UNITED STATES
NUCLEAR REGULATORY COMMISSION
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MEMORANDUM FOR: L. C. Shao, Acting Assistant Director
for Engineering Programs
Division of Operating Reactors

FROM: H. E. Polk, Seismic Review Group
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THRU: P. T. Kuo, Section Leader
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SUBJECT: COMPARISON OF OLD AND NEW DESIGN CRITERIA FOR BEAVER VALLEY AND SURRY 1 & 2

Attached is the comparison you requested for the original seismic design criteria and the reevaluation seismic design criteria. Also enclosed is a history of the development of the elastic half-space theory and the answers to a couple of questions you raised.

If we can be of further assistance, call on us.

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1. Are other countries using SSI in the design of NPP?

The A&E firms and NSSS suppliers of other countries are using SSI procedures in the analysis and design of NPP. The firms recognize the importance of the phenomenon and use the same methods as used in the U.S. Some examples of foreign plants that have used the procedure are:

Country	Plant
Spain	Cofrentes Almaraz
Germany	KWU (NSSS Supplier)
Brazil	Angra
Iran	New Plant
Korea	KO-RI
Taiwan	Kuosheng, Manshan
Japan	Tsuraga, Chuda, Toshiba, Hitachi

2. Do we use the SSI procedures to design structures other than NPP in this country?

SSI becomes important when the dominant natural frequency of the structure approaches the natural frequency of the soil. In general, NPP's are very massive,'stiff structures and the SSI effects tend to have significant influence on the structural response. Conventionalbuildings are very flexible and the effects of SSI are diminished to the point of being negligible.

Therefore, it would be of no value to use the same procedure that is used on NPP. So, instead of using the mathematical procedures, the governing bodies have mostly relied on the building codes which impose impirical procedures for addressing earthquake loads. Notwithstanding, there were a few conventional structures and dams for which SSI effects were considered in their analyses, such as Golden Gate Bridge, California State Capitol Building, Dumbarton Bridge, San Fernando Dam and Fort Peck Dam.

Changes in the analytical techniques since the original seismic analysis was accomplished:

1. Removal of an arbitrary limit on the modal damping. This limit did not conform with the physics of the problem being analyzed. The modal damping reflects the viscous damping of the materials (soil, concrete and steel) and the loss of energy in the system due to radial dissipation thru the soil as defined by the elastic half-space theory. This loss of energy is incorporated into the procedures by using an equivalent viscous damping which is a large fraction of the modal damping. By imposing an arbitrary low limit on the modal damping the characteristics of the system were changed which resulted in higher loads calculated for the structure and equipment.

2. The procedures used on generating the floor response spectra (FRS) were changed. The original FRS were computed using conservative simple techniques. The reevaluation uses the standard technique.

3. The original analysis did not account for the variation of soil properties with depth (layering effect). The procedures used for reevaluation incorporates the change in soil properties with depth and the level of excitation in each layer. This technique more realistically reflects the actual physical site conditions.

The net result of the above improvement in the implementation of the current techniques leads to a reduction of the loads.

BRIEF HISTORY OF DEVELOPMENT

OF

ELASTIC HALF-SPACE THEORY

In 1936, E. Reissner pioneered the work in attempting to provide a theory for evaluating the dynamic response of a vibrating footing as influenced by properties of the soil. His published paper, "Stationäre, Axialsymmetrische durch eine Schuttelnde Masse erregte Schwingungen eines homogenen elastischen Halbraumes" is considered a classic work in this field.

In 1953, T. Y. Sung and P. M. Quinlan extended Reissner's work to consider the effects of changes in pressure distribution over the circular area of contact on the surface of the half-space. Their published papers were: Sung, "Vibrations in Semi-Infinite Solids due to Periodic Surface Loadings", Quinlan, "The Elastic Theory of Soil Dynamics."

In 1956, G. N. Bycroft in his paper, "Forced Vibration of a Rigid Circular Plate on a Semi-Infinite Elastic Space and on an Elastic Stratum", further extended Sung's work and evaluated the weighted average of the displacements beneath the footing. In Sung's work, he assumed a constant pressure distribution throughout the range of frequencies considered. This correctly predicts a uniform displacement of the loaded surface under static conditions but does not produce uniform displacement under dynamic conditions.

In 1965, J. Lysmer in his work, "Vertical Motion of Rigid Footings", attempted to approximate the dynamic response of a rigid circular footing to vertical motions and discovered that constant values for compliance functions of the half-space could be used. This established the bridge between the elastic half-space theory and the mass-spring-dashpot system.

In 1971, J. E. Luco and R. A. Westmann in their work, "Dynamic Response of Circular Footings", and A. S. Veletsos and Y. T. Wei in their work, "Lateral and Rocking Vibrations of Footings", extended the previous work which assumed a uniform half-space to a two layered half-space.

PLANT		SEISMIC INPUT MOTION	DAMPING	SEISMIC ANALYSIS METHOD	FLOOR RESPONSE SPECTRA	METHOD OF PIPING ANALYSIS	NUMBER OF COMPONENTS	METHOD OF COMBINATION OF RESPONSES
URRY & 2	ORIGINAL	Modified Housner Spectra .15g SSE .07g OBE Vert. = 2/3 horiz. max ampli 2.33 @ 2.% damping	Structures 2% OBE 5% SSE Piping 0.5% OBE 1.p% SSE 10% limit damping (Radiation & Struc)	SSI Lumped Mass Soil Springs	Taft Record Used to Generate Floor Response spectra Peak Broadening was done from .125 sec to .9 sec period varies slightly with struc max accel 1.68g OBE 2.475g SSE for all elev in all structures	3 D model linear elastic	3	Algebraic sum for intramodal response intermodal responses combined $R_i = R_{im} + \sqrt{\Sigma R_{ij}^2 - R_{im}^2}$
	NEW	Same Comparisons with Reg. Guide 1.60/ 1.61 very good	Same Except 10% limit removed	SSI with multi layered halfspace	Standard Technique Used today	Same	Same	SRSS

PLANT		SEISMIC INPUT MOTION	DAMPING	SEISMIC ANALYSIS METHOD	FLOOR RESPONSE SPECTRA	METHOD OF PIPING ANALYSIS	NUMBER OF COMPONENTS	METHOD OF COMBINATION OF RESPONSES
Beaver Valley	ORIGINAL	Modified Newmark .125g SSE .06g OBE Vert=2/3 Horiz. Max amplif. 4.2 @ 2% Damping	Structures 2% OBE 5% SSE Piping 0.5% OBE 1.0% SSE 10% limit on modal damping (radiation and structural)	SSI Lumped Mass Soil Springs	Approximate Technique (very conservative)	3D Model	3	Algebraic
	NEW	Same Comparisons with R.G. 1.60/1.61 very good	Same Except 10% limit Removed	SSI with multi layered halfspace	Standard Technique Used today	Same	Same	SRSS