E. I. Hatch Nuclear Plant - Unit 1

Seismic Margin Assessment (SMA)

Soil-Structure Interaction Analysis

Prepared for

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April 1988

Background

Southern Company Services, Inc. (SCS) and Georgia Power Co. (GPC) have received the approval of the Electric Power Research Institute (EPRI) to perform a Seismic Margin Assessment (SMA) of the E. I. Hatch Nuclear Plant, Unit 1, and have engaged the services of EQE, Inc., to perform the structural response analysis for this effort. The methodology to be employed is that previously developed by EPRI and approved by the USNRC. As part of the SMA, in-structure response spectra will be generated for the Hatch buildings of interest for the seismic margin earthquake (SME). These in-structure response spectra will be used to assess the High Confidence Low Probability of Failure (HCLPF) level of components and equipment supported in buildings.

Soil-structure interaction (SSI) analyses conducted for plant design have been extremely conservative in many instances. A vivid example of this conservatism for the Hatch plant structures themselves was obtained from a previous study conducted by EQE for the NRC. In that study comparisons of in-structure response spectra for the Hatch Unit 1 buildings -- design spectra vs. two more realistic cases -- showed that the reduction in spectral accelerations was significant and dramatic, which emphasizes the importance of SSI when calculating seismic response. All cases were for the same free-field ground motion time history but the latter two assumed realistic soil properties, included embedment effects, and the SSI analysis procedure was not artificially restricted in modeling radiation damping effects.

The EPRI seismic margin assessment methodology recommends that median-centered SSI evaluations, structure models, and parameter values be utilized. Median-centered SSI evaluations require that full credit be taken for: vertical spatial variation of ground motion, kinematic interaction, and radiation of energy from the structure into the soil. The procedures and parameter values are to be median-centered. However, considerable uncertainty exists in soil-structure system frequency estimates and in items such as vertical spatial variation of free-field ground motion. The SMA needs to account for this uncertainty. A mechanism to do so is to shift soil stiffness properties over a range to encompass the effects of approximately plus - and minus - one standard deviation parameter variation. The result, in terms of in-structure response spectra, is three distinct spectra, each of which is treated as a representative input to components and equipment. For the Hatch SMA, three cases are identified for each structure for analysis purposes -- each case corresponds to a different soil profile (a median or best estimate and approximately plus - and minus - one standard deviation profile). Results for each case will be generated and presented.

Approach

The soil-structure interaction (SSI) and structure response analyses of the Hatch buildings will be performed using the substructure approach as implemented in the CLASSI system of computer programs . Several assumptions apply to this analysis procedure. The foundation is assumed to behave rigidly. Full bonding is assumed between the embedded portion of the structure and the foundation with the soil. Strictly speaking, the analysis procedure is linear. Soil is modeled as a series of linear viscoelastic horizontal soil layers. Nonlinear soil material behavior is modeled in an equivalent linear fashion, i.e., equivalent linear soil shear moduli and material damping values for each layer. The remaining constants for the material model are mass density and Poisson's ratio. The substructure approach separates the SSI problem into a series of simpler problems, solves each independently, and superposes the results. The elements of the substructure approach as applied to structures with rigid bases subjected to earthquake excitations are: specifying the free-field ground motion; defining the soil profile; calculating the foundation input motion; calculating the foundation impedances; determining the dynamic characteristics of the structure; and performing the SSI analysis, i.e., combining the previous steps to calculate the response of the coupled soil-structure system. A brief discussion of these elements as they pertain to the Hatch analysis is presented next.

Free-field ground motion. Specification of the free-field ground motion entails specifying the control point, the frequency characteristics of the control motion (typically, time histories or response spectra), and the spatial variation of the motion. In all cases, the control point will be defined at the free surface at the top of finished grade. This is compatible with seismic margin assessment methodology and is assumed to be compatible with the seismic margin earthquake specification. The control motion is specified as ground response spectra and acceleration time histories compatible with these spectra. Three components of motion are to be considered; hence, three acceleration time histories are required. The spatial variation of motion will be defined by vertically propagating waves.

Soil profile. Soil profiles and their variation will be provided by Woodward-Clyde Consultants (WCC).

Foundation input motion. Foundation input motion differs from the free-field ground motion in all cases, except for surface foundations subjected to vertically incident waves, for two reasons. First, the free-field motion varies with soil depth. Second, the soil-foundation interface scatters waves because points on the foundation are constrained to move according to its geometry and stiffness. The foundation input motion is related to the free-field ground motion by means of a transformation defined by a scattering matrix. For the proposed analysis, the Hatch reactor building and intake structure will be modeled with embedded foundations which require scattering matrices. For the control building scattering effects will be calculated either using the computer programs SUPERFLUSH or SHAKE. For the diesel generator building, the foundation input motion will be identical with the free-field ground motion. Scattering for the intake structure will be determined using computer program SUPERFLUSH. A sensitivity study will be performed to determine the effect of partial embedment of the reactor building on foundation impedances and input motions and the method to use to calculate them. If reasonable, the reactor building scattering matrix will be obtained using computer program SUPERALUSH treating the foundation as fully embedded and bonded to the soil and accounting for uncertainties by increasing the variability of the soil parameters.

Figures 1 to 3 give examples of the types of foundation models that may be used.

Foundation impedances. Foundation impedances describe the force-displacement characteristics of the soil. They depend on the soil configuration and material behavior, the frequency of the excitation, and the geometry of the foundation. In general, for a linear elastic or viscoelastic material and a uniform or horizontally stratified soil deposit, each element of the impedance matrix is complex-valued and frequency dependent. For a rigid foundation, the impedance matrix is a 6 x 6 which relates a resultant set of forces and moments to the six rigid body degrees-of-freedom. The reactor building foundation impedances will be calculated using SUPERALUSH if deemed reasonable by the sensitivity study mentioned above. The control building and diesel generator building foundation impedances will be generated assuming surface foundations and using CLASSI. The procedure to be utilized for the intake structure will be to generate surface foundation impedances using CLASSI and correct them for embedment effects.

Structure model. The dynamic characteristics of the structures to be analyzed are described by their fixed-base eigensystem and modal damping factors. Modal damping factors are the viscous damping factors for the fixed-base structure expressed as a fraction of critical damping. The structures' dynamic characteristics are then projected to a point on the foundation at which the total motion of the foundation, including SSI effects, is determined. Structure models which model horizontal and vertical dynamic characteristics will be provided by GPC/SCS. The models to be used are as follows:

Reactor Building	N-S, E-W, and vertical models
Control Building	3D Model
Diesel Generator Building	N-S, E-W, and vertical models
Intake Structure	3D Model

The N-S and E-W models for the reactor building and diesel generator building will be essentially the same as those used in the studies. New three-dimensional models of the control building and intake structure will be provided. Vertical models for the reactor building and diesel generator building will be provided. Structural damping values will be specified by GPC/SCS.

SSI analysis. The final step in the substructure approach is the actual SSI analysis. The results of the previous steps are combined to solve the equations of motion for the coupled soil-structure system. For a single rigid foundation, the SSI response computation requires solution of, at most, six simultaneous equations -- the response of the foundation. The derivation of the solution is obtained by first representing the response in the structure in terms of the foundation motions and then applying that representation to the equation defining the balance of forces at the soil/foundation interface. The formulation is in the frequency domain. Three SSI analyses will be performed for each Hatch building. Each analysis will be three-dimensional. The difference in each will be the soil profile. For each structure, one set of SSI parameters (foundation impedances and scattering functions) will be developed explicitly for the median or best estimate soil profile. The second and third sets to be used in the second and third SSI analyses will be obtained by scaling the first. The end results of the SSI analyses will be maximum displacements and accelerations at all mass points for each building. In-structure acceleration response spectra at 3%, 5% and 10% damping will be provided as follows:

Reactor building	22 mass points
Control building	5 mass points
Intake structure	3 mass points
Diesel generator building	2 mass points

All will be provided for three different soil profiles and three directions. The format is proposed to be overplots of response spectra for the three soil profiles holding all other factors constant.

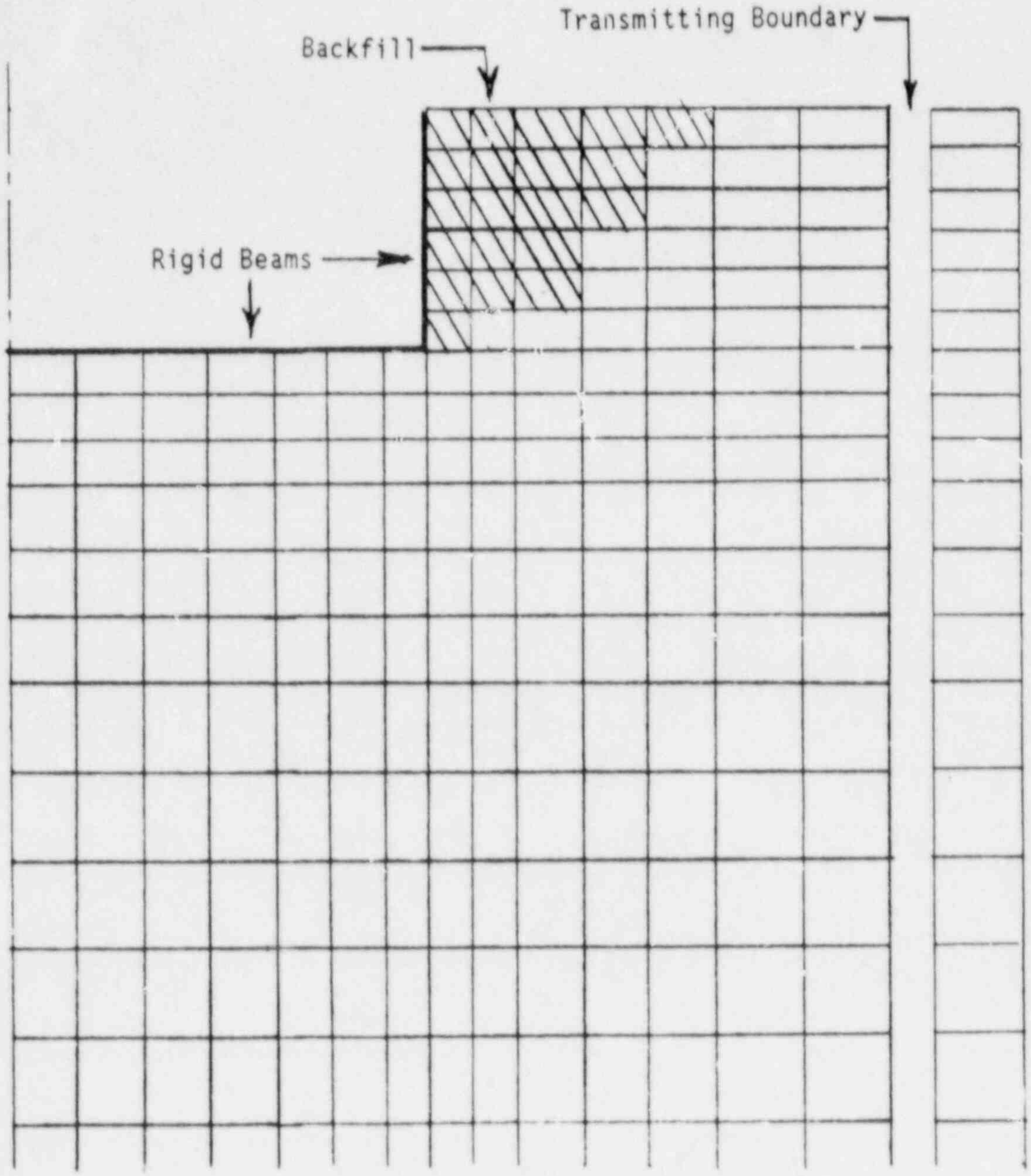

Fig. 1 Typical SUPERALUSH Foundation Model of Reactor Building

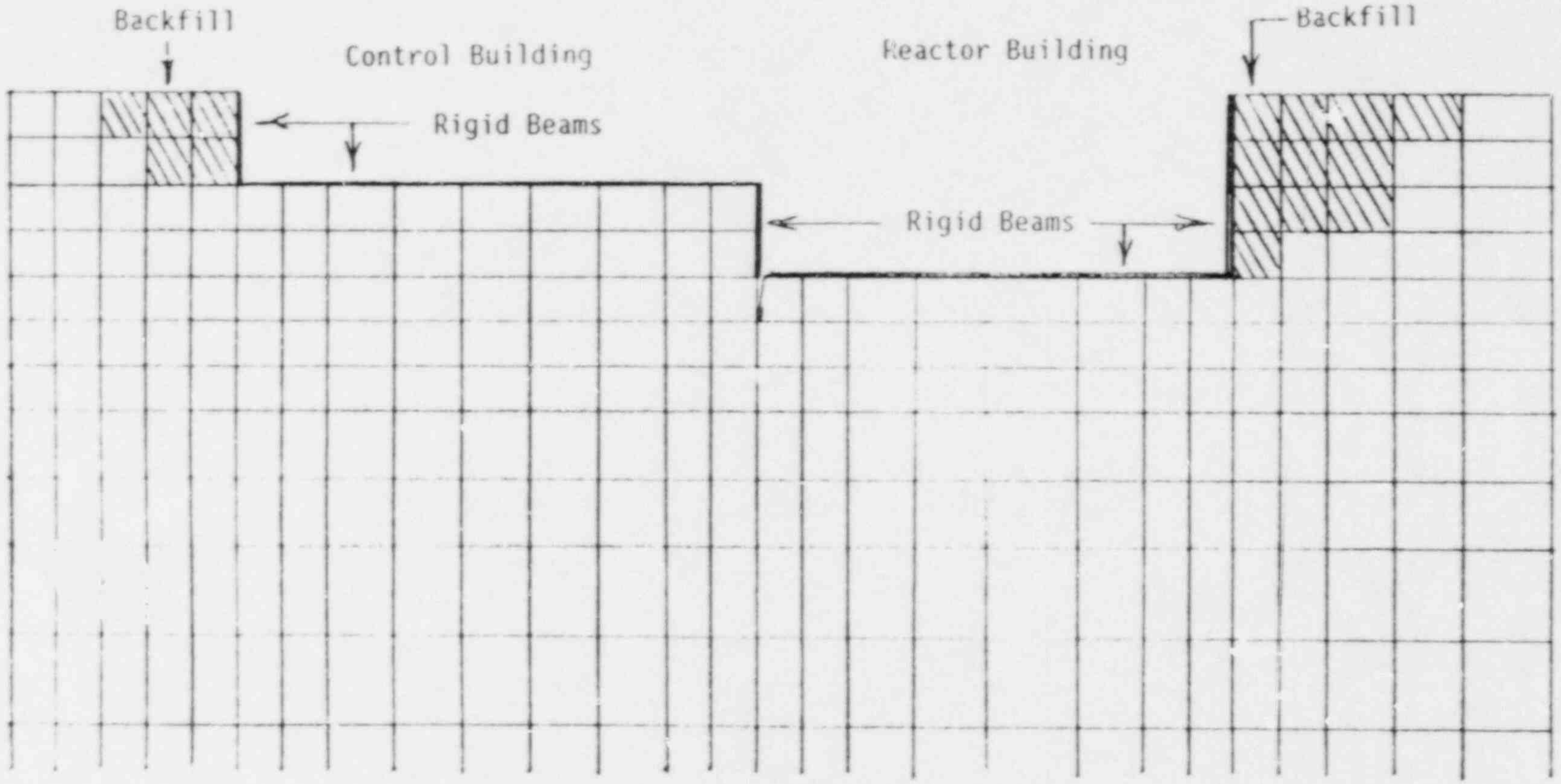

Fig. 2 Typical SUPERFLUSH Foundation Model of Control Building and Reactor Building

EQE

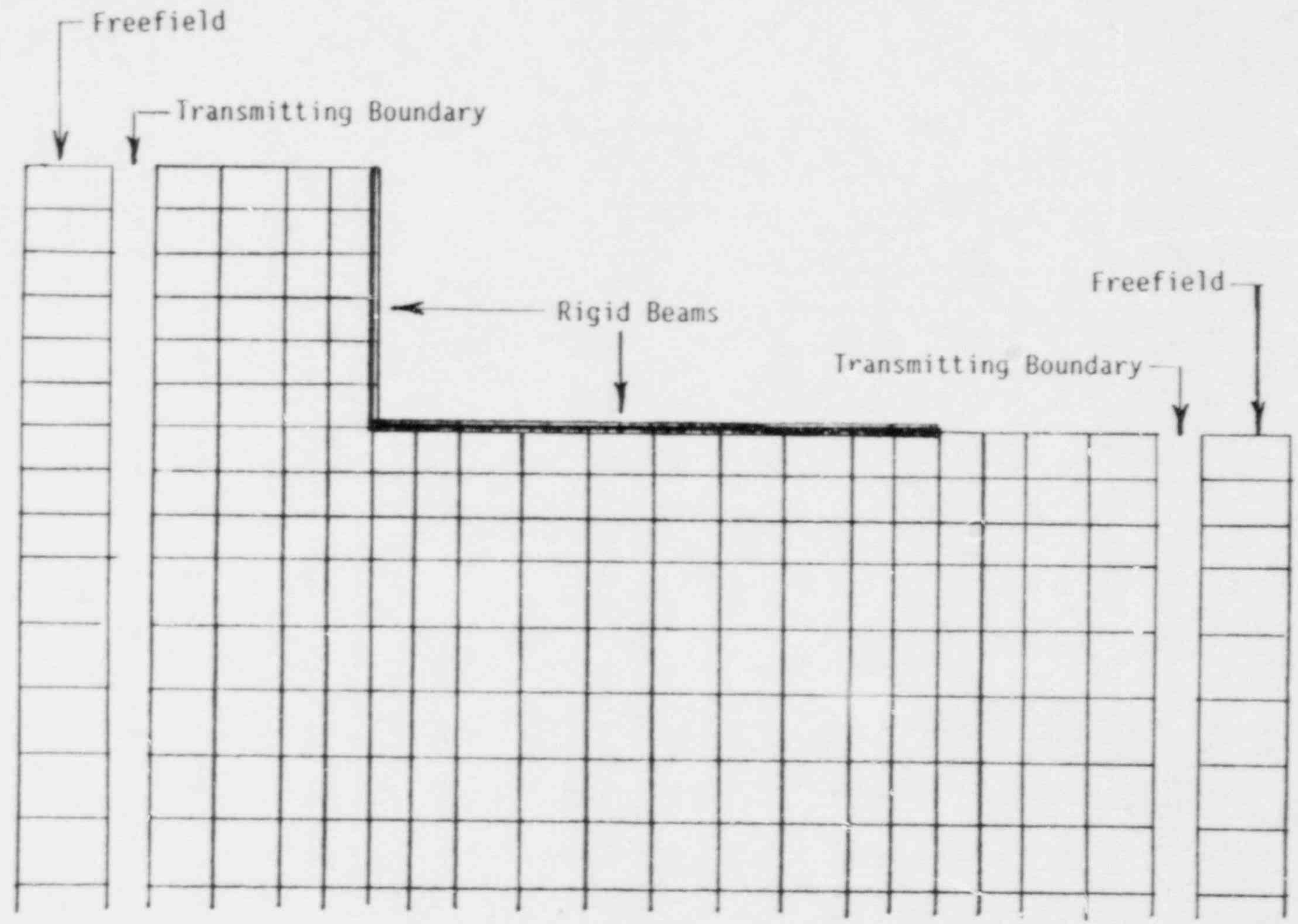

Fig. 3 Typical SUPERFLUSH Foundation Model of Intake Structure

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