Shaking table experimental study on the effectiveness of polymer bearings for seismic isolation of structures

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Seismic isolation has been recognised to be a very effective way of protecting structures from damage during earthquakes. It allows us to extend the natural period of the structure and therefore avoid resonance with the ground motion. Moreover, by increasing damping in the isolation devices, more energy can be dissipated and thus the structural response can be further reduced. The aim of this paper is to show the results of the study focused on verification of the applicability of the innovative method of seismic isolation by installing bearings made of a polymer mass, which is an especially designed flexible elastoplastic two-component grout based on polyurethane resin. In the study, a model structure was tested experimentally on a shaking table under earthquake excitation. First, the structure was fixed directly to the table and its response was recorded. Then, the response of the structure with polymer bearings installed at its base was observed and both responses were compared. The results of the study show that equipping the structure with the polymer bearings can considerably reduce the structural response under earthquake excitation. The innovative method considered in the study has been verified to be an effective seismic isolation technique.

1 Introduction

There are a number of different ways of protecting structures from damage during earthquakes. One of the most effective methods is to use the seismic isolation [1]. It allows us to extend the natural period of the structure and therefore avoid resonance with the ground motion. Moreover, by increasing damping in the isolation devices, more energy can be dissipated and thus the structural response can be further reduced [2].

In the practical applications, the base isolation is usually introduced in the form of bearings installed at the base of the structure [3]. The idea behind designing such bearings is to make them flexible enough in the horizontal direction, while keeping their high vertical stiffness. Without significant lateral forces bearings should act as a normal fixed support. When the earthquake comes, and the lateral forces occur, bearing ought to move horizontally without a decrease in vertical stiffness. Such behaviour ensures that the displacements at the top of the structure are similar as the base displacements what minimizes structural damage.

The aim of this paper is to show the results of the experimental study focused on verification of the applicability of the innovative method of seismic isolation by installing bearings made of a polymer mass. The polymer mass considered in the study is a new flexible material in the form of elastoplastic two-component grout based on polyurethane resin (see [4,5] for details).

Fig. 1 Setup of the experiment.

2 Experimental setup

A small shaking table was used in the experimental study focused on the effectiveness of the polymer bearings. It is a unidirectional device with the platform dimensions of 0.75×0.6 m excited by the linear actuator PARKER ET50 with the stroke of 0.5 m and maximum acceleration of 10 m/s^2. A 1 m high model tower was built to be tested during the experiment. It was constructed from four steel columns of the rectangular cross section of 8×8 mm with the mid-height horizontal connections and

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additional skew bracings to prevent transverse as well as torsional vibrations. The columns were arranged in a rectangular pattern with a spacing of 0.22 m along the shaking direction and a spacing of 0.3 m along the orthogonal direction. The mass of the supporting columns was 3.864 kg. There were also two additional plates mounted on the top (mass 9.485 kg) and at the base (mass 18.337 kg) of the structure. The laser displacement meter was used to measure the response time history during the earthquake. The setup of the experiment is shown in Fig. 1.

3 Results of the study

The experimental study was conducted under the scaled NS component of the El Centro earthquake (18 May 1940). The experiment had two phases. First, the structure was fixed directly to the table and its response was recorded. Then, the response of the structure with polymer bearings installed at its base (see Fig. 1) was investigated. The bearings used in the study were of cylindrical shape with the height of 28 mm and the diameter of 15 mm. The displacement time histories of the fixed-base structure as well as the structure with polymer bearings installed at its base are presented in Fig. 2a and 2b, respectively. The comparison between the figures shows that the use of polymer bearings results in suppressing the structural vibrations of the top of the tower during the earthquake. It can also be seen from the figures that the peak relative displacement (difference between the top and the base displacement) is considerably reduced for the isolated structure. In fact, the value of the peak relative displacement for the fixed structure has been found to be equal 12.1 mm, whereas the peak relative displacement for the isolated structure reached 9.9 mm (reduction by 18.2%).

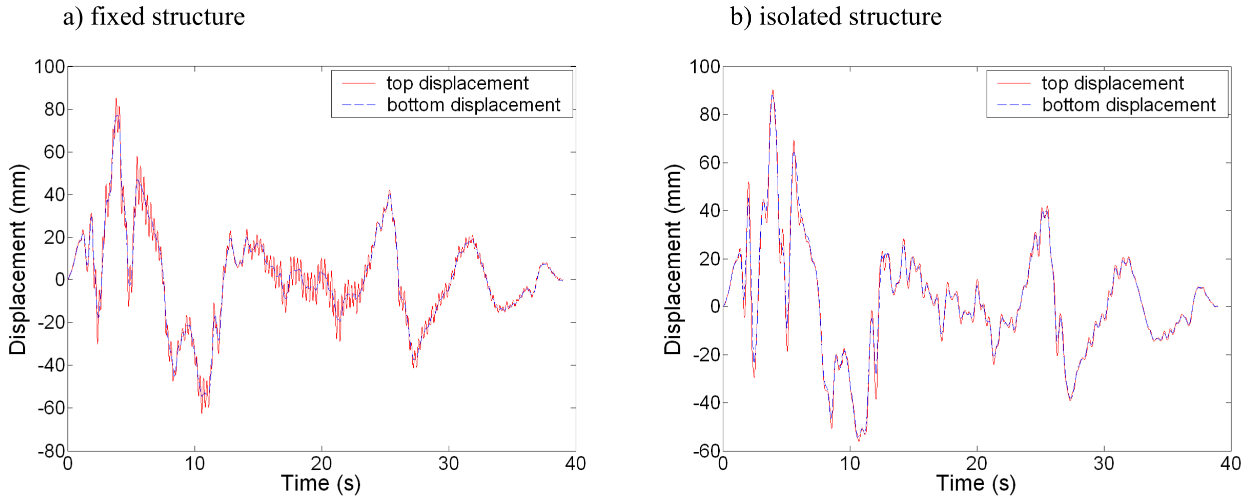

Fig. 2 Displacement time histories of the tower under the El Centro earthquake.

4 Conclusions

The experimental investigation focused on verification of the applicability of the innovative method of seismic isolation by installing bearings made of a polymer mass has been carried out in this paper. The results of the study show that the use of polymer bearings leads to the suppression of vibrations and substantial reduction of the structural response. In the case of the analysed structure, the reduction in the peak relative displacement was as high as 18.2%. The results of the experimental study indicate that the innovative method of using polymer mass for bearings can be considered as a promising seismic isolation technique.

The experiment described in this paper was performed on relatively small structural model. Therefore, further experimental studies are required on full scale models of real structures in order to verify the results obtained.

References

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