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Seismic Analysis of the Machine Foundation with the Vibration Isolation Systems

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ABSTRACT

This paper presents the seismic analysis of the machine foundation with the vibration isolation systems. The structure is represented by a 3-D finite element model. From seismic analysis of this model the floor response spectrum of this structure is obtained for the artificial ground motion and a condensed stick-spring model is developed. This stick model is used for the seismic analysis in which the soil-structure interaction is considered. The machine foundation with vibration isolation systems(VIS) exhibits lower acceleration and smaller fundamental frequency than the machine foundation without them. And this effect is the same in the case of soil-structure interaction(SSI).

1 INTRODUCTION

The machine foundations in nuclear power plants can be classified as the high-tuned foundation and the low-tuned foundation according to the characteristics of vibration response(Arya,S.C.1979). The low tuned foundation has its fundamental frequencies much lower than the running speed of the machine and is characterized by extremely slender supporting columns.

Recently, to reduce the transmissibility of machine vibration on the upper deck, a designer is in favor of the machine foundation with vibration isolation systems among which helical springs possess the advantage that they have precisely defined stiffness constants in both the vertical and horizontal planes.

In the following chapter, the analysis method of this study is introduced, and as an example the 3-D finite element model for a machine foundation with VIS is presented. For the purpose of seismic analysis the ground input motion is generated, consistent with the design response spectrum. After the analysis, the comparison of floor response spectra of the foundations with vibration isolation systems and the soil-structure interaction effect is considered.

2 ANALYSYS METHOD

In this study, the program to carry out the seismic analysis of a machine foundation with the vibration isolation systems by using finite element method is developed. For the the purpose of this analysis , the artificial acceleration time history generated to be consistent with the design response spectrum supplied by the designer can be used or the previous earthquake accelogram can be used as an input motion. In the case of the artificial acceleration, the several intensity functions among which rectangular shape function or trapezoidal shape function is included can be applied to simulate the transient character of real earthquakes. And the correction of this generated acceleration is possible by suppressing and raising the artificial data to reduce the difference of amplitude between the target design response spectrum and the generated response spectrum. Then this data is regarded as the input motion.

To model the structure, two methods are applied. One thing is to use the 3-D finite element model to gain the exact solution, and the other is the lumped parameter model ,that is, the stick-spring model to gain the approximate solution. For the vibration isolation systems, the internal spring elements of which the stiffness and damping value are given can be used. This spring element can be also transformed into the boundary spring element. If the modeling is over, the time history analysis is followed, including the soil-structure interaction. Finally the floor response spectrum is obtained to the selected point. The example of using this program is shown in the next chapter.

3 EXAMPLES

3.1 Description of structure

The machine foundation is located within the main turbine building which houses other equipment and piping necessary for power generation. The shape of the structure is shown in Fig.1. Seen in the Figure, the machine foundation is of monolithic reinforced concrete consisting of a foundation mat, columns, partial mezzanine floors, and the deck.

The top horizontal frame of the pedestal called the operating deck, supports the turbine-generator unit. This deck is composed of reinforced concrete transverse beams perpendicular to the longitudinal axis. For condensor, its neck is rigidly connected to the turbine there by eliminating the effects of the vacuum load on the foundation.

The vibration isolation systems of which unit bearing capacity varies from 160kN to 300kN and its height 400mm are placed between the pedestal(operating deck) and the columns. The number of helical-spring units of different load-carrying capacity that is required to support both the reinforced concrete foundation deck and the turbine generator on the basis of the calculated portion of this combined load that has to be borne by each of the substructure columns is determined by the foundation designer.

For 3-D finite element modeling shown in Fig. 2, the deck and columns are represented by a three dimensional finite element beam model. And the vibration isolation systems are modelled by internal springs which have the vertical elastic constants and the similar horizontal elastic constants and have their own masses. The masses of turbine and generator are distributed to the connecting nodes as concentrated masses. Base mat is depicted by fixed boundary condition without the soil-structure interaction.

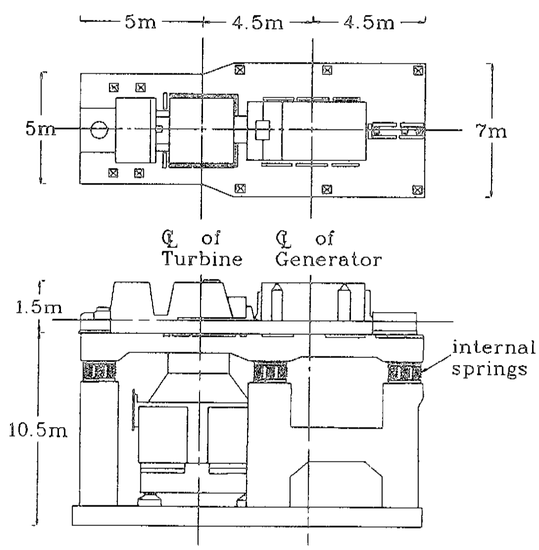


Fig. 1 The Plan of the machine foundation with the vibration isolation systems

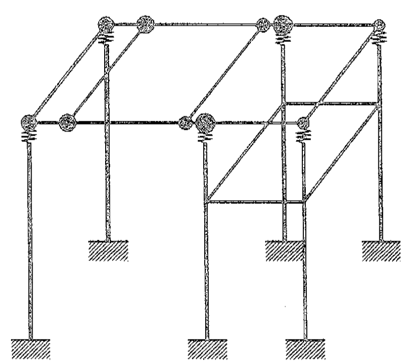


Fig. 2 The 3-D finite element model

3.2 Seismic analysis

The seismic responses of the machine foundation structure are determined from a dynamic analysis using the well-known time history analysis. For ground input motion, the artificial acceleration-time history by the method of superposition of sine waves, matching the site-independent design response of the NRC(Nuclear Regulatory Commission) Regulatory Guide 1.60. The artificial acceleration can be modified for any design control point by Tsai method. In Fig. 3, the dashed line shows the design response spectrum and the solid line shows the response spectrum for artificial ground acceleration.

Prior to seismic analysis, the free vibration analysis for machine foundations with and VIS is carried out. As a result, the natural frequencies of both cases are obtained as following Table 1. Seen in the table, a 42.1% reduction of fundamental frequency in the machine foundation with VIS is observed.

Table 1. Natural frequencies (Hz)

Mode No.	Finite Element Method without V.I.S.	Finite Element Method with V.I.S
1	3.13	1.32
2	3.25	1.36
3	9.53	1.92
4	11.67	2.05
5	14.47	2.82

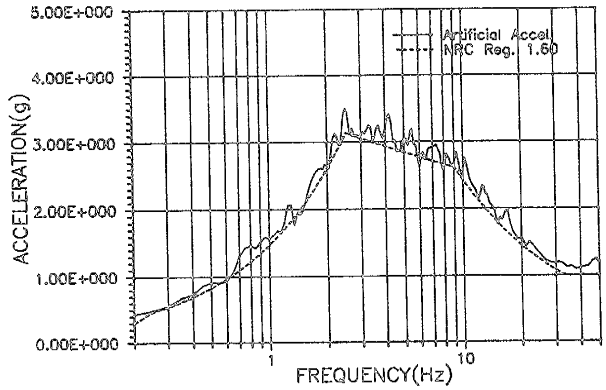
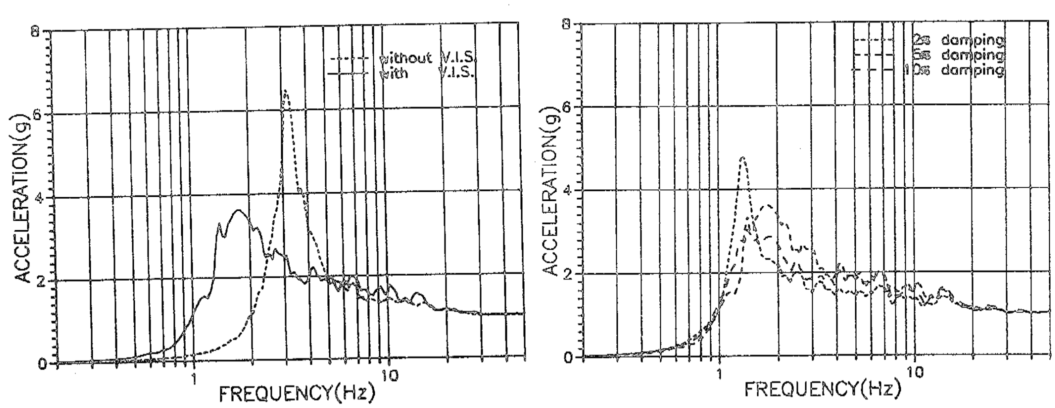


Fig. 3 Design response spectrum and the artificial acceleration spectrum

In seismic analysis, the floor response spectrum of acceleration on the deck level ,5% structrual damping is given in Fig.4 (a), represents the smaller peak amplitude in the machine foundation with VIS than in the machine foundation without VIS. With respect to the varying damping value, the floor response spectrum of the foundation with VIS is shown in Fig. 4 (b). Seen in the figure, the greater the damping value is, the lower the peak value of the floor response is and the flatter the shape of floor response spectrum becomes.



(a) (b)

Fig. 4 The floor response spectrum of machine foundation with VIS and without VIS

3.3 Soil-structure interaction

Recently, the soil-structure interaction effect is regarded as the very important factor to determine the resistance capacity of the structure. Therefore, in this study, the 3-D finite element model is reduced to lumped parameter model,stick-spring model, to apply the soil -structure interaction as shown in Fig. 5.

The structure-foundation system is assumed to be subjected to the horizontal free-field motion. Then the frequency-independent impedence function of soil material for the elastic half space is obtained, that is, the horizontal and rocking stiffness is computed. And the stiffness and material damping as provided in the soils are added to the lumped parameter model.

Also, as the previous case, the floor response spectrum of foundation with and without VIS is displayed. The result in Fig. 6 shows the outstanding lower peak value and reduced fundamental frequency. Finally, Table 2. summarizes the above results. In this table the reducing effect of the response of the machine foundation with VIS is observed.

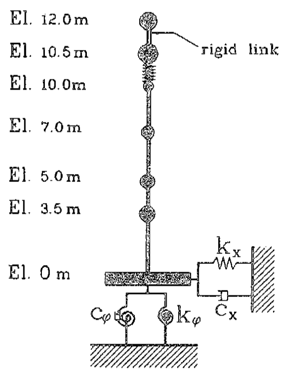


Fig. 5 The stick-spring model for SSI

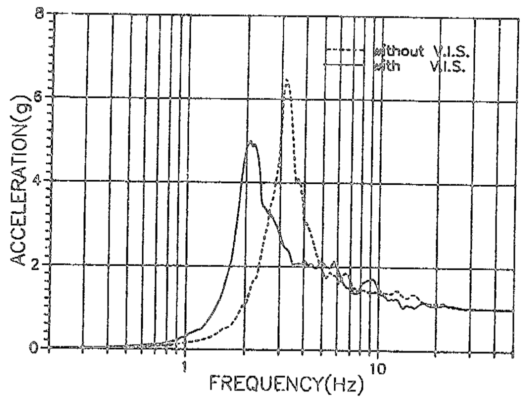


Fig.6 The floor response spectrum of machine foundation

Table 2. The summary of this study (for 5% structural damping)

	Fixed Boundary Fundamental Frequecy	Ratio*	Soil-Structure Interaction Fundamental Frequency	Ratio*
Foundation without VIS	3.13	1.0	3.07	1.0
Foundation with VIS	1.32	0.42	1.99	0.65

* represents the fundamental ratio of machine foundation with VIS to foundation without VIS

4 CONCLUSION

As a result of this study, it is certain that the vibration isolation system of the machine foundation, especially helical coil spring, exhibits the reduced transmissibility of ground motion to the secondary system on the deck level clearly. On the deck level the acceleration of the machine foundation with VIS is computed as 3.8 times ground acceleration , on the other hand, the acceleration of the machine foundation without VIS is 6.4 times the ground acceleration. Considering the soil-structure interaction its reducing effect becomes duller than above case but the acceleration of the machine foundation with VIS is still less than the machine foundation without VIS by the 25% of reduction ratio. This result will be very useful for the designer who has something to do with spring-mounted machine foundation. In this study, the soil is modeled by considering only material damping, and this value is used to obtain the impedence functions for the soil-structure interaction, therefore, it is hoped that the radiation damping representing the propagation of wave energy away from the foundation will be considered in soil-structural interaction afterwards.

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