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Seismic Analysis of a Base Isolated Structure

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Summary

This paper presents the seismic analysis of a structural model with fixed base and isolated with a multi-stage system made up of four layers of elastomeric bearings.

The steel structure has an opening of 1.4 m, a span of 1 m and a height of 1.5 m. The seismic analysis of structure was performed in SAP2000 program.

The aim of this paper is to study the behavior of the base isolated structure with a multi-stage system, in the case of some artificial accelerograms compatible with the elastic response spectrum for the horizontal components of ground acceleration, in areas characterized by the corner period T_c*=0.7s, as recommended by the P100-2013 design norm.*

The artificial accelerograms were generated using the ANCO SPECTIME program. The accelerograms are characterized by a peak ground acceleration of 0.3g, a duration of 45 seconds, 2250 steps at equal time intervals of 0.02 seconds.

Following the numerical analyses of the structural model, it was noticed that the effect of seismic actions was reduced for each accelerogram and the multi-stage isolation system can take over large displacements safely.

KEYWORDS: time-history analysis, artificial accelerogram, seismic base isolation, multi-stage system, elastomeric bearing with holes.

1. INTRODUCTION

In literature, many experimental tests regarding multilayer elastomeric bearings are presented (Barbat, et al., 1997), (Connor, 2002). These bearings have high vertical stiffness, a large deformation capacity and are stable. The main characteristic of the multilayer elastomeric bearings consists in obtaining a high isolation period compared to conventional bearings.

The multi-stage system design is more flexible compared to conventional bearings due to the possibility of choosing the bearing dimensions and the number of layers of the isolation system in order to take over the vertical force and to obtain the necessary horizontal frequency. The design displacement is equal to the product between the displacement of an elastomeric bearing and the number of layers (JNES-RC-2013-1002, 2014), (Murota, et al., 2005).

The aim of this paper is to determhine the dynamic characteristics of a base isolated structure with a system consisting of four layers of elastomeric bearings, at different seismic actions corresponding to three artificial accelerograms compatible with the elastic response spectrum for the horizontal components of ground acceleration, in areas characterized by the corner period T_c= 0.7 s, according to P100-2013.

2. EXPERIMENTAL MODEL

The experimental model has an opening of 1.4 m, a span of 1 m and a height of 1.5 m. The columns and the beams of the structure are made of INP 80 steel profiles. The steel type is S235JR. The structure is recessed at the base.

The base isolated structure will be unidirectional tested in the opening direction, on the shaking table of the Faculty of Civil Engineering and Building Services of Iasi, fig. 1.

Figure 1. The base isolated structure on the shaking table

The additional mass consists of concrete slabs with dimensions of 1500x700x100 mm, each of them having a weight of 360 kg.

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The multi-stage isolation system consists of a metal frame made of HEB 180 steel profiles, with a length of 150 cm respectively 121.5 cm in the other direction, fig. 2.

Figure 2. Multi-stage isolation system with elastomeric bearings

The seismic analysis of the structure was performed for the multi-stage system with elastomeric bearings with nine holes with a diameter of 20 mm. The bearing dimensions are shown in fig. 3.

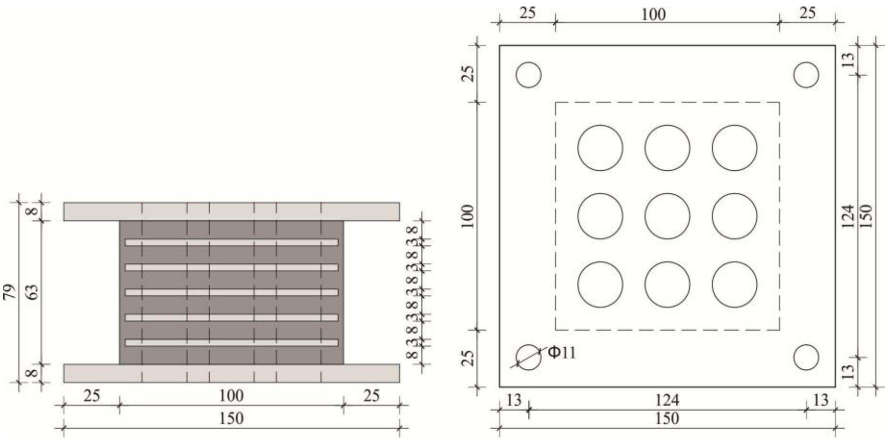

Figure 3. Elastomeric bearings with nine holes

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3. TIME-HISTORY ANALYSIS

Time-history analysis is to determine the accelerations and displacements recorded at the isolation system level and at the top of the structure and to evaluate the shear force recorded in the structural elements.

Time-history analysis helps to check and eventually to optimize the chosen bearings after the design process. Time-history for a seismic isolated structure can be achieved in any program that has implemented this type of analysis.

The artificial accelerograms were generated using the ANCO SPECTIME program. In the program, the target response spectrum, the fraction of critical damping ξ= 5 %, the duration and the time step that define the accelerogram were introduced.

The imposed elastic response spectrum (red color) and the resulted response spectrum (green color) can be seen in fig. 4

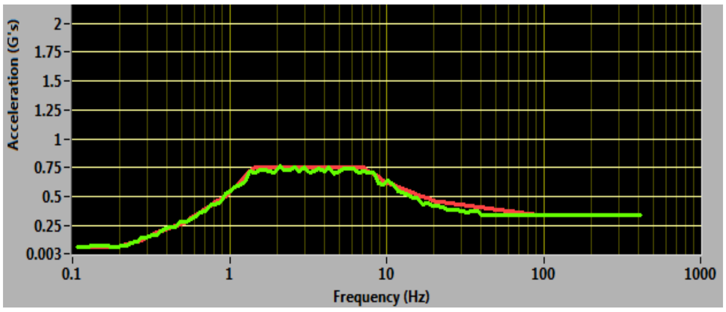

Figure 4. The imposed and resulted response spectrum

According to design standards, a minimum number of three accelerograms were imposed, figs. 5, 6, 7. The accelerograms are characterized by a peak ground acceleration of 0.3g, a duration of 45 seconds, 2250 steps at equal time intervals of 0.02 seconds.

The elastic response spectrum for the critical damping fraction of 0.05 was generated using the PRISM program.

Modal and time-history analyses of the structure were performed in SAP2000 program.

For the modal analysis, three concrete slabs on the top floor of the fixed base structure were considered. A fundamental vibration period of 0.2 seconds was obtained for the fixed base structure.

In the case of seismic isolation, an additional mass (four concrete slabs) was introduced at the base of the structure using beams of UNP 260 steel profiles.

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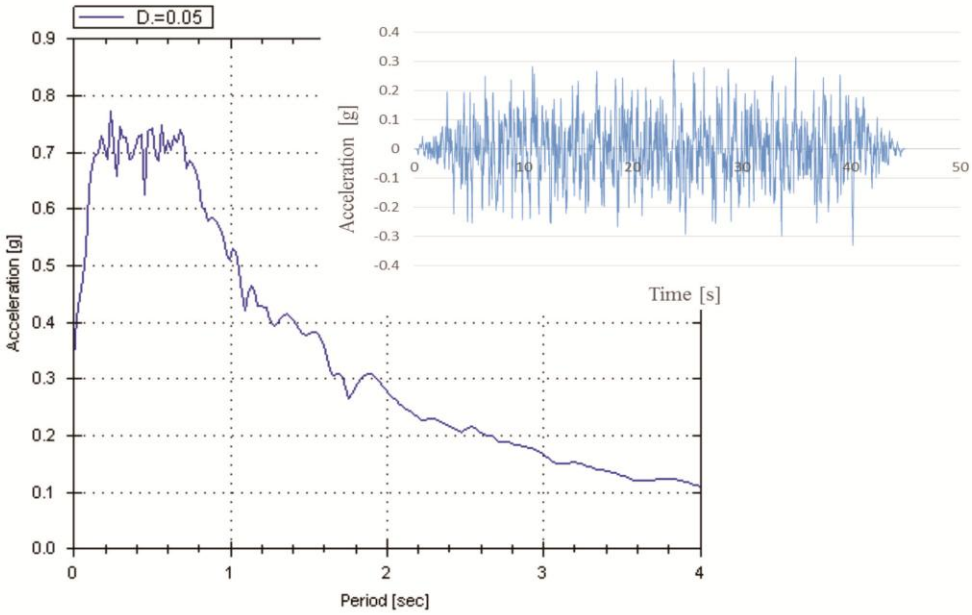

Figure 5. Artificial accelerogram 1 and the response spectrum

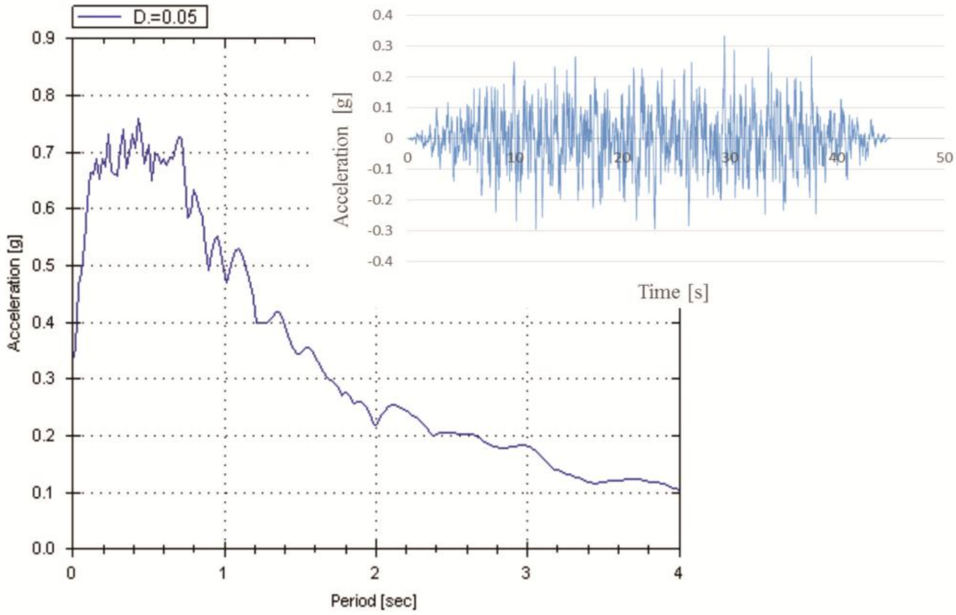

Figure 6. Artificial accelerogram 2 and the response spectrum

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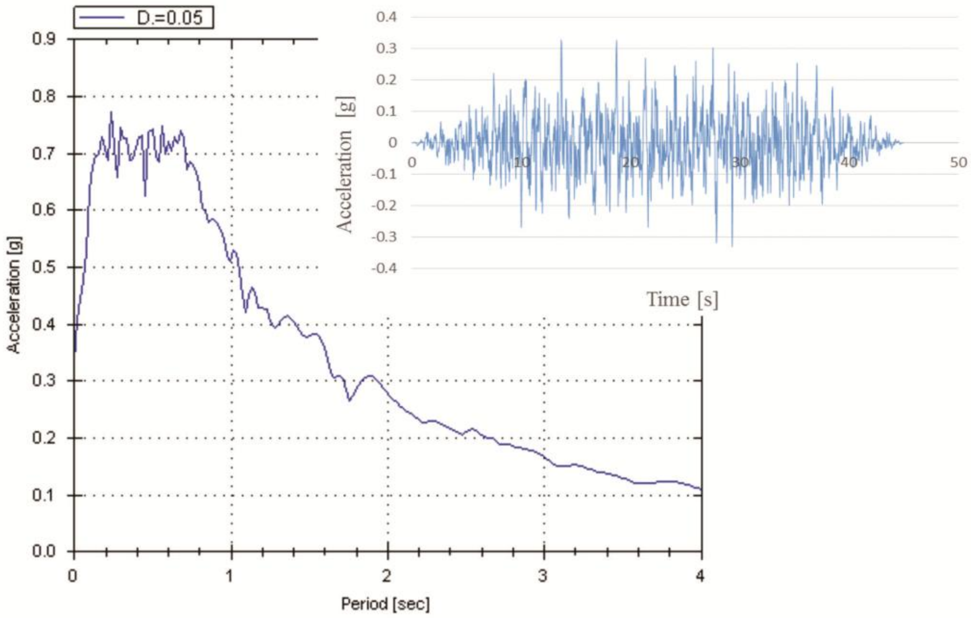

Figure 7. Artificial accelerogram 3 and the response spectrum

A multi-stage system was used for the seismic isolation of steel structure in order to obtain a high vibration period of the isolation system. The elastomeric bearings properties were defined with a Rubber Isolator link provided in SAP2000 program.

A fundamental vibration period of 2 seconds was obtained for the base isolated structure with multi-stage system made up four layers of elastomeric bearings with nine holes. The first three vibration modes of the base isolated structure are shown in fig. 8.

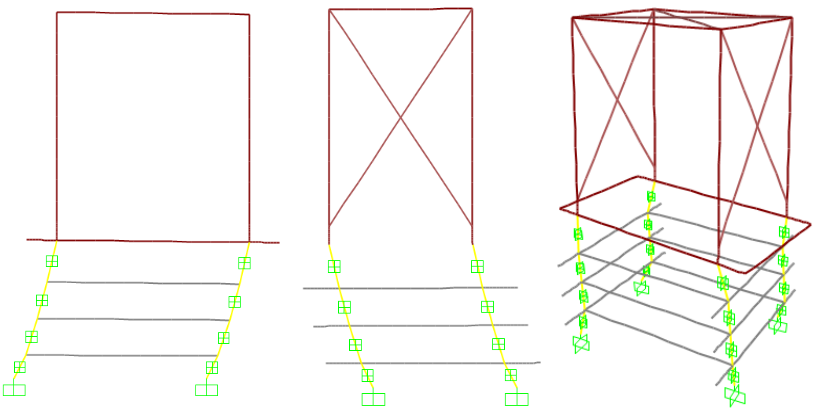

Figure 8. Vibration modes of the base isolated structure

The displacements and accelerations recorded at the top floor of the structure with fixed and isolated base, obtained for the artificial accelerogram 3, are presented in figs. 9 – 12.

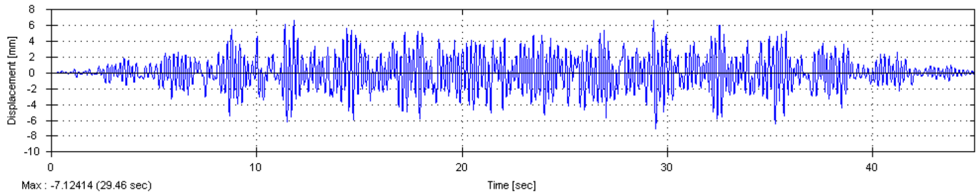

Figure 9. Displacements recorded at the top floor of the fixed base structure

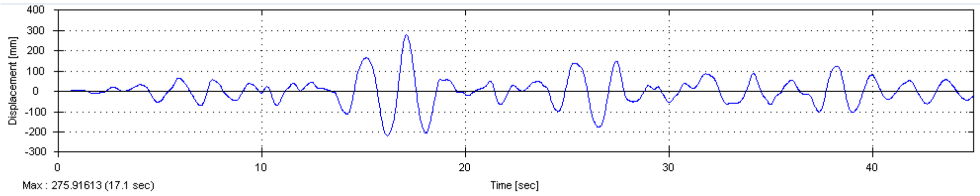

Figure 10. Displacements recorded at the top floor of the base isolated structure

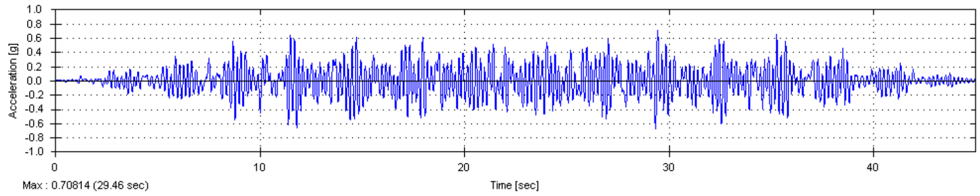

Figure 11. Accelerations recorded at the top floor of the fixed base structure

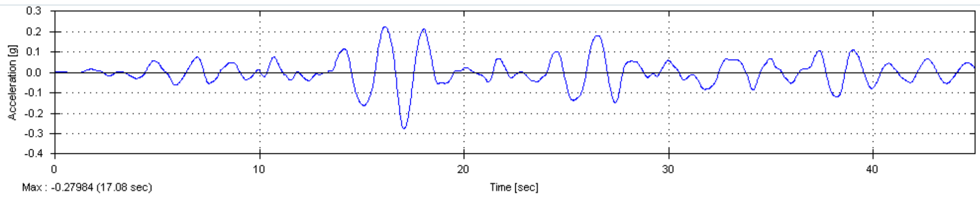

Figure 12. Accelerations recorded at the top floor of the base isolated structure

4. CONCLUSIONS

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The paper presents the determination of dynamic characteristics of a base isolated structure with multi-stage system, at different seismic actions.

The multi-stage isolation system was used in order to prevent the stability loss of elastomeric bearings at large displacements and to make the system more flexible.

Three artificial accelerograms compatible with the elastic response spectrum for the horizontal components of ground acceleration, in areas characterized by the corner period T_c= 0.7 s, were generated.

Following the numerical analyses of the structural model, the accelerations recorded at the top of the fixed and isolated base structure were compared. In the seismic isolation case, the values of accelerations resulted by 2.5 times lower for accelerograms 1, 3 and 3 times lower for accelerograms 3.

The displacement and acceleration values at each level of the seismic isolated structure resulted approximately equal, the structure having a rigid body displacement.

In the case of base isolated structure with multi-stage system with four layers of bearings, a vibration period of ten times higher was obtained compared to the fixed base structure.

Considering the obtained results, the multi-stage isolation system can take over large displacements safely and is stable compared with the classical system.

References

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