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VARIATION OF A STRUCTURE SEISMIC RESPONSE AS A RESULT OF SOIL IMPROVEMENT AT THE CONSTRUCTION SITE

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ABSTRACT

A treatment of NPP building foundation's soil is an effective measure for optimization of the whole NPP project: in the case of soft soil, the designer may face a number of problems relevant to seismic protection, possible soil liquefaction, as well as structures' capacity. The article discusses the most suitable methods with relation to practical implementation: deep soil mixing (DSM) and jet grouting (JG). With DSM, cementitious material is mechanically mixed with the in-situ soil by using a hollow stem auger and paddle arrangement. In JG, a high-pressure fluid is utilized to erode the soil in a predrilled hole and loose soil cuttings are mixed with cement. As a result of soil improvement, an increase in such important parameters of the foundation as the deformation modulus, compression and shear strength, and the elastic wave velocities can be expected. With DSM/JG, the treatment can be done by means of individual improved soil columns or the entire soil volume underlying the foundation. The maximum improvement depth can be up to 30 m, but usually it is in the range from 15 m to 20 m. Soil treatment by DSM/JG method allows:

− to erect constructions on sites initially unsuitable to locate of NPPs due to geological conditions;
− to reduce structure settlements and tilts;
− to achieve the necessary foundation bearing capacity under the seismic impact;
− to achieve, under certain conditions, a reduction in the seismic response of buildings, thus reducing seismic loads on equipment and piping.

The second part of this paper presents computational studies focused on the reduction of seismic loads due to soil treatment. In this regard, the problem of structure seismic response variation due to local soil improvement at the construction site was considered. The problem of soil - treated soil - structure dynamic interaction was solved using the ACS SASSI program. The influence of the improved soil characteristics on the kinematic parameters of soil surface seismic effect is considered as well. It is shown that variation of the soil properties can both reduce and increase the seismic effect on the construction site. Further, the influence of the soil improvement on the seismic response of the whole structure is considered. Moreover, the paper discusses how the treated soil conditions may reduce structure seismic response on the example of a typical reactor building.

INTRODUCTION

Different approaches were used to consider soil irregularities at the construction site. An example is the article of A.Tyapin, see Tyapin (2013). In this paper the influence of introducing softer soil deposits at the rock construction site on the site seismic excitation was investigated. That was opposite case to deep soil mixing (DSM) method (see Kitazume (2012) and FHWA (2013) for more information) with which a hard soil deposit in the soft surrounding soil will be created. The presented paper discusses possible influence of soil treatment on the nuclear building seismic response.

CALCULATION METHOD AND INPUT DATA

This study was carried out utilising ASC SASSI software for soil-structure interaction calculation, see Ghiocel (2016). The treated soil was modelled as an embedded part of the structure. The consideration of embedded part was performed using flexible volume method for which two separate meshes were created: one part for excavated volume of the original soil and second part for the threated soil. A model representing typical VVER (PWR) reactor building (RB) was used for this study (Figure 1). Figure 1 a) shows model for the structure placed on original soil and Figure 1 b) shows structure with excavated volume mesh. The main parameters of the modes are presented in Table 1.

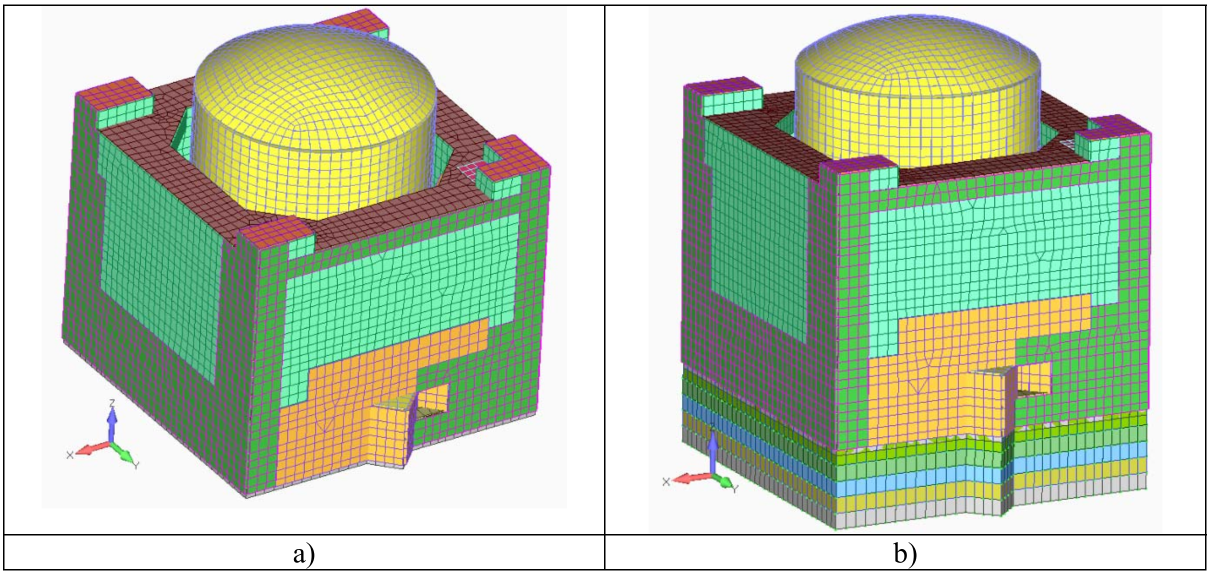

Figure 1. Reactor building model overview, a) on soil b) with TS.

Table 1: RB model properties.

	Model on soil	Model with TS
Number of elements	25054	37054
Excavated soil elements	-	6000
Number of nodes	21115	33000
Number of interaction nodes	1257	7542

The building was considered placed on homogeneous soil half space with following properties: soil density ρ = 1774 kg/m^3, shear wave velocity Vs = 400 m/s, P-wave velocity 800 m/s, damping 5%. Threated soil (TS) was considered having lower density ρ = 1600 kg/m^3 and higher Vs. Two variants of treated soil stiffness were considered: variant 1 with Vs = 800 m/s, Vp= 1360 m/s and variant 2 with Vs = 1200 m/s, Vp= 2040 m/s.

Seismic excitation was simulated using three dimensional synthesized accelerogram. Accelerogram components for both comparative cases were created statistically independent using the same base acceleration response spectra which has a typical shape (Figure 1, curve “SPECTRA.dat”). Vertical acceleration intensity was considered as 2/3 of the horizontal components.

CALCULATION RESULTS

Calculation results are presented in terms of accelerations at different buildings elevations. The following elevations for seismic response acceleration output were considered:

- “Basemat” presents different points at the basemat centre and corners;
- “RV” reactor vessel supports;
- “EL 36 m” presents different points on containment operation level;

- "AUX" presents different points at auxiliary rooms around containment shell;
- "shell top" is the point at the top of containment.

Figures 1 – 4 show accelerations response spectra with 5% damping in X direction at different levels. All spectra are presented as enveloped spectra over the corresponding points. The curve with spectra for building without TS is marked with "Soil" designation, curves for TS conditions are marked as "Vs=800" and "Vs=1200" accordingly to the used TS shear wave velocity.

Figure 2 show acceleration reduction up to 40% due to TS implementation in the frequency area of 3 -4 Hz for the basemat points. On Figures 3 – 4 the response spectra for other output levels are presented showing also significant acceleration reduction up to 20 % in different frequency ranges.

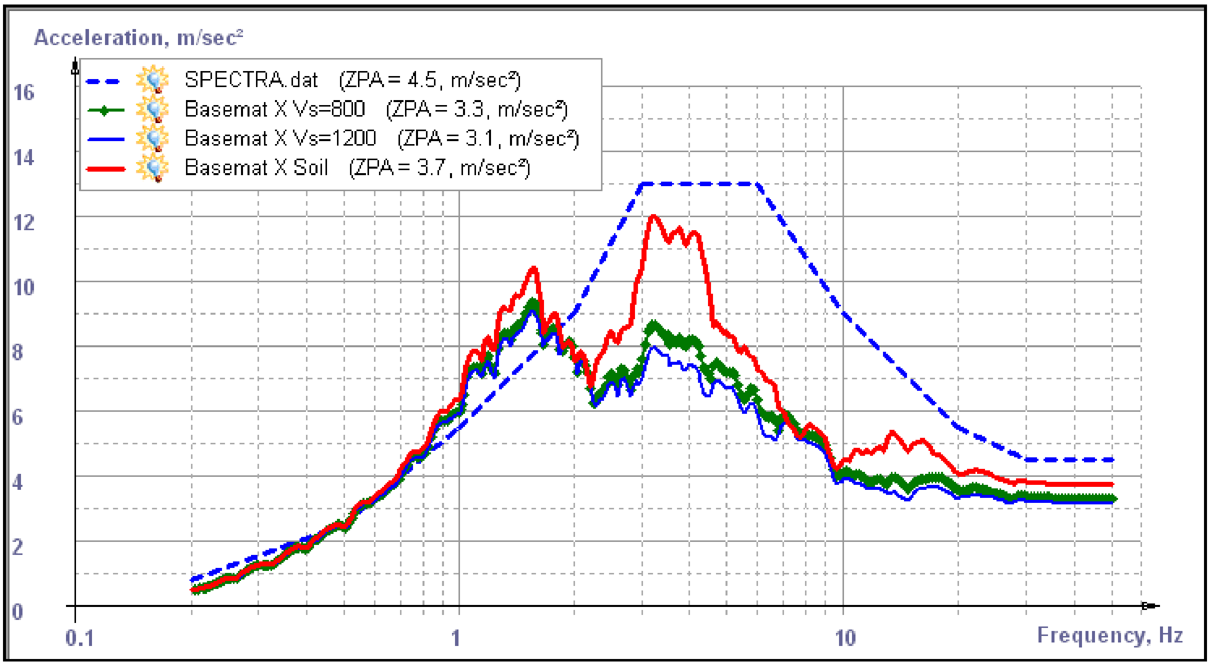

Figure 2. Acceleration response spectra for RB basemat, X direction.

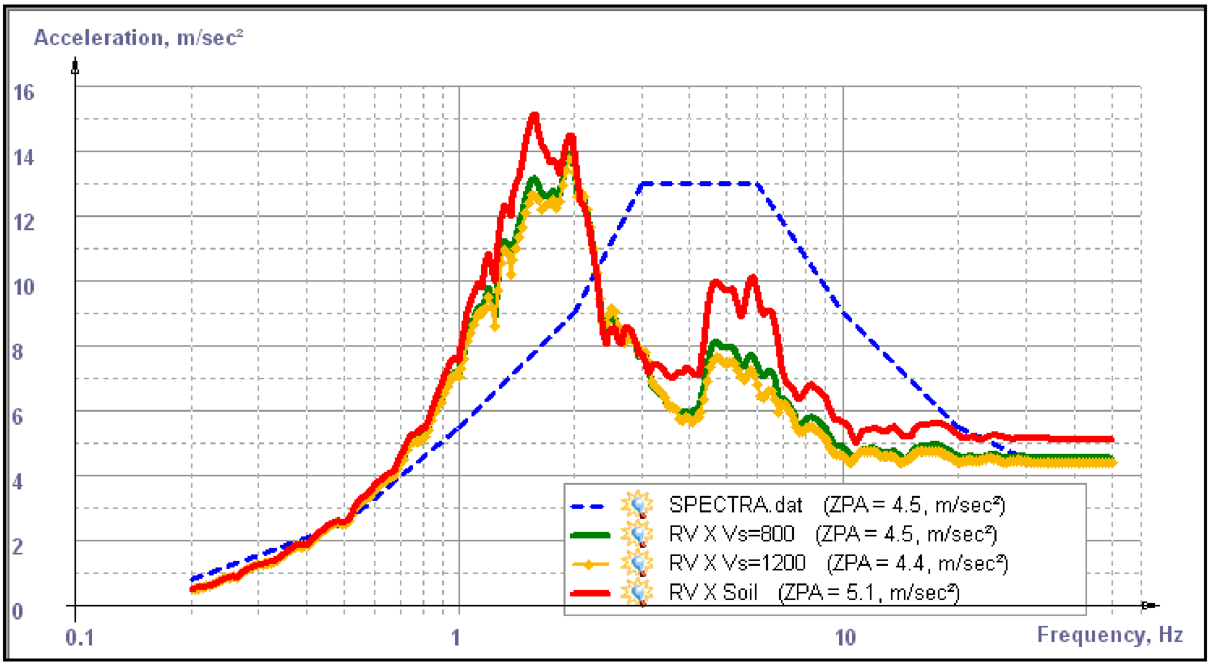

Figure 3. Acceleration response spectra for RV supports, X direction.

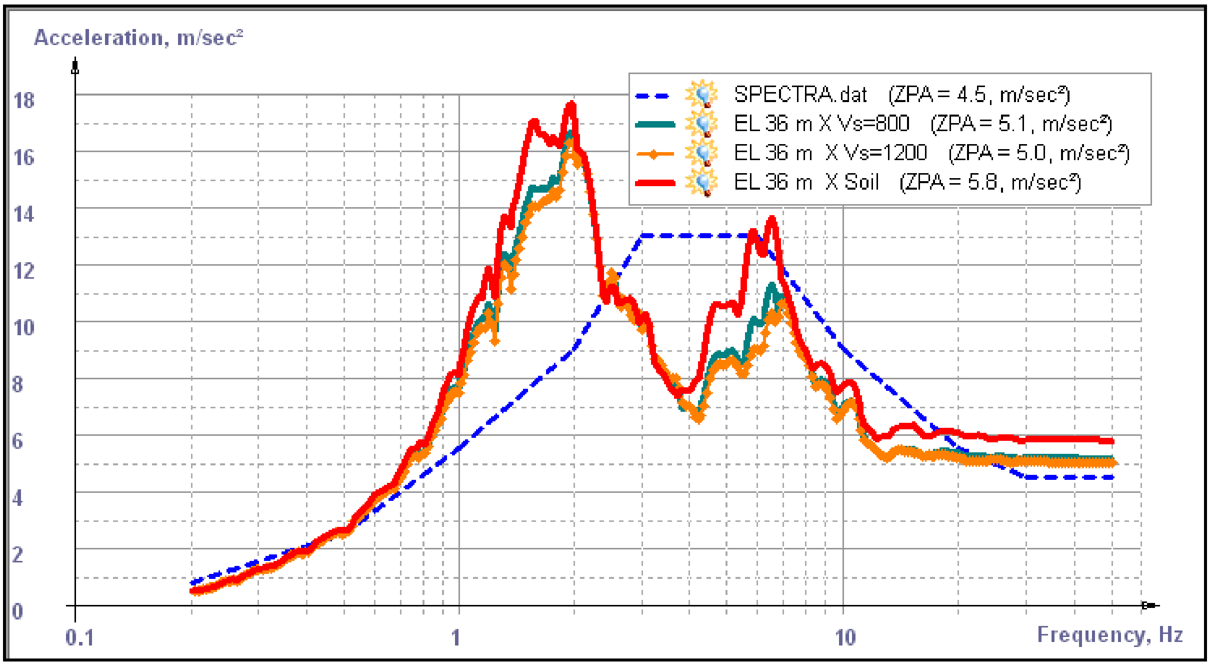

Figure 4. Acceleration response spectra for El 36 m, X direction.

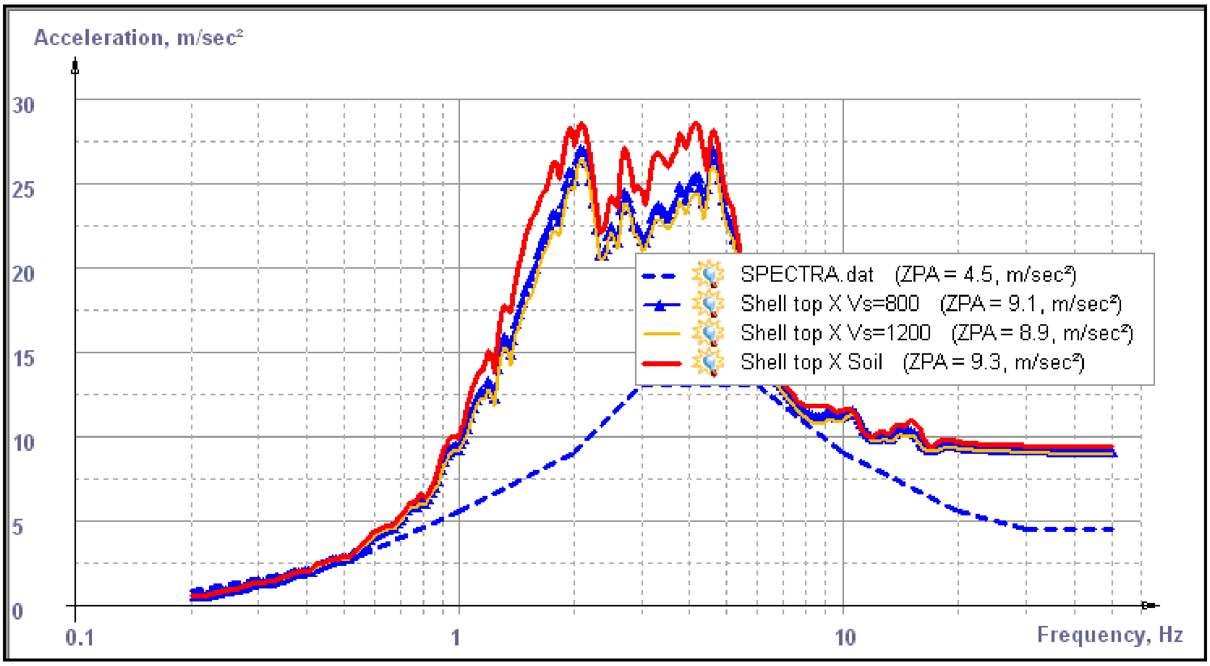

Figure 5. Acceleration response spectra for containment shell top, X direction.

Table 2 shows maximum accelerations (zero period accelerations, ZPA) calculated for all output levels in three dimensions. It can be seen that using TS technology reduces ZPA in horizontal directions X, Y. On the other hand the strong soil treatment with Vs = 1200 m/s may increase vertical accelerations. It is better illustrated in Table 2 where relative acceleration difference caused by using TS technology is presented. Reduction in horizontal ZPA from 2 % to 16 % can be observed steadily increasing with increased TS Vs. However the vertical ZPA may be reduced with lower Vs up to 23 % for basemat level and increased up to 49 % for containment top in case of higher Vs.

Table 2: Maximum accelerations (ZPA), m/s^2.

	On Soil			Vs = 800 m/s			Vs = 1200 m/s		
Building structure	X	Y	Z	X	Y	Z	X	Y	Z
Basemat	3.7	3.6	5.2	3.3	3.2	4.0	3.1	3.1	4.5
RV supports	5.1	4.4	2.9	4.5	4.0	2.7	4.4	3.9	3.8
EL 36 m	5.8	5.4	3.8	5.1	4.9	3.4	5.0	4.7	4.5
AUX	6.7	4.7	6.1	6.2	4.5	4.9	5.9	4.5	5.4
Containment shell top	9.3	9.8	5.1	9.1	8.9	5.2	8.9	8.6	7.6

Table 3: Maximum accelerations (ZPA) variation, %.

	Vs = 800 m/s			Vs = 1200 m/s		
Building structure	X	Y	Z	X	Y	Z
Basemat	-10.8	-11.1	-23.1	-16.2	-13.9	-13.5
RV supports	-11.8	-9.1	-6.9	-13.7	-11.4	31.0
EL 36 m	-12.1	-9.3	-10.5	-13.8	-13.0	18.4
AUX	-7.5	-4.3	-19.7	-11.9	-4.3	-11.5
Containment shell top	-2.2	-9.2	2.0	-4.3	-12.2	49.0

CONCLUSION

- Influence of soil treatment on seismic dynamic response of a typical reactor building has been investigated;
- Acceleration reduction up to 40% due to TS implementation in the frequency range of 3 Hz to 4 Hz for the reactor building basemat points is possible;
- Response spectra for other output levels show also significant acceleration reduction up to 20 % in different frequency ranges;
- Reduction in horizontal ZPA from 2 % to 16 % can be observed with increasing effect following increased TS Vs;
- Vertical ZPA may be reduced with lower Vs up to 23 % for basemat level and increased up to 49 % for containment top in case of higher Vs.

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