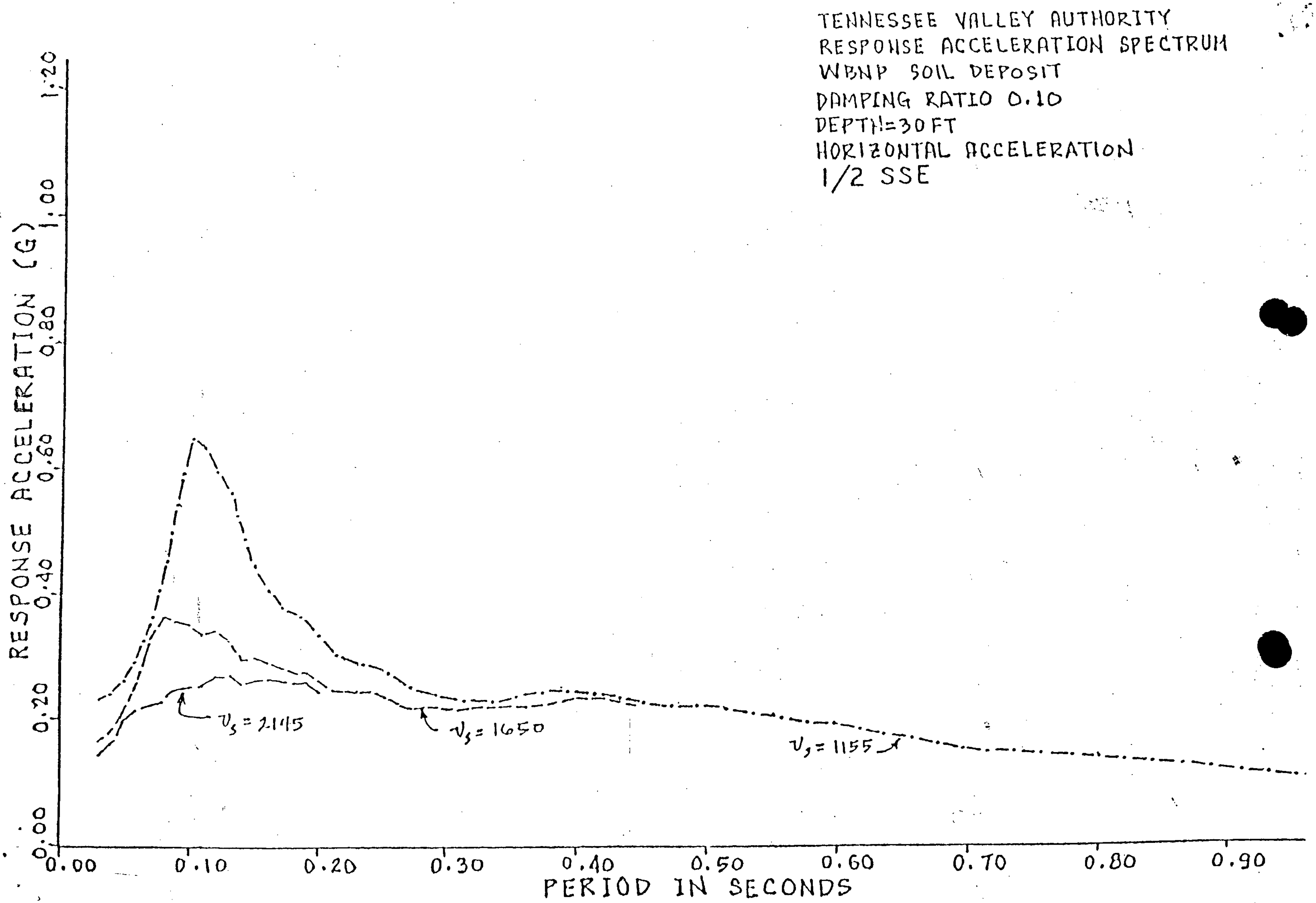

FIGURE 2 Top of Ground Response Sepctra for High, Average, and Low Soil Properties