Effects of Base Mat Flexibility and Structure-Soil-Structure Interaction on the Seismic Responses of a Nuclear Stack Building

A. F. KABIR, L. E. MALIK
Advanced Engineering Consultants, Inc., San Francisco, CA USA
M. E. MARYAK
Westinghouse Savannah River Co., Aiken, SC USA

ABSTRACT

A nuclear exhaust stack building was analyzed considering flexibility of the base mat and through-soil coupling with a nearby massive reactor building. The analysis indicated that the base mat flexibility and the proximity of the reactor building significantly affect the seismic responses of the stack building.

1 INTRODUCTION

A nuclear exhaust stack building with complex structural configuration has been analyzed for seismic motions. A detailed mathematical model of the stack building and a nearby massive reactor building was developed to consider the structure-soil-structure interaction (SSSI) and base mat flexibility on the seismic responses of the stack building. In the current study, the effect of these two phenomena on the floor acceleration response spectra (FRS) were studied. The FRS is an important seismic response parameter for a nuclear exhaust stack building as it is used as input for seismic evaluation of equipment and piping supported in the building.

2 DESCRIPTION OF THE BUILDINGS

The exhaust stack building consists of a tall reinforced concrete exhaust stack supported on a platform of reinforced concrete beams and girders, as shown in Figure 1. This platform is supported by eight massive columns. These columns are supported on a 7 ft thick, 135 ft x 100 ft base mat embedded 14 ft in ground. The stack building foundation is 14.5 ft from the deeply embedded (50 ft below ground surface) foundation of a reactor building. The reactor building foundation is massive (approximately 220 ft x 200 ft) with approximately 10 ft thick reinforced concrete walls and base mat. Both the buildings are founded on a deep deposit of sandy soil with shear wave velocity in the range of 925 fps to 1500 fps.

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3 MATHEMATICAL MODELS

The proximity of the stack building to the massive reactor building suggested that the responses of the stack building will be influenced by the reactor building through soil coupling. The 7 ft thick base mat is also flexible in out-of-plane directions when compared to the supported columns. Accordingly, a structure-soil-structure interaction (SSSI) model of the two building were developed to calculate proper seismic responses of the stack building. This rigorous SSSI model included a detailed finite element representation of the stack building, its base mat, a finite element model of the reactor building base mat and structure, and, model of the soil consisting of semi-infinite horizontal linear elastic layers over a semi-infinite half space. Figure 2 presents a schematic representation of this SSSI model. The superstructures of the stack and reactor building were not shown completely for the sake of clarity.

The above-mentioned SSSI model was incorporated in the computer code SASSI (Lysmer, 1988) for analyses purposes. The basic method of analysis, adopted by the computer program, is formulated in the frequency domain, using the complex response method. The finite element technique is utilized to obtain structural stiffness and mass matrices. The variations in soil dynamic properties with depth, i.e., soil layering effects, can be rigorously accounted for in the impedance calculations.

The stack building alone was also modeled using a lumped parameter SSI computer code AEC/LASSI (1990). The superstructure model of the exhaust building is the same as that used in the SSI model. The reactor building and its foundation was not modeled. The base mat was assumed to be an equivalent embedded rigid cylinder. Its frequency-dependent soil impedances were based on the work reported by Kausel (1979). This model, referred herein as the LP (lumped parameter) model, has two main differences with the SSSI model. It does not consider base mat flexibility and through-soil coupling with the reactor building.

4 ANALYSIS AND DISCUSSION OF RESULTS

The SSSI and LP models were analyzed for horizontal and vertical acceleration time-histories matched to USNRC Regulatory Guide 1.60 spectra shapes anchored at a zero period acceleration of 0.20g.

Figure 3 presents the vertical FRS at the top of the base mat due to vertical input motion for the two models. The FRS at the east side are very similar for SSSI and LP models. This is to be expected as this side is away from the reactor building and the base mat is stiffened by thick shear walls in this area. So, the base mat flexibility and through-soil coupling effects are not important here. The base mat at the west side is relatively flexible out-of-plane as there are no stiffening shear walls and it is also close to the reactor building. The FRS here are very different indicating the effects of the base mat flexibility and the presence of the reactor building. It is also interesting to note that the LP FRS for the two sides are very similar which is to be expected as the base mat is assumed rigid in this model.

Figure 4 presents the east-west FRS due to vertical input motion at west side base mat and at a higher elevation for the two models. The SSSI FRS indicates high amplification in rocking motion when compared to the LP FRS. This again indicates the base mat flexibility and reactor building coupling effects.

Figure 5 presents the vertical deflected shape of the base mat at a critical time step. Again, the flexibility of the west side of the base mat is pronounced as the slab here curves considerably compared to the almost straight line deflection of the east side.

5 CONCLUSIONS

The major conclusions of this study are:

(1) Flexibility of the base mat of the stack building has a significant effect on the seismic responses of the building. The vertical motion at the flexible areas of the base mat were significantly amplified when compared with the rigid base mat case. These amplified motions resulted in higher FRS in the superstructure.

(2) The reactor building has a significant influence on the vertical motions of the stack building base mat, introducing appreciable rocking motions to the stack building areas closest to the reactor building.

REFERENCES

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AEC/LASSI, (1990). A Lumped-Parameter Approach to Soil Structure Interaction Analysis, Users Manual.

Kausel, E., et al. (1979), Vertical and Torsional Stiffness of Cylindrical Footings, Publication No. R79-6, Dept. of Civil Eng., MIT.

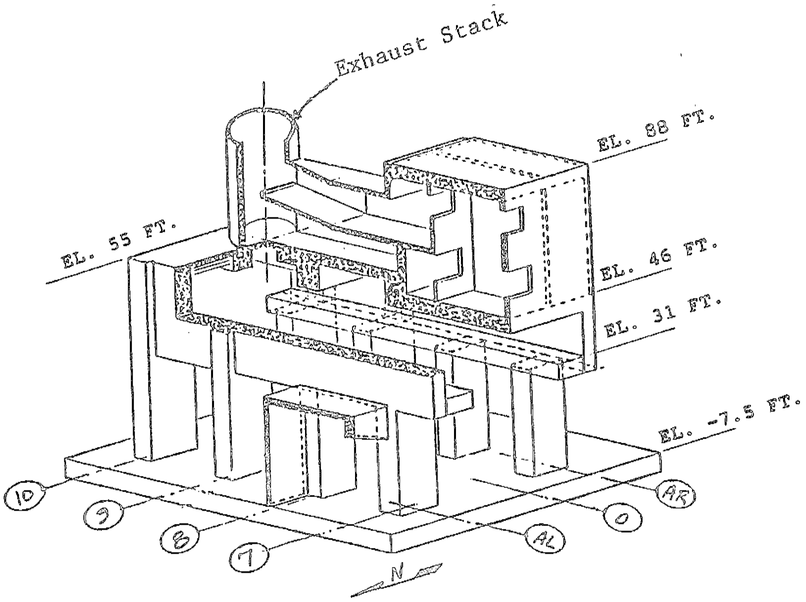
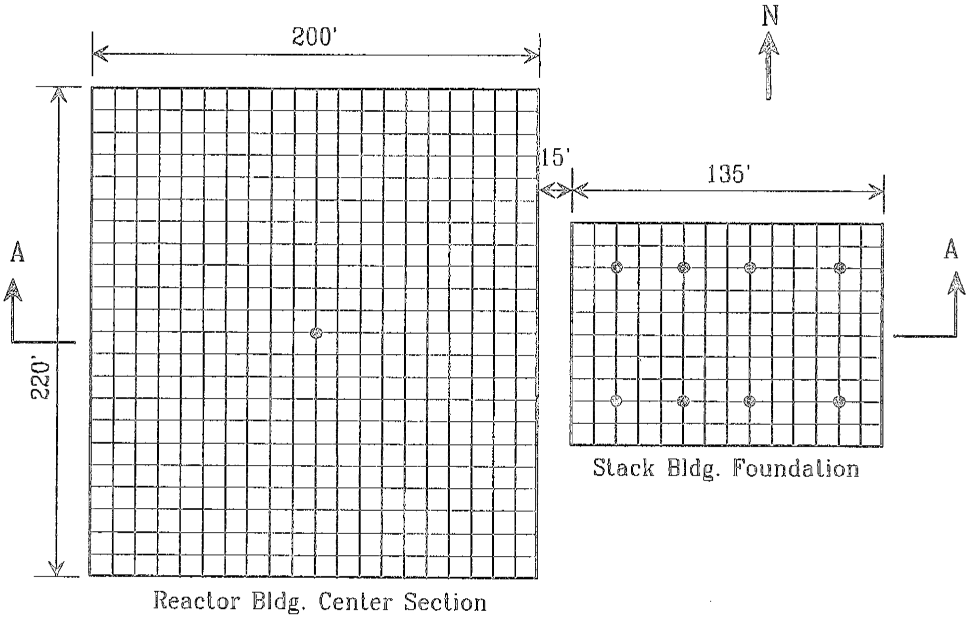
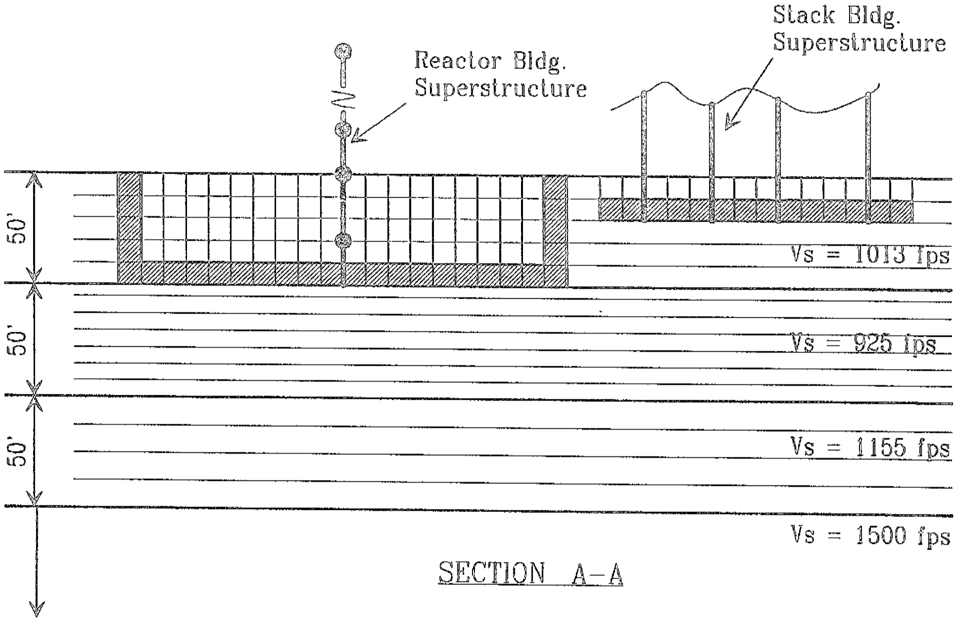


FIGURE 1 ISOMETRIC VIEW OF STACK BUILDING



PLAN VIEW



SECTION A–A

FIGURE 2 SSSI MODEL FOR STACK AND REACTOR BUILDINGS

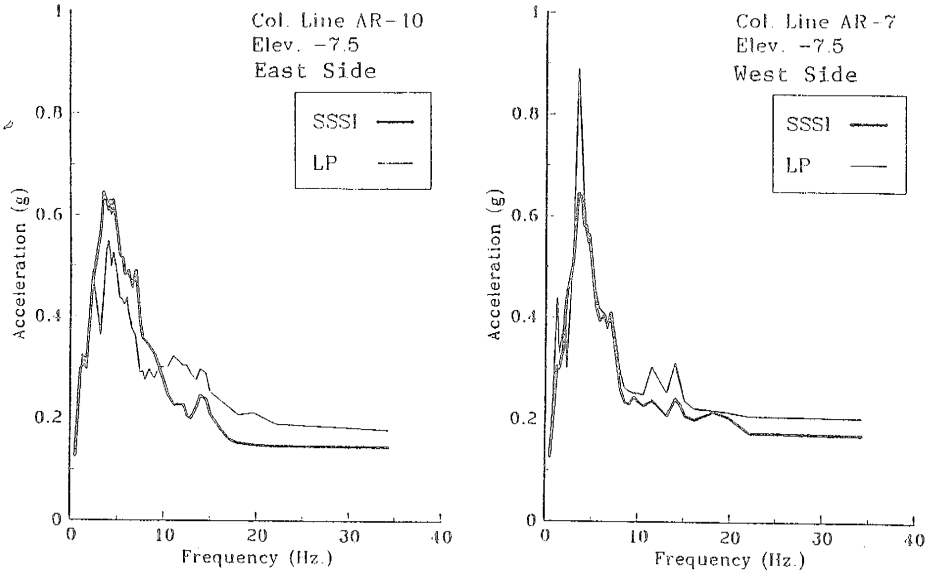


FIGURE 3 VERTICAL FRS DUE TO VERTICAL INPUT

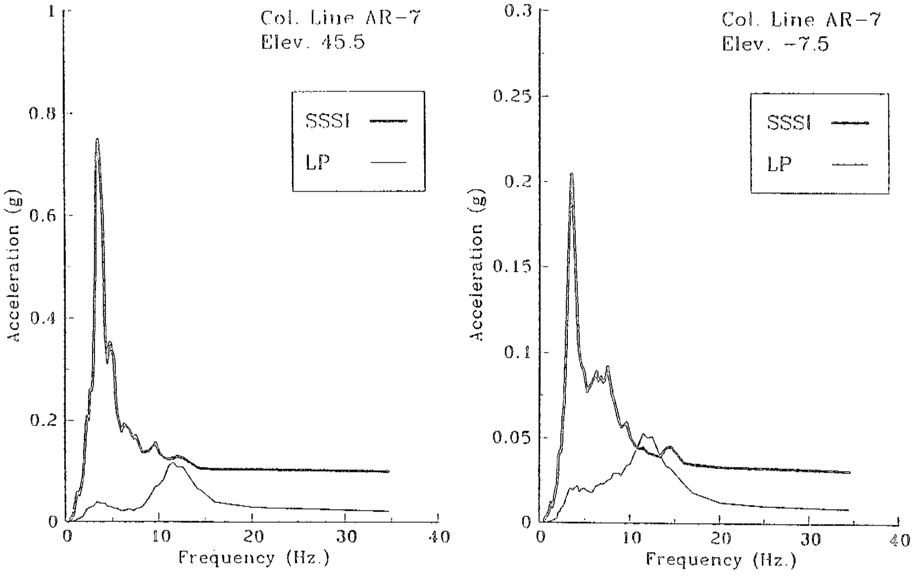
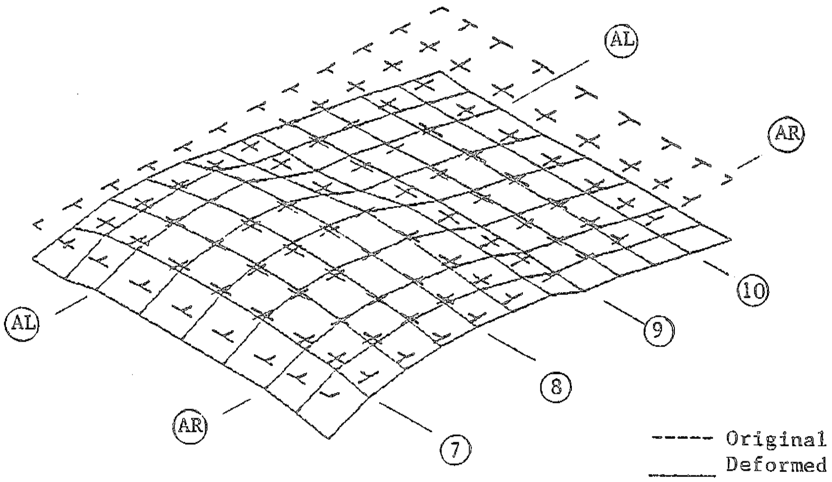
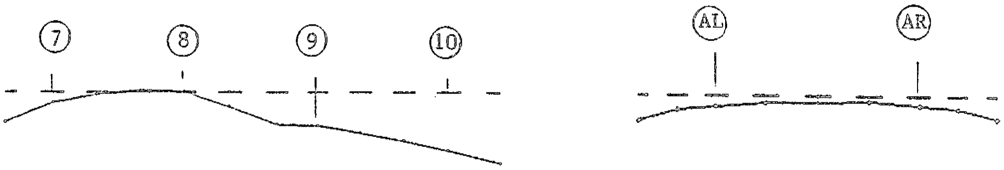


FIGURE 4 EAST-WEST FRS DUE TO VERTICAL INPUT

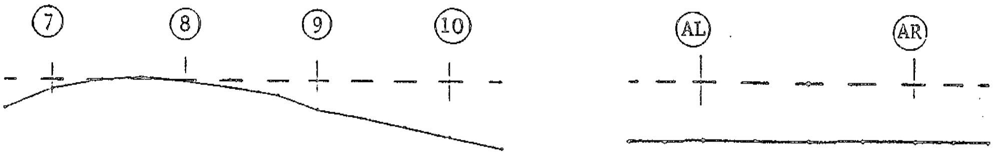


a. Entire Basemat



b. Line AL

d. Line 7



c. Line AR

e. Line 10

FIGURE 5 VERTICAL DISPLACEMENTS OF STACK BUILDING BASEMAT
DUE TO VERTICAL INPUT MOTION, TIME = 9.47 SEC.