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THE SEISMIC RESPONSE AND FLOOR SPECTRA OF OL3 NPP BUILDINGS IN FINLAND

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ABSTRACT

The purpose of the present work is the computation of seismic response and floor spectra of the nuclear power plant OL3 buildings in Olkiluoto.

The following OL3 plant buildings were included in the analysis:

- the Reactor Building UJA/UJB,
- the Safeguard Buildings UJH/UJK 1-4
- and the Fuel Building UFA

The in-structure spectra were generated using the ground motion response spectra documented in YVL GUIDE 2.6 “Seismic events at nuclear power plants” issued by Finnish Centre of Radiation Protection. The floor spectra were computed for the following equipment damping values: 2%, 4%, 7%, and 10%. The joint model for the plant buildings was generated. All analyses were linear and the direct time integration method was used with time step of 0.001 sec. All response runs were carried out with MSC/Nastran general purpose structural analysis program. The development of floor spectra has been carried out in accordance with the US NRC –Regulatory Guide 1.122: “Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components”.

The response results show that the dominant frequencies of the reactor building are located around 5 Hz in frequency space and that the typical amplification of spectral peaks for 4% damping is from 8 -10 times when compared to peak ground acceleration.

Keywords: seismic response, floor spectra, equipment damping, amplification of spectral peaks.

1. INTRODUCTION

The purpose of the present work is present the preliminary seismic response analysis and floor spectra development for the EPR type nuclear power plant Olkiluoto3 in Eurajoki, Finland. The EPR reactor is a PWR in the 1,600 MW class. Its design is based on experience feedback from extensive operational experience of light water reactor operation, primarily the French N4 and the German KONVOI reactors.

The design is based on the 4 primary loops and 4 safety trains concept which applies to mechanical equipment as well as the electrical power supply and the associated instrumentation and control (I&C).

Operating and safety functions are separated to simplify the plant layout. Special attention is paid to ensure the plant safety against external hazards. To withstand severe earthquakes, the plant is designed with large safety margins. The entire nuclear island stands on a single reinforced concrete basemat. The height of the buildings has been minimized. The heaviest components, in particular the water tanks, are located at the lowest possible level.

The general view of the Ol3 plant site is depicted in Figure 1:

Figure 1 General view of the Olkiluoto NPP site. In the foreground is the model of the OL3 unit

2. DESCRIPTION OF THE PLANT

The nuclear island plot plan is characterized by the following features : 1) the reactor building is surrounded by the safeguard buildings and the fuel building; 2) the operational auxiliary systems are housed in the nuclear auxiliary building; 3) the access to the radiological controlled area of the nuclear island buildings is given through the access building; 4) the diesel buildings are located at the east side of safeguard building four and west side of the safeguard building one. The plot Plan of the Nuclear Island is shown in Figure 2:

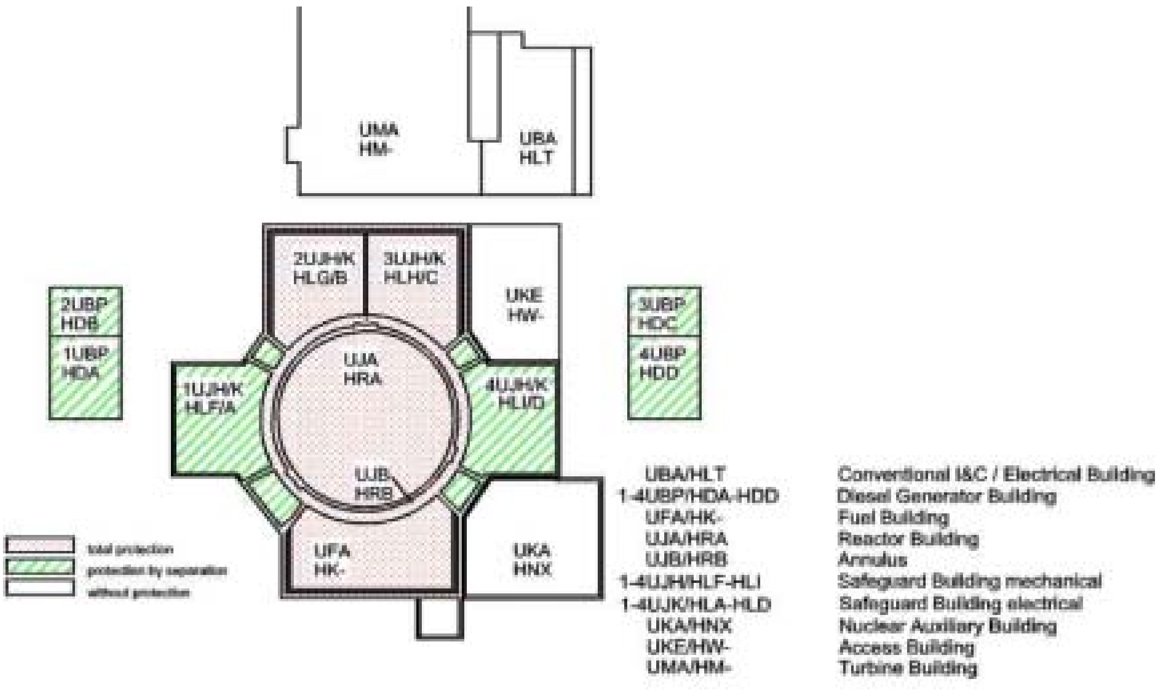


Figure 2. The plot plan of EPR plant.

The Containment has a cylindrical prestressed inner wall surrounded by the Annulus and the outer wall of reinforced concrete.The main containment characteristics are as follows: 1) The inner containment free volume is about 80000 m^3 ; 2) The inner containment diameter is 46,8 m and the inner containment height is 57,5 m. The primary system arrangement is characterized by following parameters: 1) Symmetrical location of hot and cold leg nozzles at RPV, 2) Pressurizer located in a separate area, 3) Vertical column supports for Reactor Coolant Pumps and Steam Generators, 4) Concrete walls between the loops, and between the hot and cold leg of each loop to protect from consequential failures, 5) Concrete wall (secondary shield wall) around the primary system to protect the Containment from missiles and to reduce radiation from the primary loop to the surrounding areas.

The arrangement of the primary circuit of EPR plant is given in Figure 3.

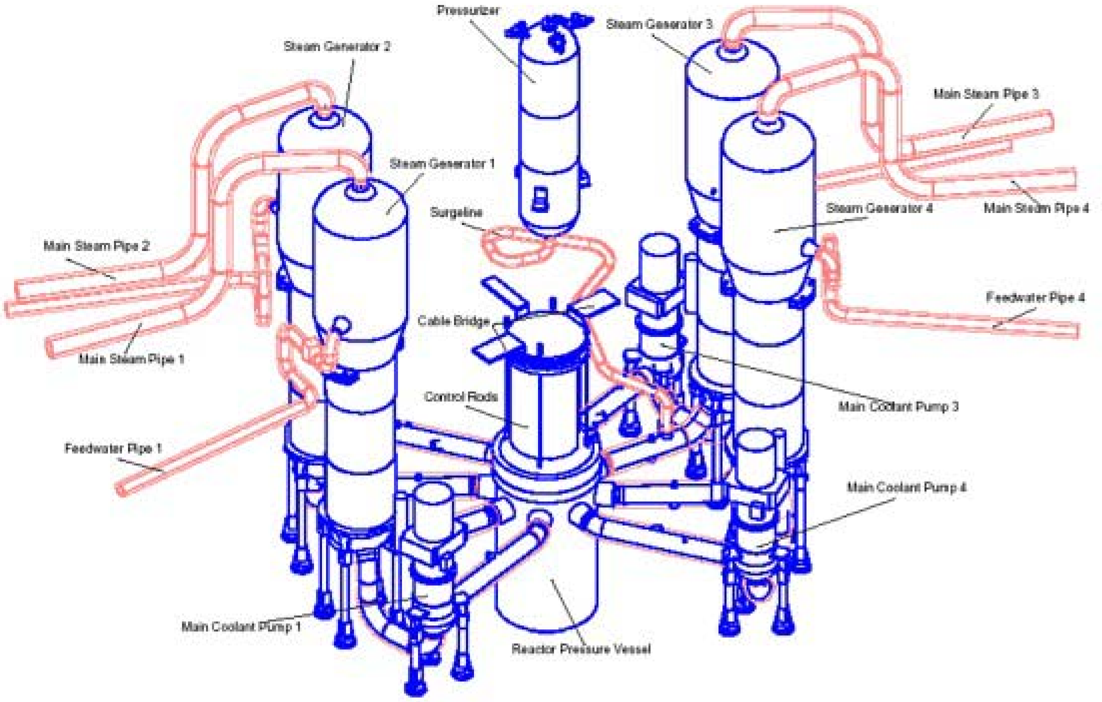


Figure 3. The arrangement of the primary circuit

3. DESIGN OF SEISMIC CATEGORY 1 STRUCTURES

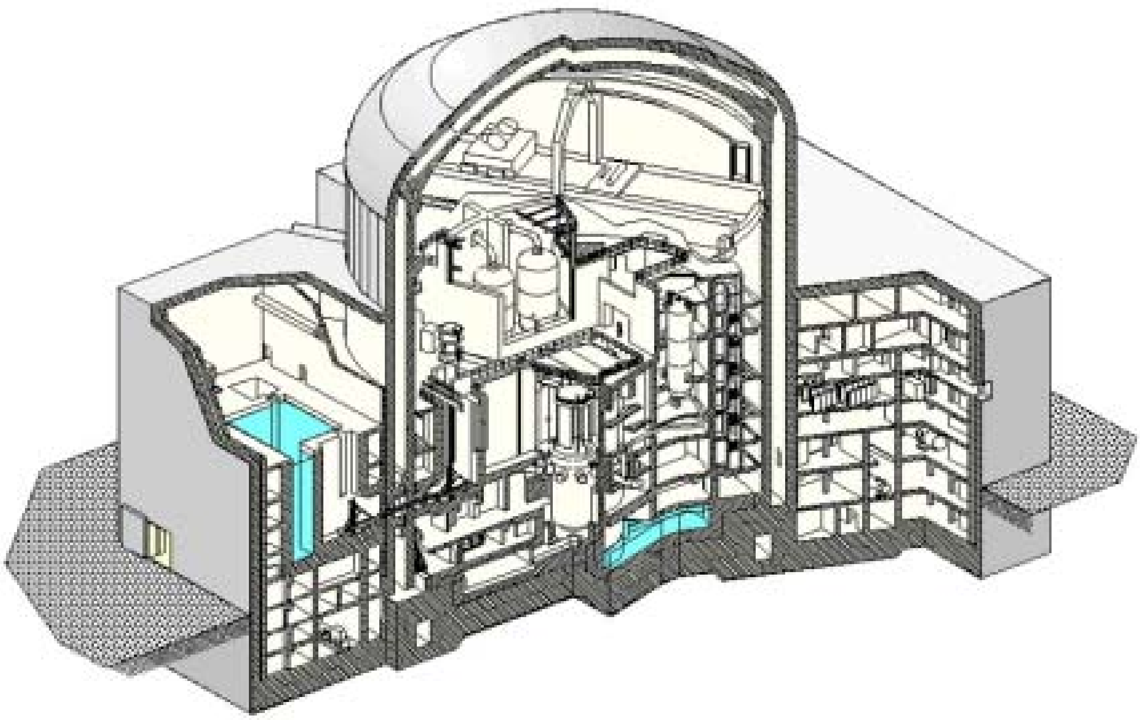
The containment is a double-wall structure founded on a basemat. The inner containment shell is a prestressed containment with a steel liner. The outer containment shell is a reinforced concrete structure. It guarantees protection against external hazards such as airplane crash and explosion pression wave. The two shells are separated by the annulus, 1,80 m wide, placed under subatmospheric pressure in order to collect the leaks through the inner containment and filter them before release to the environment. This double wall structure provides an efficient environmental radiation protection under all conceivable circumstances including the Severe Accident which is defined as a reactor vessel melt through by the corium. The basemat is a reinforced structure. The containment dimensions provide the necessary free volume compatible with the hypothetical Severe Accident. Available space is sufficient for the polar crane to handle the largest items of equipment. (e.g. the steam generators in one piece).

The inner shell and the basemat are designed to stay leaktight within the specified criteria of 0.1 % per day of the mass of gas in the containment for maximum pressure of 0,5 MPa (design pressure) in accidental conditions. Measures are taken to prevent global fast deflagration and to preclude events which would raise the pressure above 0,65 MPa. The metallic penetrations through the containment are designed for the same ambient conditions inside the containment. They are designed by analysis and rules with conservative assumptions and boundary conditions and have therefore intrinsic built-in margins.

The governing requirements for the steel liner leaktightness are the strain limits in operational and accidental loading conditions.

The outer containment shell is formed by a reinforced cylindrical wall and a reinforced dome. The outer containment shell is designed against airplane crash, Design Earthquake, explosion pressure wave and climatic loads. The containment includes various penetrations such as equipment hatch, personnel and emergency airlocks, piping and electrical cable penetrations, and the fuel transfer tube, enabling connections with the other buildings and different systems. In case of an accident, the systems are isolated by closure devices, according to safety rules, ensuring automatic containment isolation.

The general view of the nuclear island buildings is given in Figure 4:



.Figure 4. The general view of the nuclear island buildings of Olkiluoto unit 3.

The internal structures inside the inner containment are reinforced concrete structure, mainly composed of the primary shield (reactor pit), the secondary shield (cylindrical wall plus intermediate walls and floors) and the reactor pool (reactor cavity plus storage compartment). The internal structures rest on the reactor building containment basemat (level - 7,80m) through a thick concrete slab.

4. COMPUTATION MODEL OF THE CONTAINMENT BUILDINGS

The computation model was generated based on the plant layout described in earlier sections. All the structural response analyses were linear and the direct time integration method was used with time step of 0.001 sec. The software products Patran [i] and Nastran [ii] were used in this structural response analysis task. Only From the nuclear island buildings the outer containment, the inner containment and the reactor building internal structures were modeled. It was judged that the inner containment and internal structures response were not much affected by the surrounding safety and fuel buildings because of the structural separation. The reason for this decision was the fact that the foundation soil underneath the reactor island is solid rock with very high stiffness characteristics and also the fact that the foundation slab under the safeguard building was significantly thinner than the foundation slab under the reactor building.

The units in all diagrams and Figures are meters, seconds, gigagrams and megapascals. The origo of the global system of rectangular coordinates is at the Elevation +0.00 and is located in the reactor vertical axis. The x-axis is the axis of the building traversing the UJH/UJK 1-4, y-axis is the axis of the building traversing the UJH/UJK 2-3 and UFA buildings, z-axis is the vertical axis.

The concrete material properties used in all models are given in the following table. The material properties have been selected in accordance with Reference [iii].

Table 1Concrete Properties

Item	Poisson constant	Young's modulus	Density	Damping
Outer Containment	0.2	30000.	2.5E-3	5%
Inner Containment	0.2	30000.	2.5E-3	5%
Internal Structures	0.2	30000.	2.5E-3	5%

Reference [iv] documents the design ground motion response spectra, and the time histories has been developed to developed to match the ground motion response spectra established in with a peak ground acceleration (PGA) of 0.109.

In the following Figure 5 the outer containment, the inner containment, the reactor building internal structures are depicted. All the spectrum and time history results presented in the further sections of this report are calculated from this model.

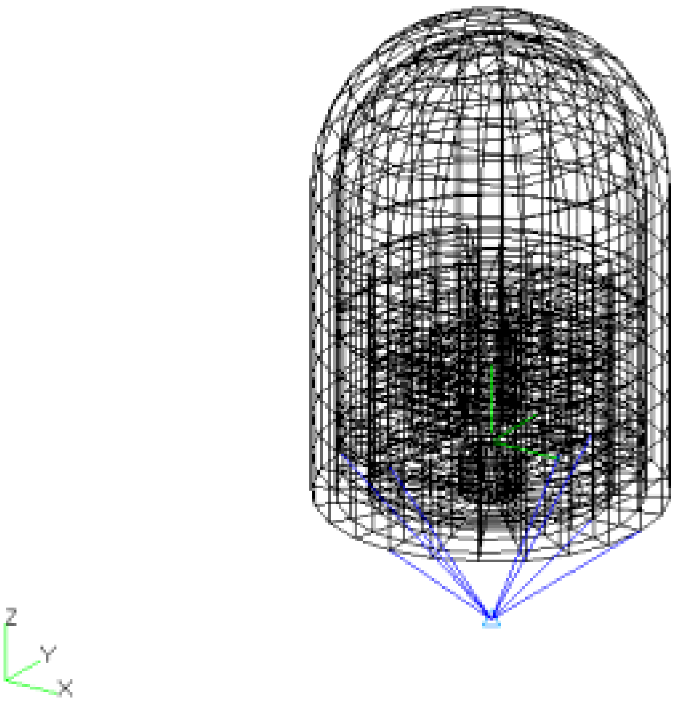


Figure 5. The plot of reactor building model for the preliminary calculation of OL3 floor spectra.

5. RESULTS

The three lowest eigenfrequencies of Fortum verification calculation are given in the following Table 2:

Table 2. The three lowest modal frequencies

Mode No.	Frequency Hz	Comments
Mode 1	2.66	Trans. hor
Mode 2	2.68	Long. hor.
Mode 3	3.99	Vertical

The spectra are calculated at 9 points explained in the following Table 3:

Table 3. Location table response points

Building	Elevation	Node No.	Location
Reactor building	-30.0	54187	Big mass
Reactor building	+5.15	1948	Reactor pit
Reactor building	+13.80	2366	Reactor shaft
Reactor building	+19.50	2451	Main operation deck
Reactor building	+28.50	3213	Steam generator box
Inner containment	+19.50	404	Main operation deck el.
Inner containment	+38.50	407	Crane elevation
Outer containment	+19.50	1144	Main operation deck el.
Outer containment	+38.50	1147	Crane elevation

The development of floor spectra has been carried out in accordance with the Reference [v]. The global x-direction acceleration response spectra for Elevations +5.15, +13.80, +19.50, +28.50, +38.5 are given in the following Figures:

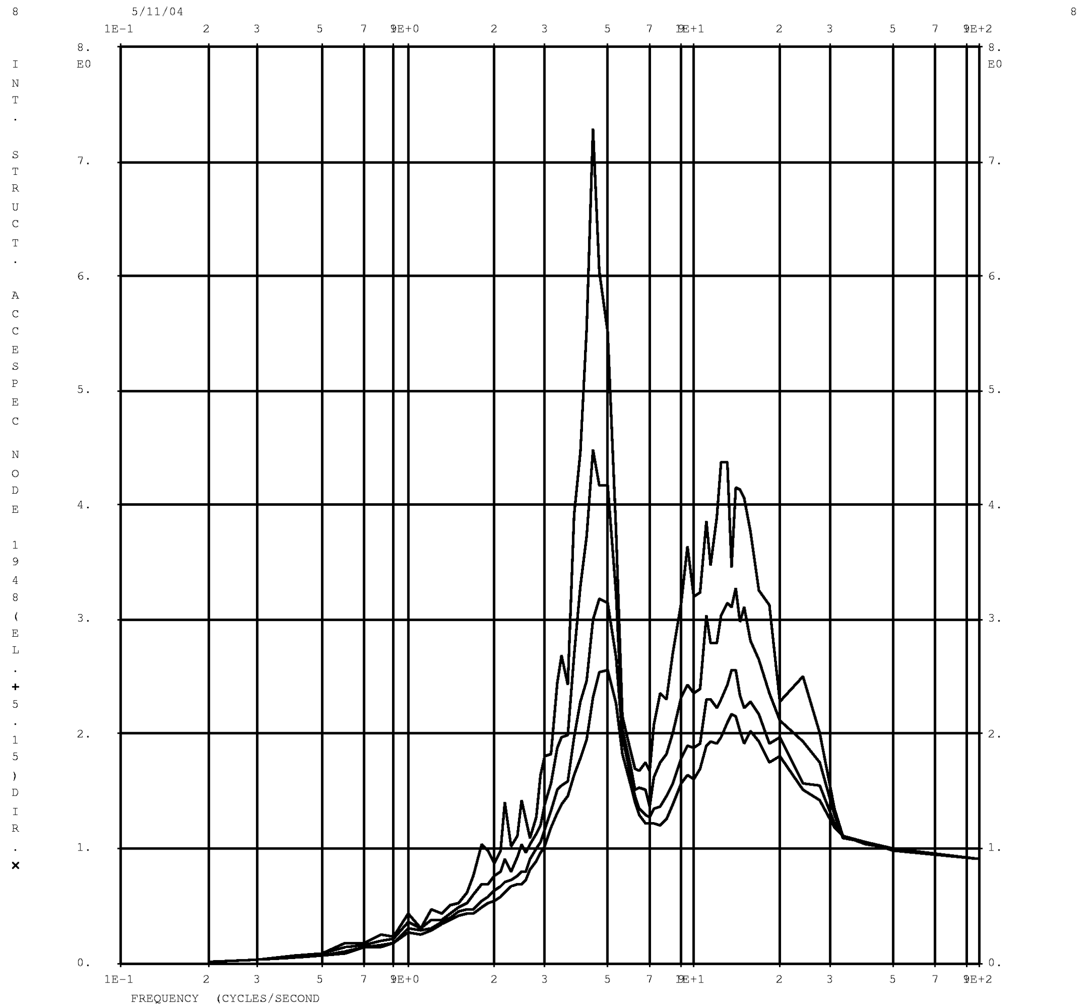


Figure 6 *X-direction response spectra for Elevation +5.15*

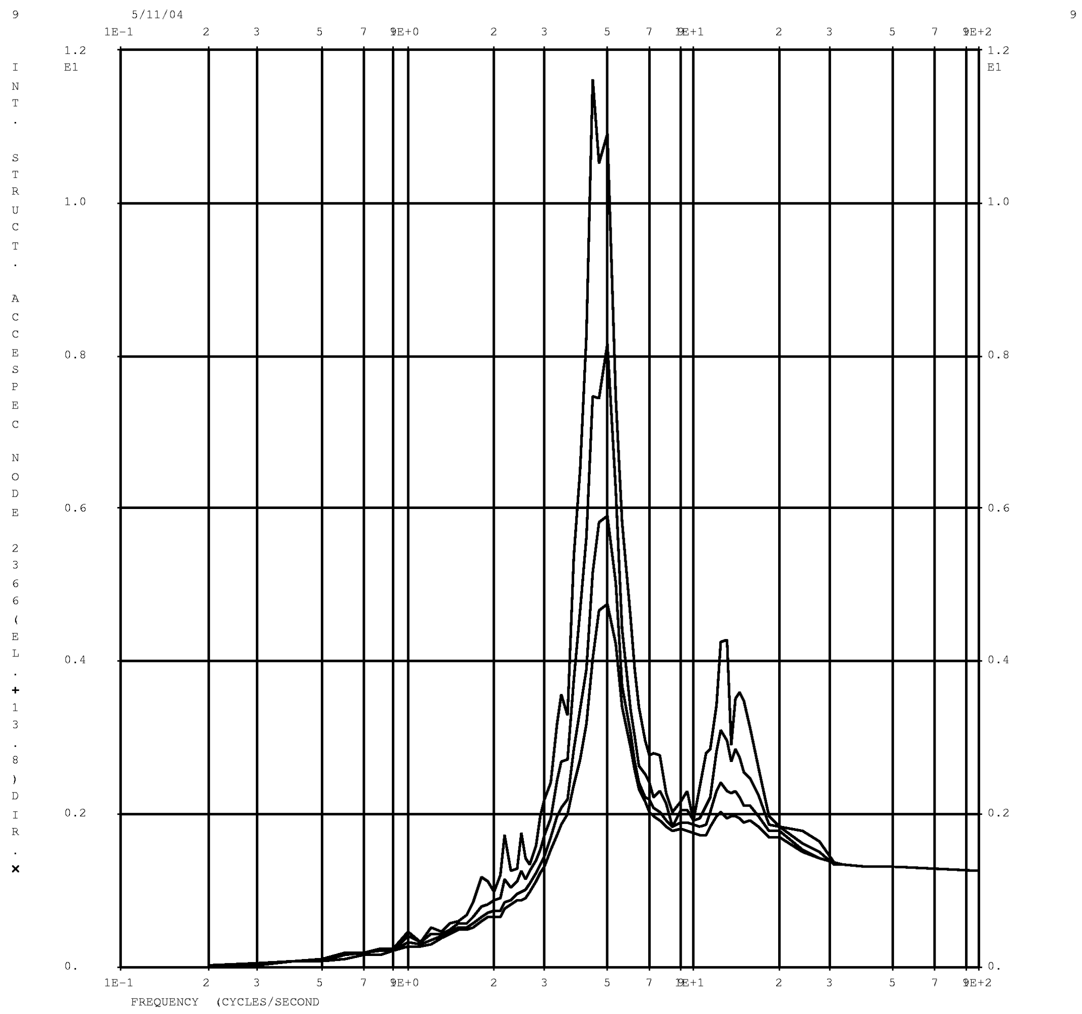


Figure 7 X-direction response spectra for Elevation +13.80

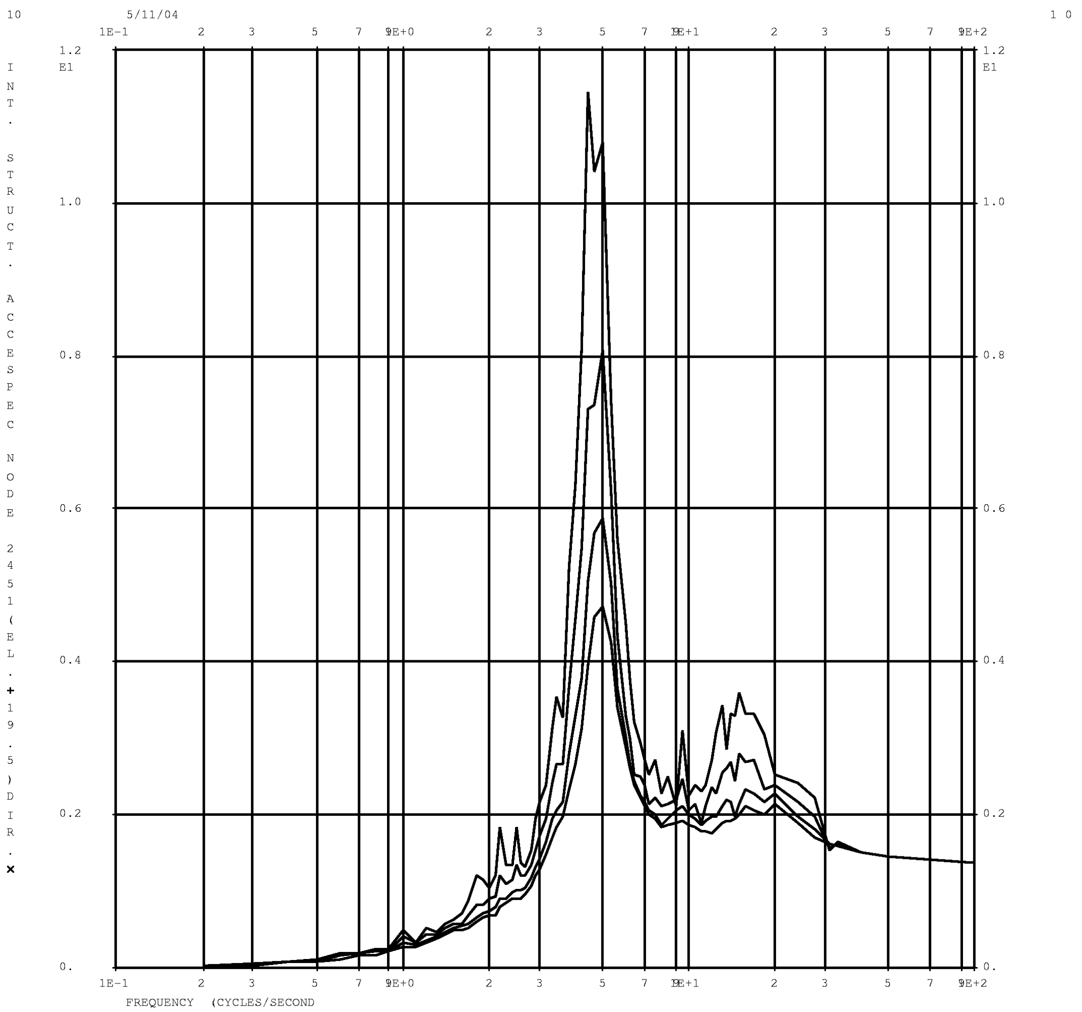


Figure 8 *X-direction response spectra for Elevation +19.50*

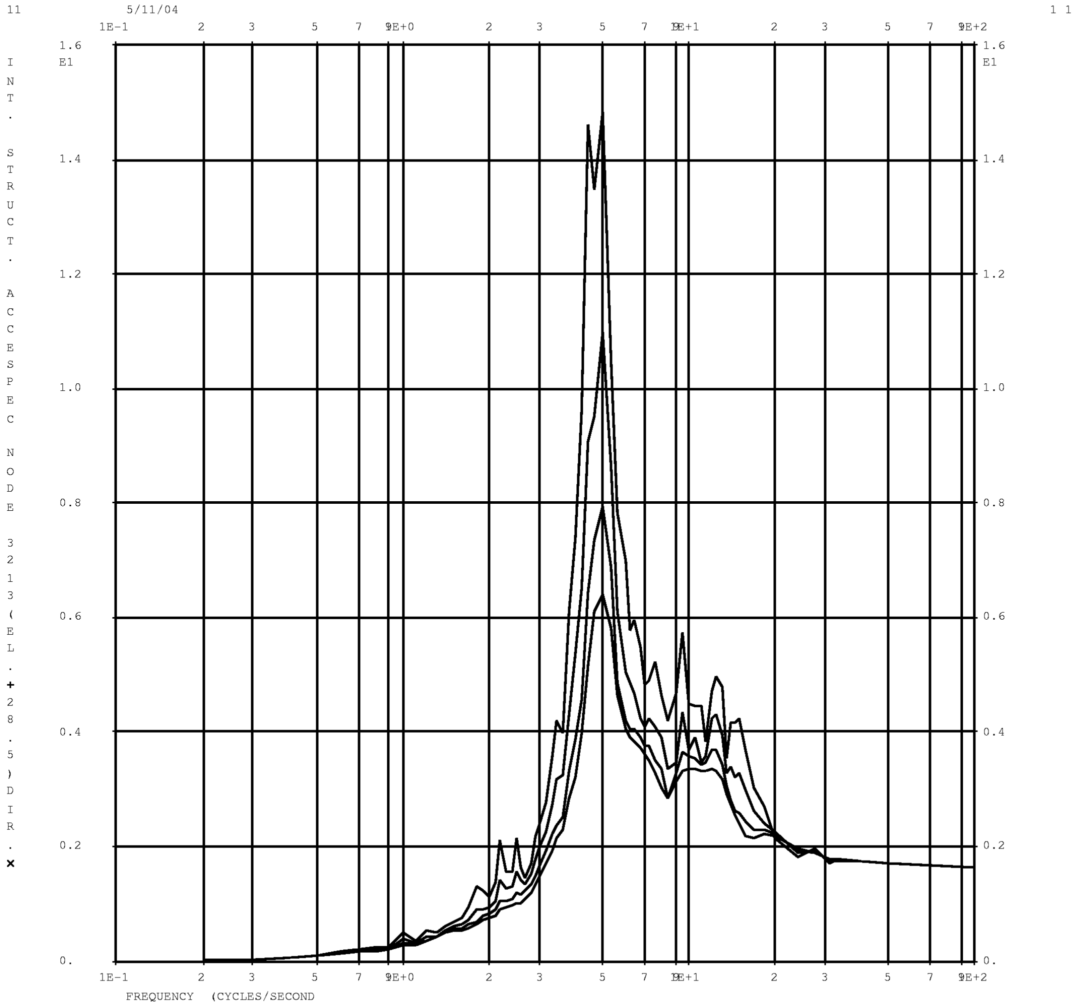


Figure 9 *X-direction response spectra for Elevation +28.50*

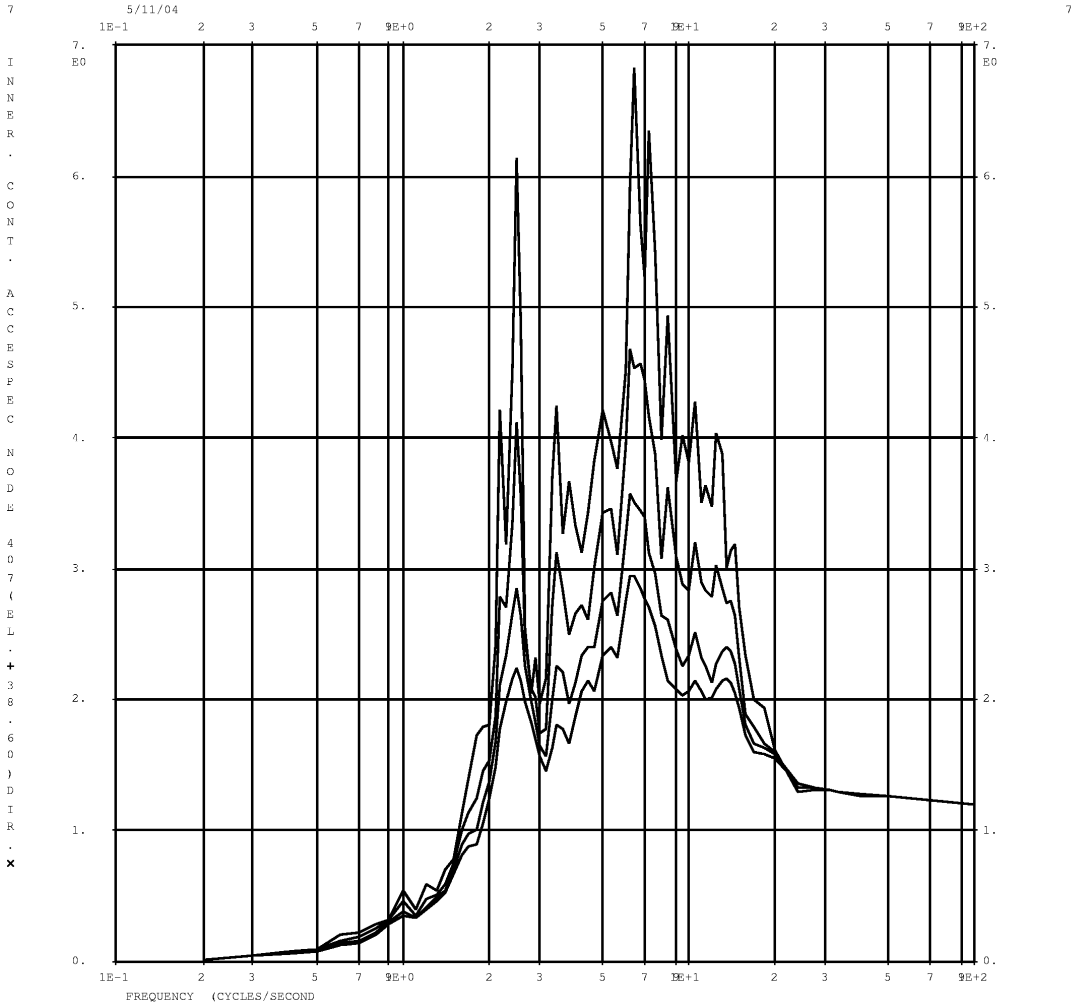


Figure 10 *X-direction response spectra for Elevation +38.50*

6. CONCLUSION

Inspecting the Figures 6, 7, 8, 9 and 10 the following conclusions can be made:

- For the elevations upto +28.50 the spectra show a pronounced peak around the frequency of 5 Hz
- For the elevation +38.50 the spectra show broader band from 2 Hz until 12 Hz

REFERENCES

[i] MacNeal-Schwendler Corp., “MSC/Patran User’s Guide. Los Angeles, 2003.

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[v] US NRC Regulatory Guide 1.122, Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components, Revision 1, 1978.

