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The FEM analysis of the behavior of a welded column–joist joint under seismic loading

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Abstract

Destructive earthquakes have been more important subject in Turkey, especially in Marmara region after the İzmit and Düzce Earthquakes in 1999. The welded joints are the most critical regions in steel structures when the structure is subjected to dynamic loads. In this study, the finite element analysis (FEM) of the behavior of a welded column–joist joint under seismic loading was performed. The equivalent earthquake loading process (EELP) according to the Turkish Earthquake Code 1998 (TEC-98) was used for calculating the seicmis loads. By using FEM, heat analysis was performed, the residual stresses were determined and the deformations in a welded column–joist joint were observed. The results were illustrated in figures. The stress states after seismic loading in the most critical joint were compared with material properties of the base metal, and the behavior of the welded column–joist joint under seismic loading was discussed.

Keywords: FEM analysis; Seismic loading; Welded steel structure

1. Introduction

In Marmara region, the destructive earthquakes have been reported due to the north Anatolia fault (NAF), since ancient years. The last samples of these earthquakes are 17 August 1999 İzmit and 12 November 1999 Düzce. The Marmara region has developed in recent 20 years and its population has reached 20 million. This region has generally buildings with five to eight stories. A part of these buildings have destroyed due to earthquakes (approximately 78,000) and 17,000–18,000 persons have died. After these earthquakes, plastic strain behavior of steel and reinforced concrete buildings have discussed [1–3]. During the earthquakes, it was reported that the steel structure buildings have higher performance compared to reinforced concrete buildings [4]. After the earthquakes, the acceleration values were measured as 0.04–0.76 g (M7.2) in Düzce earthquake and 0.031–0.48 g (M 7.4) in İzmit earthquake [5]. In this study, the stress and strain behavior of a welded steel structure and welded areas were investigated after seismic loading (Fig. 1).

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2. Process

The selected structure is a building having seven stories with 12 m × 6 m dimensions and each floor has 3 m high and all joints are manufactured by welding. The used joist type is I-30 and column type is I-40. Column and joist materials are AH 36 structural steel which has 350 MPa yielding strength and 425 MPa ultimate tensile strength. Fig. 2 shows a model of the designed steel building in three dimensions using SAP 2000 structural analysis programme.

2.1. Equivalent earthquake loading process (EELP)

The buildings which in equivalent earthquake loading process can be applied are determined in Turkish earthquake code (TEC-98). EELP converts the time-dependent dynamic earthquake load to a equivalent static earthquake load, and EELP can be applied to the used structure in this study. There are two conditions for EELP:

(1) Total high limit must be under 25 m.
(2) Total equivalent earthquake load must be:

$$V_t = WA(T_1)/R_a(T_1) \geq 0.1 A_0 I A \tag{1}$$

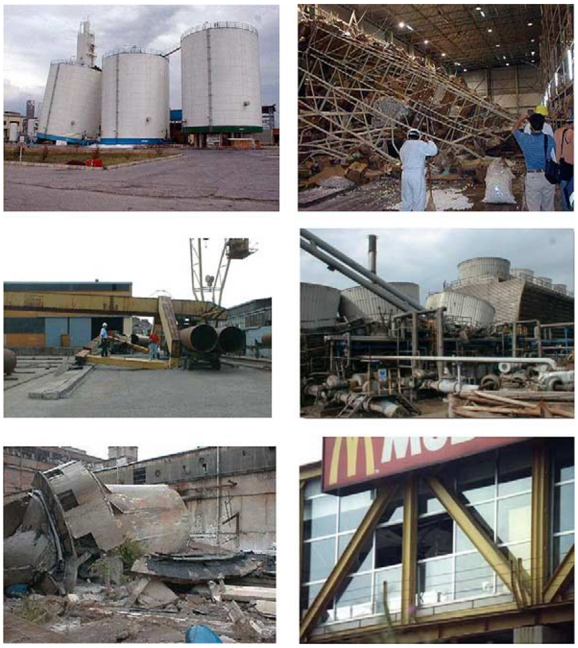

Fig. 1. Samples of the fractured steel construction in 17 Agust and 12 November 1999 İzmit.

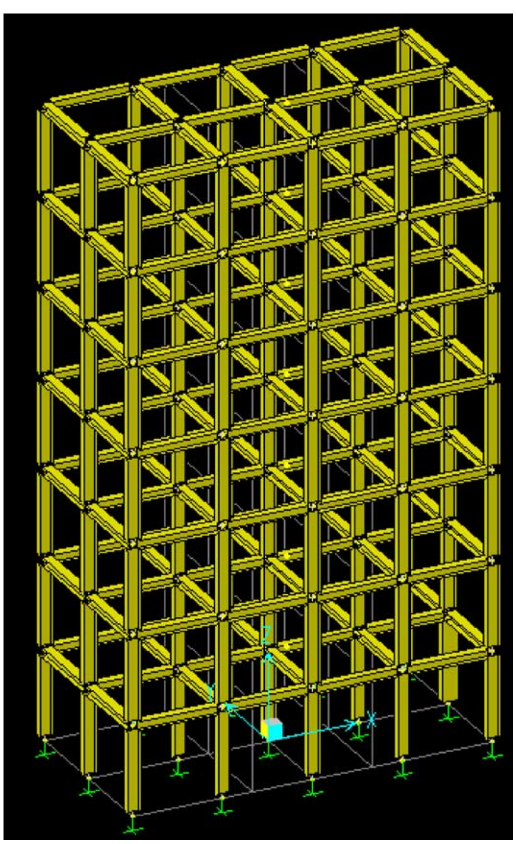

Fig. 2. Designed steel structure in three dimensions.

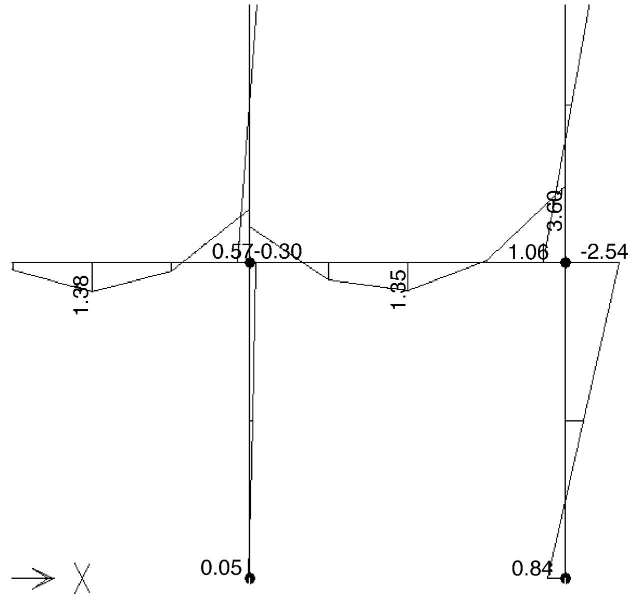

Fig. 3. Moment at the joint.

where W is total building weight and it is defined as

$$W = \sum w_i \tag{2}$$

where w_i is the weight of the each floor and it is calculated from (3).

$$w_i = g_i + nq_i \tag{3}$$

In this last equation, g_i is the static weight, q_i the dynamic weight of the each floor and n is the reduction coefficient and taken 0.3 for the structure to be studied. For steel structure, it is accepted that g_i is 5–10 kPa and q_i is 2 kPa. g_i was taken

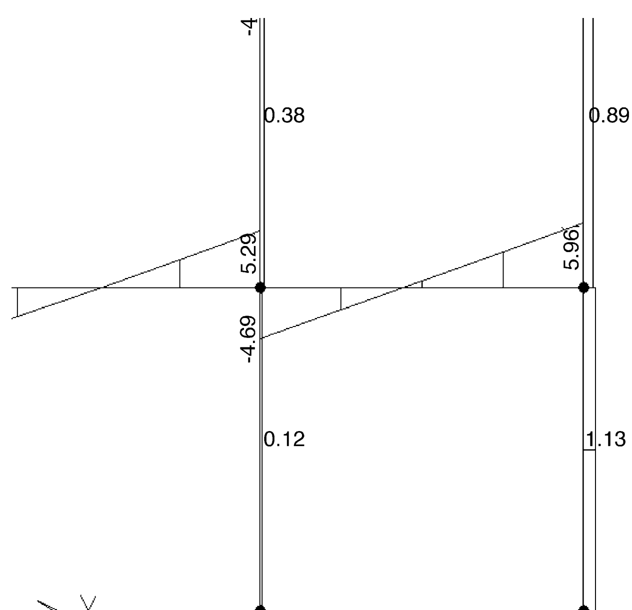

Fig. 4. Shear force at the joint.