BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LXI (LXV), Fasc. 3, 2015
Secţia
CONSTRUCŢII. ARHITECTURĂ

SHAKING TABLE TESTS OF A BASE ISOLATED STRUCTURE WITH MULTI-STAGE SYSTEM

BY

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Received: July 14, 2015
Accepted for publication: July 28, 2015

Abstract. The paper presents a series of experimental tests on ANCO R250-3123 shaking table from the Faculty of Civil Engineering and Building Services of Iaşi, in order to identify the structural response of a base isolated model with a multi-stage system made of four layers of elastomeric bearings.

In the first phase of the experimental program, the dynamic characteristics of the structural model were determined and in the second phase the behaviour under different seismic actions of the base isolated structure with multi-stage system was evaluated. Three sinus beat actions and an artificial accelerogram were applied in the longitudinal direction of the experimental model.

Following the results interpretation, a significant reduction of accelerations recorded at the top of the structure was achieved compared with the maximum acceleration recorded at the platform level.

The experimental model behaved like a rigid body (the displacement values from the top and the bottom of the structure are approximately equal).

Key words: seismic base isolation; multi-stage system; shaking table; sinus beat action; artificial accelerogram.

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1. Introduction

In recent years, many strong earthquakes have caused numerous economic disasters and life losses (Aslani & Miranda, 2005), which determined the search for new solutions regarding the increase of safety to seismic actions of the buildings.

One of the effective solutions that protect the building, its inhabitants and the material goods, consists in decoupling the structure of the ground by mounting some bearings between the building and its foundation (Rai, 2000), so that the horizontal components of movement induced by earthquake to be limited to the maximum.

The balancing phenomenon of the structure on bearings during an earthquake and the loss of stability of bearings under large horizontal displacements should be avoided when the seismic base isolation system is implemented.

The multi-stage isolation system can be used to avoid the loss of stability of elastomeric bearings under large horizontal displacements (Barbat & Bozzo, 1997; Connor, 2002; Murota *et al*., 2005).

The aim of this paper is to study the behaviour under different seismic actions of a base isolated structure with multi-stage system. The multi-stage isolation system with elastomeric bearings was used to make the experimental model to be more flexible considering that the elastomeric bearings have high horizontal stiffness.

2. Structural Model

The model is a steel structure with 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 steel profiles, Fig. 1.

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.

The elastomeric bearings have 100x100 mm plane dimensions and a height of 79 mm. They have nine holes with diameters of 20 mm and the hardness of the elastomer is 60 Sh A.

The additional mass consists of three concrete slabs at the top of the structure and four concrete slabs at the base of the structure, each of them having a weight of 360 kg.

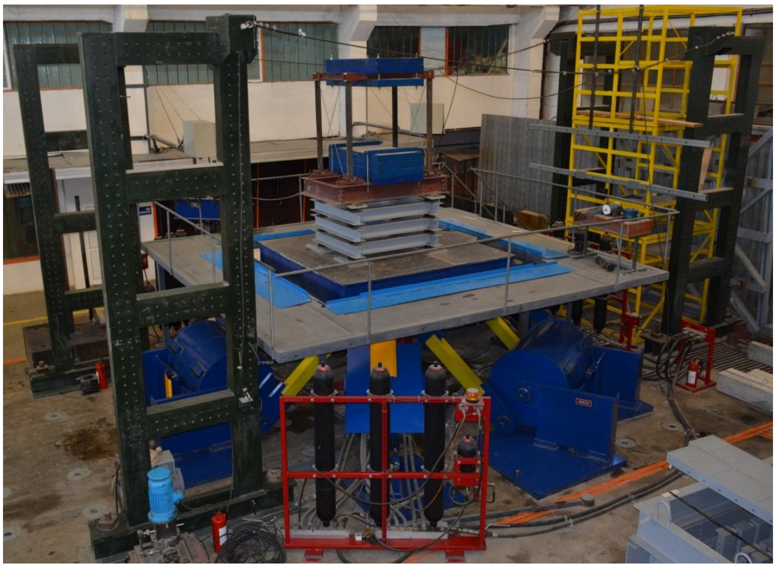

Fig. 1 – The experimental model on the shaking table.

It was used a number of three displacements transducers (D0,...,D2) mounted on a fixed frame and three accelerometers (A0,...,A2) mounted on the base isolated model with multi-stage system composed of four layers of elastomeric bearings, Fig. 2.

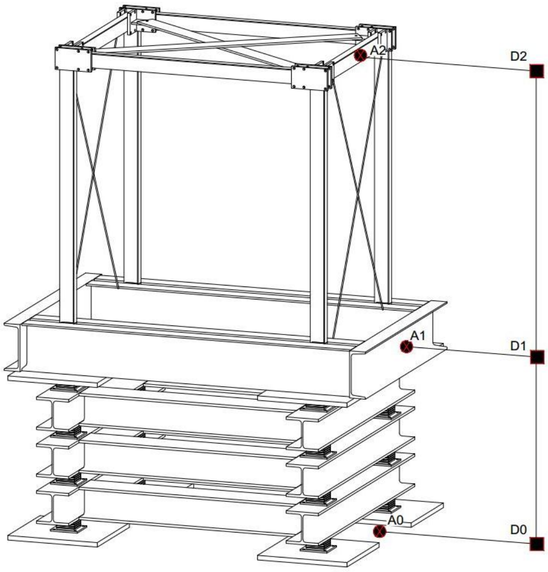

Fig. 2 – The mounting of transducers and accelerometers.

3. The Experimental Program

Prior to the dynamic tests, a series of calibrations of the equipment and shaking table were carried out.

The experimental data, regarding the action and the response of the structure, were obtained using PT5AV transducers with a recording capacity of ±0.5 m and Dytran 3202A1 LIVM accelerometers with a recording capacity of ±10 g.

In the first phase of the experimental program, a signal, a broadband sinus action between 5 and 50 Hz was introduced using a vibration generator in order to determine the dynamic characteristics of the structure.

After processing the experimental data with the ESAM program, a natural frequency of 5 Hz was obtained in the longitudinal direction of the fixed base structure, which corresponds to a fundamental natural period of vibration of 0.2 s.

In the case of the base isolated structure with multi-stage system, a sinus beat action of 5 Hz was introduced and a natural frequency of 0.965 Hz was obtained in the longitudinal direction, of 0.84 Hz in the transverse direction and of 4.4 Hz in the vertical direction of the model. Therefore the vibration periods of the structural model are equal to 1.04 s in the *x* direction, 1.19 s in the *y* direction and 0.22 s in the z direction.

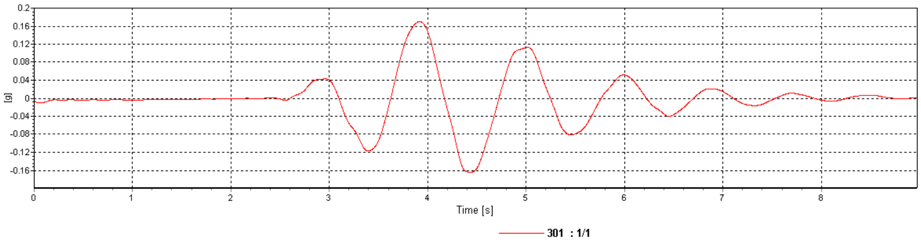

Fig. 3 – The response in time of the action in the *x* direction.

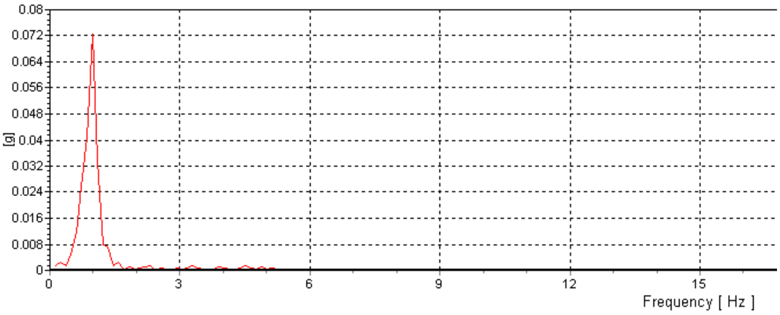

Fig. 4 – The Fourier spectrum of the action in the *x* direction.

The data were processed with a filter in order to reduce the errors that can occur due to parasitic vibrations (the filtration of the signal noise). The response in time of the action in the *x* direction and the Fourier spectrum are shown in Fig. 3 and 4.

In the second phase, a series of experimental tests were carried out on the shaking table. Sinus beat actions and an artificial accelerogram were applied in the longitudinal direction of the experimental model (the *x* direction of the shaking table):

– a sinus beat action with a frequency of 10 Hz and a maximum acceleration of 0.5 g (test 1);

– a sinus beat action with a frequency of 10 Hz and a maximum acceleration of 0.6 g (test 2);

– a sinus beat action with a frequency of 10 Hz and a maximum acceleration of 0.8 g (test 3);

– an artificial accelerogram with a maximum acceleration equal to 2.5 g (test 4).

The action and the response in accelerations and displacements of the model, recorded at each accelerometer and displacement transducer for test 4, are shown in Figs. 5,...,10.

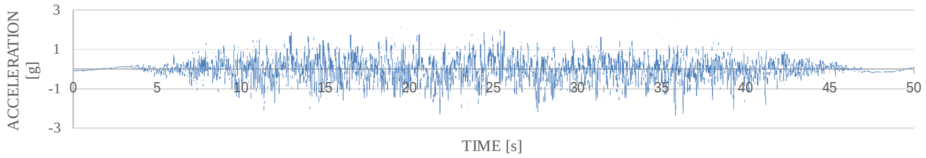

Fig. 5 – The accelerogram recorded at the platform level (A_0).

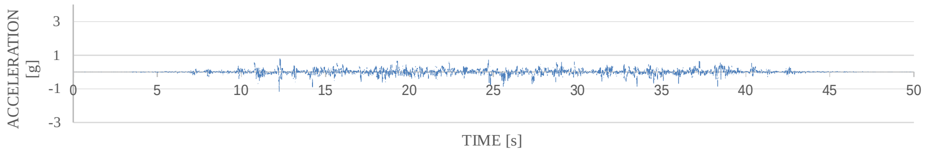

Fig. 6 – The response accelerogram at the base of the model (A_1).

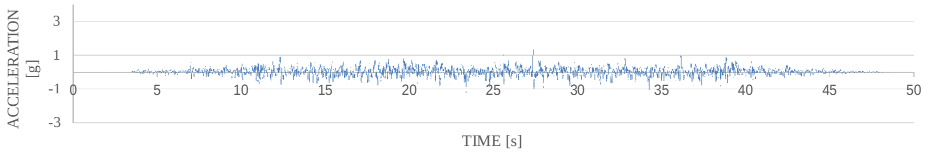

Fig. 7 – The response accelerogram at the top of the model (A_2).

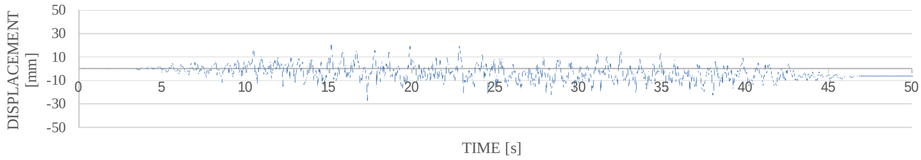

Fig. 8 – Displacements recorded at the platform level (D_0).

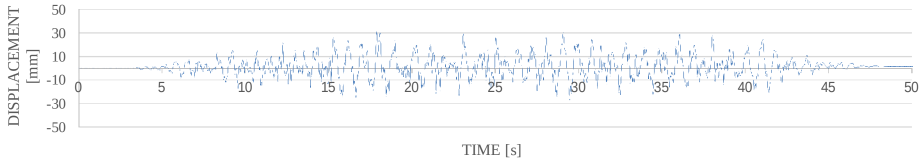

Fig. 9 – Displacements recorded at the base of the model (D_1).

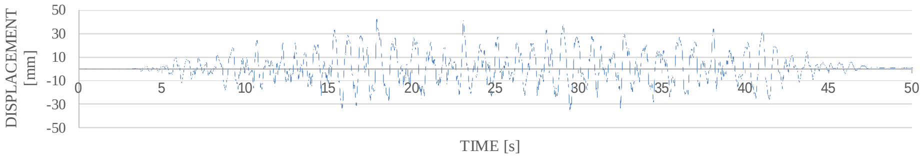

Fig. 10 – Displacements recorded at the top of the model (D_2).

The values of the maximum accelerations (PGA) and displacements (PGD), recorded at the platform level, at the base and top of the structural model during the four tests, are shown in Figs. 11,...,14.

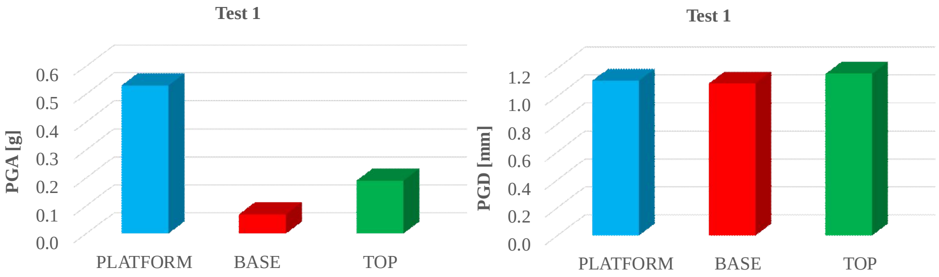

Fig. 11 – The peak values of accelerations and displacements, test 1.

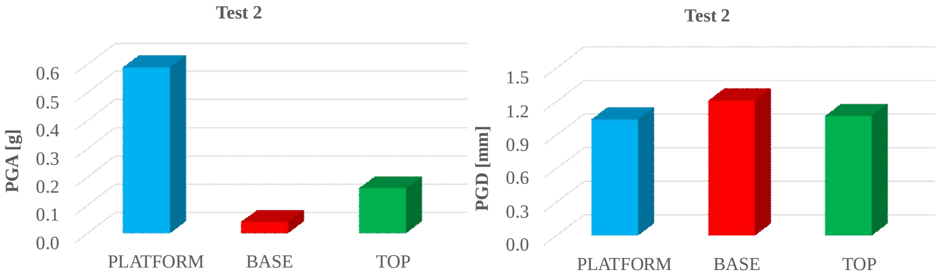

Fig. 12 – The peak values of accelerations and displacements, test 2.

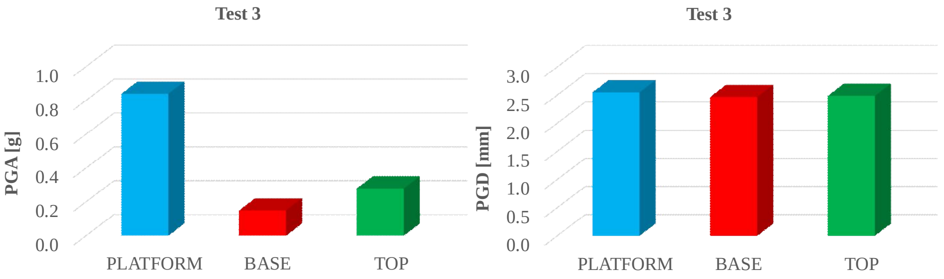

Fig. 13 – The peak values of accelerations and displacements, test 3.

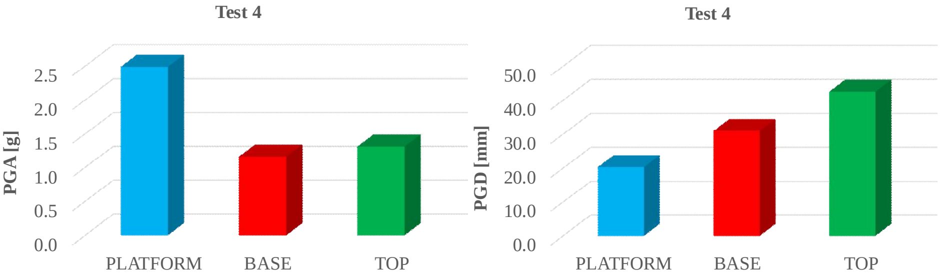

Fig. 14 – The peak values of accelerations and displacements, test 4.

4. Conclusions

Following the experimental tests, a significant reduction of accelerations recorded at the top of the structure was achieved compared with the maximum acceleration recorded at the platform level. The peak acceleration is about three times lower in the case of test 1, approximately four times lower for test 2, three times lower for test 3 and twice times lower for test 4.

The experimental model behaved like a rigid body (the displacement values from the top and the bottom of the structure are approximately equal) and the structure did not show degradation, even during severe action with PGA equal to 2.5 g.

In conclusion, the solution of the multi-stage isolation system can successufully replace the classic isolation system, especially under high stiffeness conditions of the bearings. Through this isolation system, the loss of stability of the elastomeric bearings is avoided and an increase in the operational safety of the structures subjected to seismic actions is obtained.

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ÎNCERCAREA PE PLATFORMA SEISMICĂ A UNEI STRUCTURI CU BAZA IZOLATĂ CU SISTEM MULTISTRAT

(Rezumat)

Se prezintă o serie de teste experimentale pe platforma seismică ANCO R250-3123 din cadrul Facultății de Construcții şi Instalații din Iaşi, în vederea identificării răspunsului structural al unui model cu baza izolată cu sistem multistrat alcătuit din patru straturi de reazeme din elastomeri.

În prima etapă a programului experimental, au fost determinate caracteristicile dinamice ale modelului structural şi în a doua etapă a fost evaluat modul de comportare la diferite acțiuni seismice a structurii cu baza izolată seismic cu sistem multistrat. Au fost aplicate trei acțiuni sinus beat şi o accelerogramă artificială, pe direcția longitudinală a modelului experimental.

În urma interpretării rezultatelor, s-a obținut o reducere semnificativă a accelerațiilor înregistrate la vârful structurii comparativ cu accelerația maximă înregistrată la nivelul platformei.

Modelul experimental s-a comportat ca un corp rigid (valorile deplasărilor de la baza şi vârful structurii sunt aproximativ egale).