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STONE & WEBSTER ENGINEERING CORPORATION

CLIENT & PROJECT **PRIVATE FUEL STORAGE FACILITY – PRIVATE FUEL STORAGE, LLC**	PAGE 1 OF 5 PLUS 2 OF ATTACHMENTS
CALCULATION TITLE **Evaluation of Cask Storage Pad Flexibility**	QA CATEGORY (X) __ I - NUCLEAR SAFETY RELATED __ II _X_ III __ OTHER

CALCULATION IDENTIFICATION NUMBER

J.O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
05996.02	**STRUCTURAL**	**SC-21**	**NA**	**345BE**

APPROVALS - SIGNATURE & DATE

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC NO	SUPERSEDES CALC. NO OR REV. NO.	CONFIRMATION REQUIRED (X) YES	NO
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CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
J O. or W O No 05996.02	UNIT NO./SYSTEM CODE	SC-21	OPTIONAL TASK CODE 345BE	PAGE 2

HISTORICAL DATA REVISION

REVISION NO.	PAGES AFFECTED	DESCRIPTION
Rev. 0	All	Original

CALCULATION IDENTIFICATION NUMBER

J O OR W O.NO	DIVISION & GROUP	CALCULATION NO	OPTIONAL TASK CODE	
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PURPOSE

The purpose of this calculation is to evaluate possible effects of pad flexibility on the seismic analysis of the Skull Valley cask storage pads. This assessment is performed to address Paragraphs D.1.b(i) and D.1.b(ii) of the State of Utah's unified contention L/QQ.

METHOD

The influence of the pad flexibility on the impedance functions will be estimated using the information provided in Reference 1.

REFERENCES

1. "Dynamic Response of Flexible Rectangular Foundations on an Elastic Half-Space", M. Iguchi and J.E. Luco, Earthquake Engineering and Structural Dynamics, Vol. 9, 1981.
2. Calculation 05996-G(P017)-2, "Storage Pad Analysis and Design.

ASSUMPTIONS

The paper used as a basis for this evaluation was based on a square foundation on an elastic half-space of uniform properties. The Skull Valley pads are 67' long by 30' wide (Reference 2), and are founded on a layered subgrade. To account for this, following assumptions were made:

1. The size of the equivalent square was determined by using a square with the same area as the rectangular pad.
2. Equivalent uniform soil properties (shear wave velocity, density and Poisson's ratio) were estimated from the best estimate soil properties, presented on sheet 8 of Reference 2, using the top 50' of the soil profile. Values assumed for this evaluation are:

• Shear wave velocity	750 ft/sec.
• Density	100 lb/ft^3
• Poisson's Ratio	0.40 (to be consistent with the value in Ref. 1)

3. The case presented in Reference 1 without the rigid center (model a) was considered more applicable to the real case.

CONCLUSION

The effects of pad flexibility on the impedance functions are not significant.

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CALCULATIONS

Calculate the dimensionless parameter δ:

$\delta = (Et^3)/(\mu\, a^3\, (1-\upsilon^2))$

Where:

E = Young's modulus of the pad (450,000 ksf for 3000 psi concrete)

t = Thickness of pad (3 feet)

μ = Shear modulus of soil = $\rho\, V_s^2$ = (.100 ksf / 32.17)(750 fps)^2 = 1749 ksf

$\upsilon = 0.40$

a = (sqrt (67' x 30'))/4 = 22.4'

Substituting, δ = 0.735

Calculate applicable range of the dimensionless parameter a_o

$a_o = \Omega\, a / V_s$

Where

Ω = frequency of interest, in radians per second

For frequencies between 1 Hz and 5 Hz (6.3 and 31.4 radians per second), a_o ranges from 0.19 to 0.94.

Evaluate effect on impedance functions

From figures 4 (vertical) and 5 (rocking) of Reference 1 for the case of model (a), it can be seen that for values of a_o less than 1.0 and values of δ greater than 0.5 there is little difference in the impedance functions from the completely rigid case. See Attachment A for a details.

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ATTACHMENT A

A-1

The effects of the flexibility of the foundation plate on the vertical and rocking impedance functions are illustrated in Figures 4 and 5, respectively. The results shown in these figures were calculated by subdividing the foundation plate and the contact region into 64 equal square subregions. A value of $\nu = 0{\cdot}4$ was used for Poisson's ratio in the soil. The results presented for values of the relative stiffness $\delta = 0{\cdot}005, 0{\cdot}05, 0{\cdot}5$ and ∞ (rigid plate) indicate that, at low frequencies, the dynamic stiffness coefficients $({}_eK_V, {}_eK_M)$ for a flexible foundation plate can be significantly lower than those for a rigid plate. At high frequencies, however, the dynamic stiffness coefficients for flexible foundation plates can be higher than those for a rigid plate. For Model (a), the effects of flexibility of the foundation on the vertical and rocking stiffness coefficients are similar. For Model (b), the effects on the rocking stiffness coefficients are more pronounced.

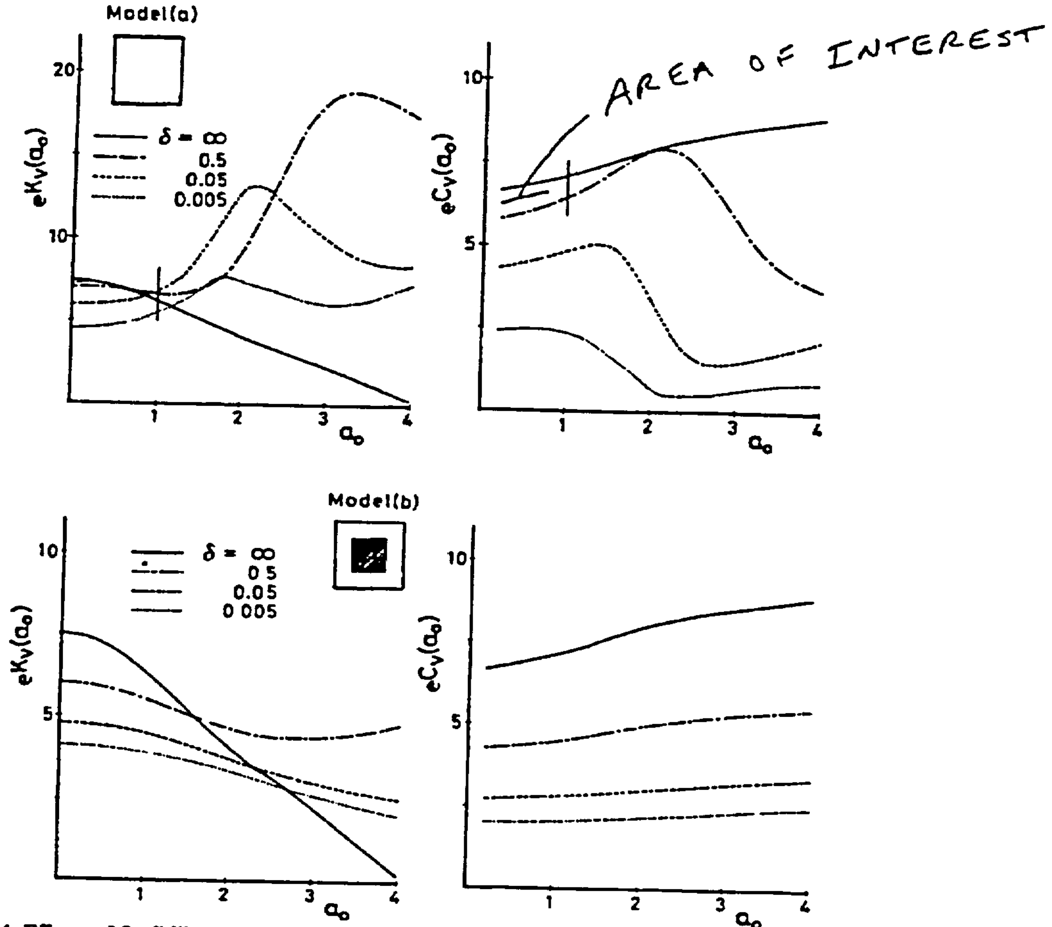
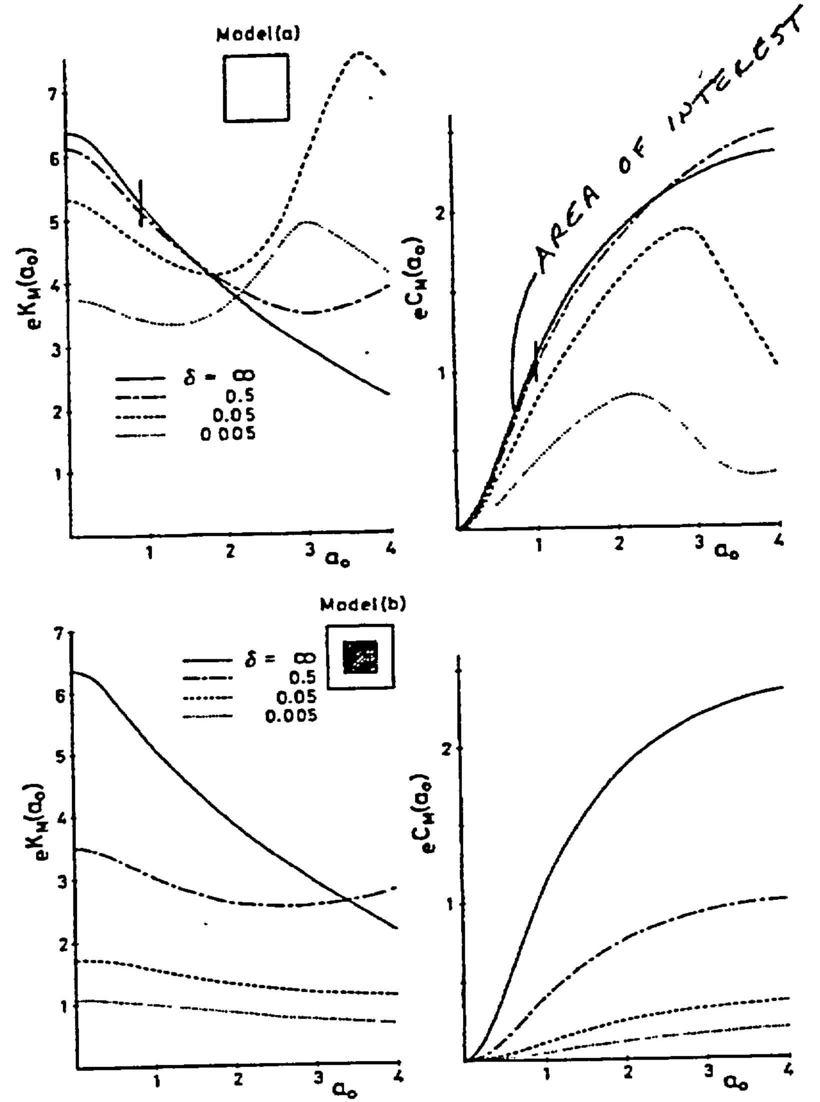


Figure 4. Effects of flexibility of the foundations on the vertical impedance functions ($\nu = 0{\cdot}4$, $\nu_f = 0$)

Perhaps the most significant effect shown in Figures 4 and 5 corresponds to the reduction of the damping coefficients $({}_eC_V, {}_eC_M)$ associated with flexibility of the foundation. It is apparent that a flexible foundation plate is less efficient in radiating energy into the ground than a rigid foundation. For Model (a), the reduction of the vertical damping coefficient is more pronounced than that of the rocking damping coefficient. For Model (b), the reduction of the rocking damping coefficient is more pronounced.

EQUIVALENT RIGID FOUNDATION

Since a considerable amount of information on the dynamic response of rigid foundations is available, it is of interest to explore the possibility of representing a flexible foundation by an equivalent rigid foundation. One possibility is to define the dimensions of the equivalent rigid foundation in such a way that the static stiffness



AREA OF INTEREST

Figure 5. Effects of flexibility of the foundations on the rocking impedance functions ($\nu = 0{\cdot}4$, $\nu_f = 0$)

coefficients (real parts of the impedance function at $a_0 = 0$) coincide with those for the flexible foundation. As an example, the lengths $2\bar{a}_V$ of rigid square foundations having the same static vertical stiffness coefficients as flexible foundations corresponding to Model (b) with $\delta = 0{\cdot}5, 0{\cdot}05$ and $0{\cdot}005$ are defined by $a_V/a = 0{\cdot}798, 0{\cdot}641$ and $0{\cdot}551$, respectively. The corresponding equivalent lengths $2\bar{a}_M$ obtained by equating the static rocking stiffness coefficients are given by $\bar{a}_M/a = 0{\cdot}820, 0{\cdot}646$ and $0{\cdot}552$. For Model (b), values of the ratios $\bar{a}_V/a$ and $\bar{a}_M/a$ range from $1{\cdot}0$ for $\delta = \infty$ to $0{\cdot}5$ for $\delta = 0$. It is interesting to notice that the equivalent length for rocking excitation is slightly higher than that for vertical excitation.

The equivalent rigid foundation described above is based on the static response of the flexible foundation. It is, then, necessary to test the adequacy of the equivalent representation at different frequencies. If the flexible foundation and its equivalent rigid representation give the same force–displacement relationships, the following equations would be satisfied:

$$C_V(a_0) = (a/\bar{a}_V)\,\bar{C}_V(\bar{a}_{0V}) \tag{19}$$

$$C_M(a_0) = (a/\bar{a}_M)^3\,\bar{C}_M(\bar{a}_{0M}) \tag{20}$$