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Experimental study on the behaviour of steel columns under seismic-induced axial impact load

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It has been observed during major earthquakes that the so called soft-storey failure of an upper floor of a structure results in large impact load acting on structural members of the lower storeys. It may further lead to progressive collapse of the whole structure substantially intensifying human and material losses. Therefore, the aim of this paper is to investigate experimentally the behaviour of columns under bending (observed during an earthquake) that are additionally subjected to an axial plastic impact load. Steel columns with high slenderness ratio were considered in the study. In the experiment, impact load was created by a weight that was dropped onto the top of the column and stayed on it. The weight with the shape of a ball was made of clay so as to simulate more plastic impact. The results of the experiment show that the value of the permanent horizontal deformation of the column observed after impact depends much on the initial relative displacement between the base and the top of the column. As the initial displacement increases the values of the permanent deformation increases significantly indicating the significant reduction in the critical buckling force. The results obtained in the study can be utilized at the design stage of the structures in order to enhance their seismic resistance.

1 Introduction

The so called soft-storey failure is one of the most typical types of damage observed in buildings as the result of earthquake excitation. During the Hyougoken-Nanbu (Kobe) earthquake of 1995, for example, most of the damaged buildings experienced failure of the first or intermediate storey due to the lack of lateral strength and ductility of columns [1]. The soft-storey failure was also very common during the south east Asia earthquake of 2004 causing major damage in downtown of Banda Aceh [2]. It has been observed during the earthquakes that the failure of an upper soft storey of a structure results in large impact load acting on the lower floors. If the resistance of the structural members of the lower storeys is not sufficient it may further lead to progressive collapse of the whole building substantially intensifying human and material losses.

The study on earthquake-induced impact has been carried out in earthquake engineering for several years now. The previous research, however, was focused on the phenomenon of horizontal structural interactions between insufficiently separated structures, which is referred in the literature as the earthquake-induced structural pounding (see [3-5] for example). According to the authors' knowledge, impact between the damaged upper part of the building falling onto the lower storeys after the soft-storey collapse has not been studied so far.

Therefore, the aim of the present paper is to investigate experimentally the dynamic buckling behaviour of columns under bending (observed during the earthquake) that are additionally subjected to an axial plastic impact load. Steel columns with high slenderness ratio were considered in the study. In the experiment, impact load was created by a weight that was dropped onto the top of the column and stayed on it after collision so as to simulate the real situation, which takes place during the earthquake.

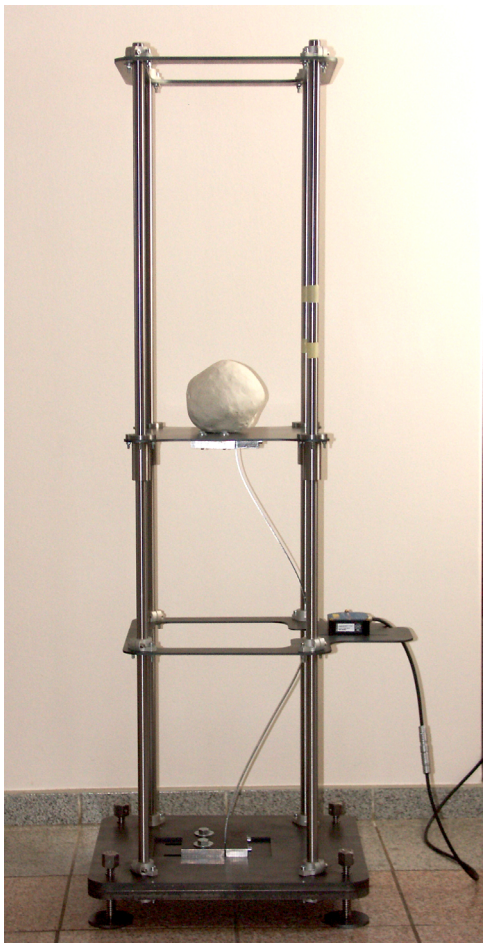

Fig. 1 Setup of the experiment.

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2 Experimental setup

A stand structure (see Fig. 1) was constructed for the purposes of the experimental study. It consisted of a thick steel plate at the bottom, to which four steel rods were mounted. Four precision shafts were used for these rods. A platform moving along the rods was installed using four linear bearings. A number of steel columns, with the length of 800 mm and cross section of 2×20 mm, were prepared to be tested experimentally. Each column specimen was mounted in fixed supports located at the bottom and at the moving platform (see Fig. 1). The critical load of the specimen was analytically calculated as equal to 168.6 N; however, the actual critical load was experimentally estimated at about 150 N. The mass of the platform was 6 kg. During the experiment, a ball made of modelling clay with a mass of 2 kg was dropped from a specified height onto the top platform. The drop height, H, was equal to 50 mm and 100 mm. Before, during and after the impact, the horizontal displacement of the specimen was measured at its mid-height using the laser displacement meter (see Fig. 1) and the peak values were recorded. In order to investigate the buckling behaviour of the columns under bending (observed during an earthquake), the initial relative displacement (pre-deflection Δ) was introduced between the base and the top of the column by moving the bottom support horizontally. In the first stage of the experiment, the straight columns were tested. Then, the pre-deflection was uniformly increased each time by 20 mm up to 60 mm.

3 Results of the study

The experimental study was conducted for two different values of the drop height, H, and for four values of the initial relative displacement between the base and the top of the columns (pre-deflection), Δ. The examples of the results of the study are shown in Fig. 2. The graph presents the value of the permanent horizontal displacement of the column after impact (related to the critical buckling force) with respect to its pre-deflection, Δ. It can be seen from the figure that with the increase of the pre-deflection, the values of the permanent deformation increases significantly, especially for the larger drop height.

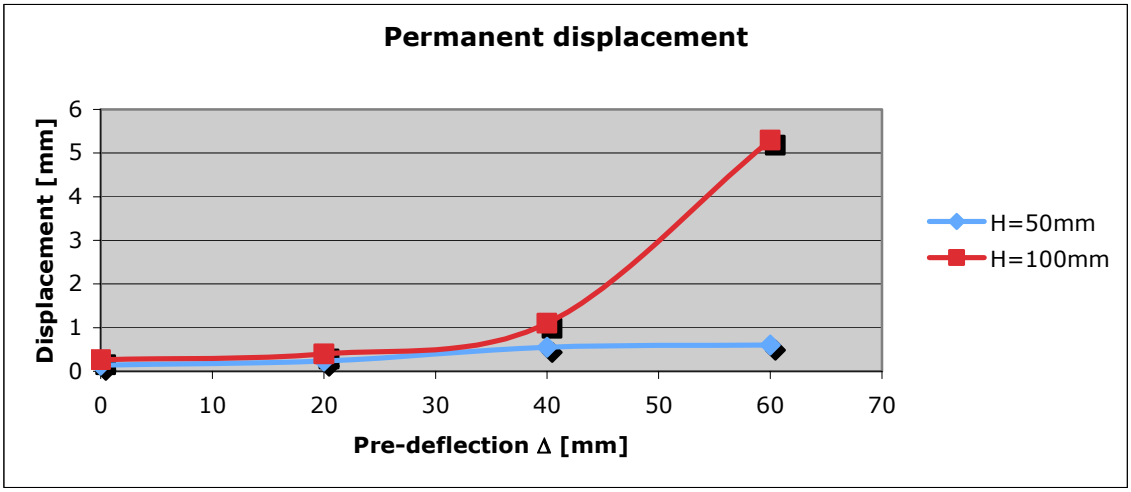

Fig. 2 Permanent horizontal displacement of the column after impact with respect to pre-deflection, Δ.

4 Concluding remarks

The experimental study focused on dynamic buckling behaviour of steel columns under bending, that are additionally subjected to an axial plastic impact load, was presented in this paper. The results of the experiment show that the value of the permanent horizontal deformation of the column observed after impact depends much on the initial relative displacement between the base and the top of the column. As the initial displacement increases the values of the permanent deformation increases significantly indicating the significant reduction in the critical buckling force.

The experiment described in this paper was performed on relatively small column models. Therefore, further experimental studies are required on larger structural models in order to verify the results obtained.

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