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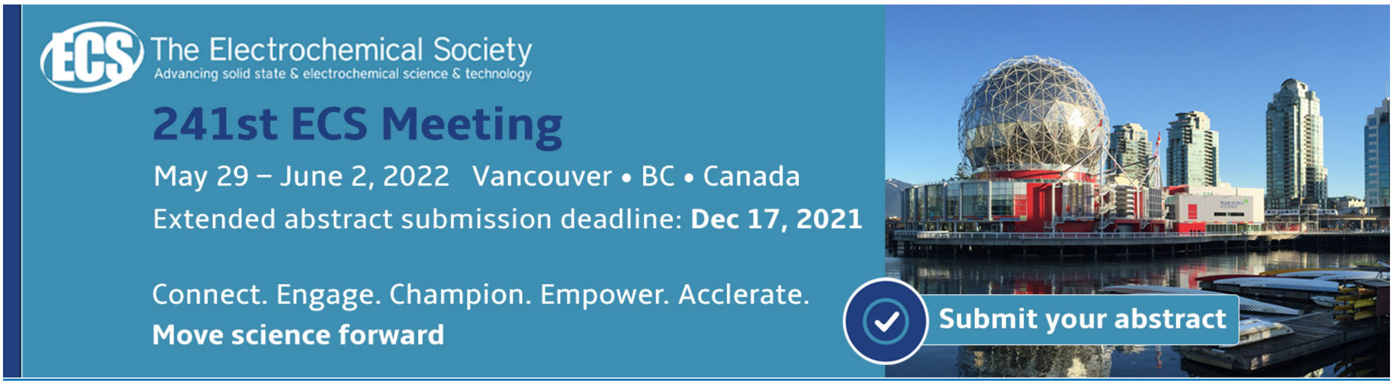

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Experimental analysis of the behaviour of different types of joints in the steel structure model subjected to earthquake loading

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Abstract. The present paper reports the results of the experimental study performed to investigate the behaviour of two different types of joints (destroyed and welded ones) in the model of the steel structure under seismic excitations. The structure was subjected to three earthquakes, namely Kobe, Loma Prieta and Northridge, using the shaking table investigation. The results obtained from the study indicate that there is a significant difference between the behaviour of destroyed joints and welded ones. It was concluded that the destroyed joints experience higher acceleration than the welded joints during different earthquakes.

Keywords: Destroyed joints, welded joints, steel structure, accelerations, earthquakes, shaking table tests

1. Introduction

Earthquakes, which are caused by a sudden release of stress along faults in the earth's crust, are claimed to be one of the most dangerous natural disasters. They may have a lot of destructive effects, including the collapse of roads and infrastructure as well as turning soil to liquid or causing landslides. With regard to buildings, one of the threats during earthquakes is the phenomenon of pounding, which results in collisions between adjacent buildings (see, for example, Mahmoud, Chen & Jankowski, 2008; Sołtysik, Falborski & Jankowski, 2016; 2017; Miari, Choong & Jankowski, 2019; Naderpour, Naji, Burkacki & Jankowski, 2019; Miari, Choong & Jankowski, 2020). The Kobe (1995), Loma Prieta (1989) and Northridge (1994) earthquakes are among the most destructive earthquakes over the past years. Taking into account their far-reaching consequences, strong ground motions have become a major concern for many scientists. Thus, the methods for decreasing the earthquakes' devastating effects have been sought by the researchers for many years. The most frequently used approach concerns the shaking table testing (see, for example, Falborski & Jankowski, 2013; 2017; 2018). It enables us to simulate the earthquake forces and analyze them. Due to this, the dynamics of building structures as well as joints are scrutinised, which helps to enhance their safety and reliability.

In the applicable standards for design of steel structures, joints are classified according to their stiffness and strength. Due to the rotational stiffness, joints are divided into rigid, classic pinned and semi-rigid. The behaviour of joints influences the distribution of internal forces and the deformation of the structure, the size of the critical and boundary load and the dynamic characteristics of the structure. In the case of systems with semi-rigid joints, the impact can be significant (see, for example, Reyes-Salazar & Haldar, 1999; Baniotopoulos & Wald, 2000; Ricles, Fisher, Lu L-W & Kaufmann, 2002;

Rassati, Leon & Noe, 2004; Radaj, Sonsino & Fricke, 2006; Diaz, Marti, Victoria & Querin, 2011; Trahair N. S, 2012).

The main objective of the present paper is to analyse the behaviour of two different types of joints (destroyed and welded ones) in the model of the steel structure exposed to seismic excitations. In order to achieve this aim, the shaking table investigation was performed, where three major earthquakes, namely Kobe (1995), Loma Prieta (1989) and Northridge (1994), were applied.

2. Experimental model

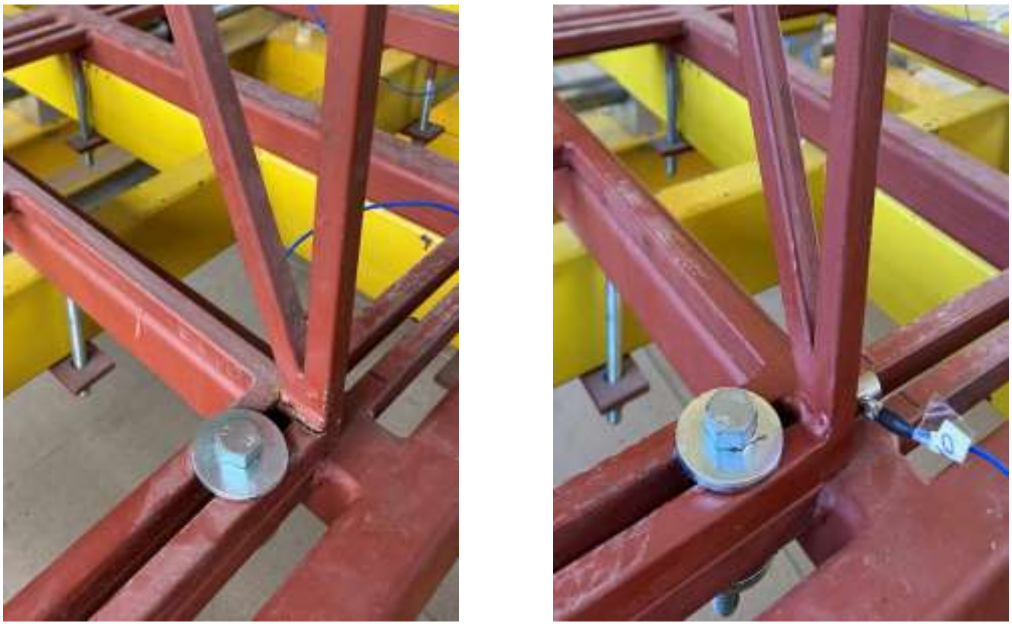
In order to conduct the experimental study, one single-storey steel structure, was employed (see Figure 1). The structure was composed of rectangular elements made of hollow section elements (RHS 15×15×1.5 mm). With regard to columns, they were set on a rectangular plan. The spacing in the transverse direction was 0.556 m and 0.465 m in the longitudinal direction. The height of the steel structure was 1.20 m.

Diagonal bracings, which were responsible for counteracting transverse and torsional vibrations, were employed in the planes of the sidewalls. Concrete plate (50×50×7 cm) was used to simulate the weight of the floor. The weight of the concrete slab was 47.56 kg.

Moreover, a number of sensors were applied in the experimental tests. They were located at the bottom of the steel structure (one sensor on the destroyed part and the second one on the welded one) (see Figure 2). They enabled us to measure the acceleration of the structure at the joints.

All the elements were placed on a middle-sized shaking table located at Gdańsk University of Technology, Poland. Three earthquakes, namely Kobe (1995), Loma Prieta (1989) and Northridge (1994) were simulated (see Table 1), and the seismic response of the experimental model to these ground motions was investigated. Firstly, free vibration tests were carried out, which enabled us to determine the dynamic characteristics of the experimental model (see Falborski & Jankowski, 2017). The fundamental frequency of the structure was found to be 3.31 Hz and the damping ratio was calculated as equal to 0.53%.

Figure 1. Experimental model of steel structure used in the study.



a) Destroyed joint b) Welded joint

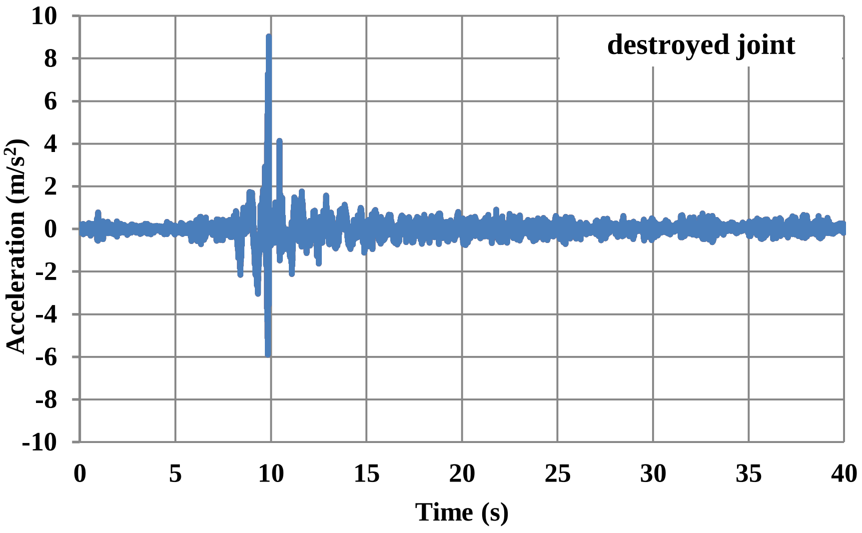
Figure 2. Different types of joints.

Table 1. Ground motions used in this study.

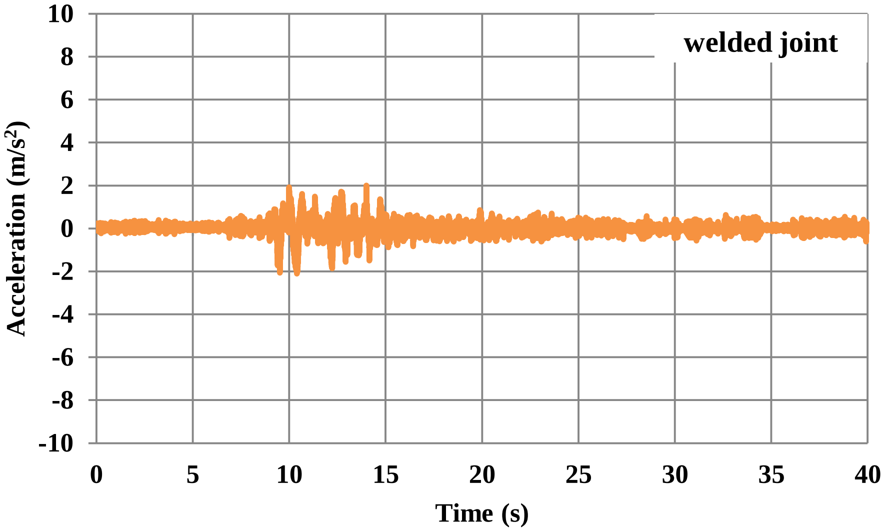
Earthquake	PGA (m/s^2)	Station	Year
Kobe	2.014	JMA	1995
Loma Prieta	3.158	Corralitos	1989
Northridge	4.332	Santa Monica	1994

3. Results and discussion

The behaviour of both destroyed and welded joints for a single-storey steel structure model is presented and discussed in this section. The acceleration time histories at the joints (destroyed and welded) for the model exposed to the Kobe, Loma Prieta and Northridge earthquake are shown in Figures 3, 4, and 5, respectively. Additionally, the peak accelerations at the joints (destroyed and welded) for the model exposed to the Kobe, Loma Prieta and Northridge earthquakes are presented in Table 2. It can be clearly seen that, for the three earthquakes, the destroyed joints had higher acceleration values and higher response than the welded ones. The maximum percentage difference between the peak accelerations at the destroyed and welded joints was found to be as large as 77.96%.

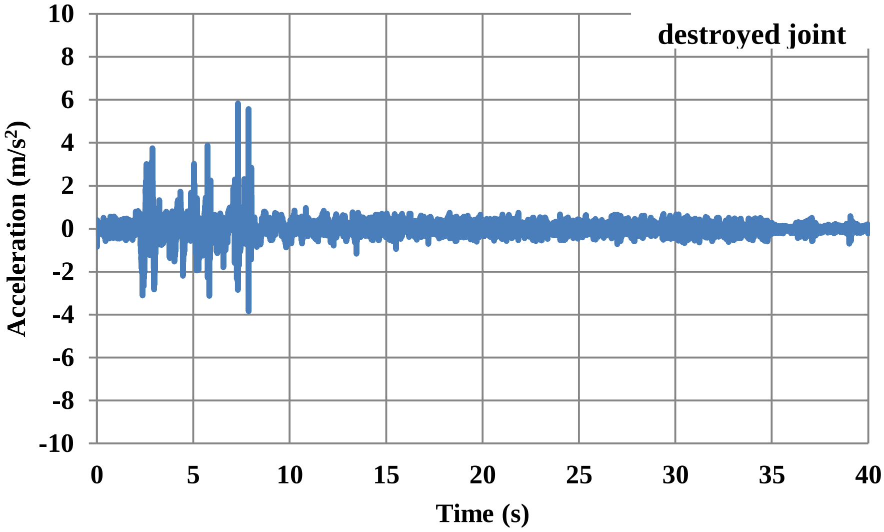


(a) Destroyed joint

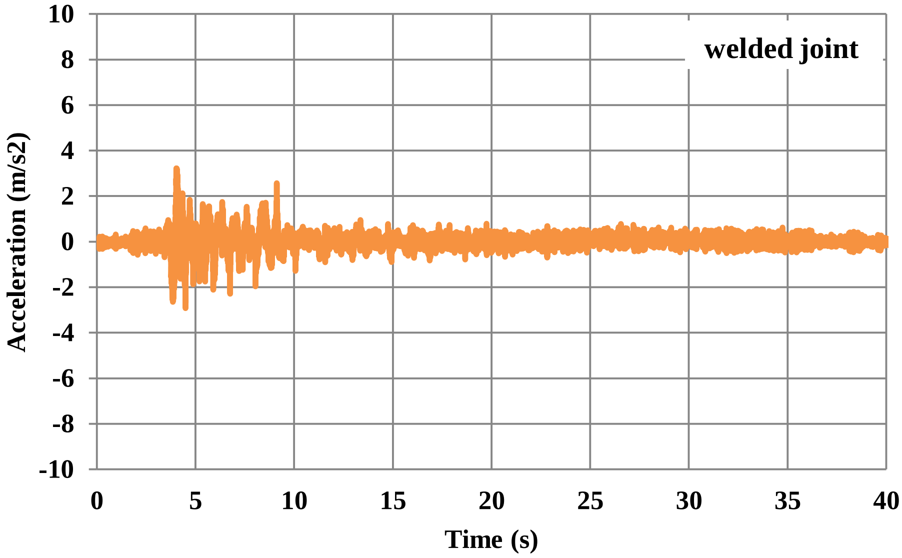


(b) Welded joint

Figure 3. Acceleration time history at the joint of the steel structure model under the Kobe earthquake.

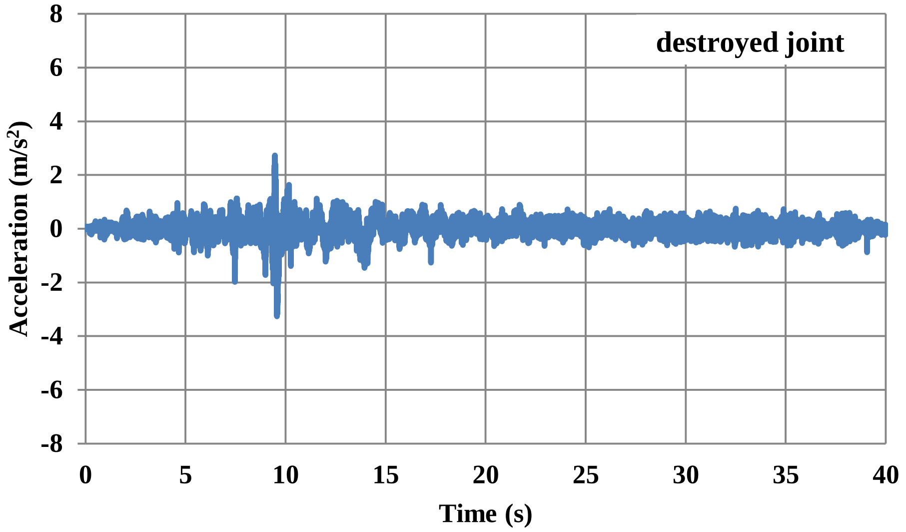


(a) Destroyed joint

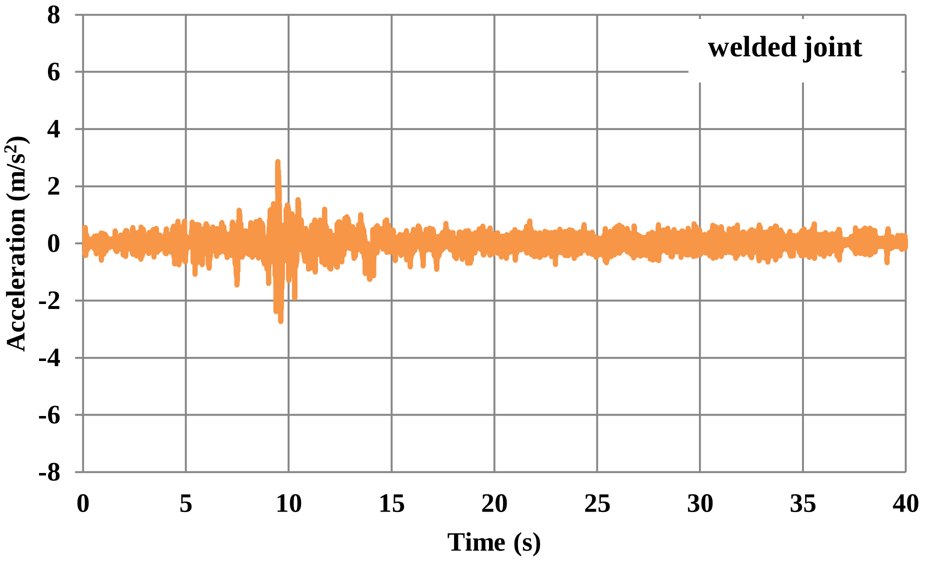


(b) Welded joint

Figure 4. Acceleration time history at the joint of the steel structure model under the Loma Prieta earthquake.



(a) Destroyed joint



(b) Welded joint

Figure 5. Acceleration time history at the joint of the steel structure model under the Northridge earthquake.

Table 2. Peak acceleration at the joints of the steel structure model under the Kobe, Loma Prieta and Northridge earthquakes.

Seismic excitation	**Peak acceleration at the joint of the steel structure model (m/s^2)**		**Percentage difference**
	Destroyed joint	Welded joint	
Kobe	9.03	1.99	77.96%
Loma Prieta	5.83	3.67	37.05%
Northridge	3.26	2.87	11.96%

4. Conclusions

This paper investigated the behaviour of destroyed and welded joints in the model of the steel structure under different earthquakes. A single-storey steel structure model was used in the study. In order to analyze the behaviour of joints, three earthquakes (Kobe, Loma Prieta and Northridge) were applied using the shaking table. The results of the experimental study indicate that the destroyed joints experience higher acceleration than the welded joints during different earthquakes. The maximum percentage difference between the peak accelerations at the destroyed and welded joints was found to be 77.96%.

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