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STRUCTURAL RESPONSE OF A STEEL STRUCTURE WITH DISSIPATIVE ELEMENTS UNDER SEISMIC ACTION EXPERIMENTAL SET-UP

BY

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Abstract. The paper presents the set-up needed for an experimental study regarding the behaviour of steel beam to column joints with dissipative elements. Three sets of torsion-bent bar type hysteretic dampers with plastic deformation were designed and manufactured for this purpose. The aim of the experimental study is to analyse the parameters that affect the behaviour of the steel beam-to-column joint. In addition, a brick masonry module was strengthened through traditional methods. Important aspects regarding the energy dissipation in the joint can be obtained and analysed by carrying out the experimental program described in this paper. These aspects refer to the characterization of the specific failure modes, the identification of the ultimate forces and the displacement and characterization of the stress-strain state.

Keywords: beam-to-column joints; hysteretic dampers; seismic action; energy dissipation.

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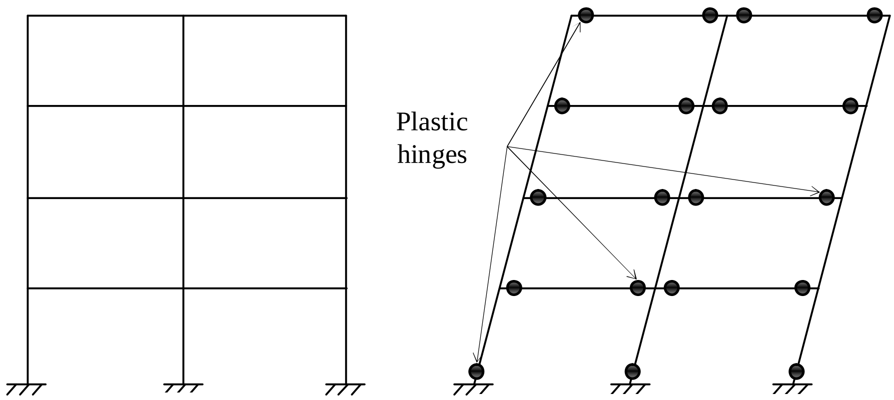
1. Introduction

Steel structures are widespread in seismic areas due to their ductile behaviour and increased energy dissipation capacity (Venghiac *et al.*, 2018). The steel beam-to-column joints must be capable of simultaneously providing the strength and ductility of the structures.

Major earthquakes in Northridge 1994 and Kobe 1995 showed that classical welded joints had a reduced dissipation and rotation capacity that caused the premature and brittle failure of the beam-to-column joints before the plastic hinge could perform in the beam. This fact contradicts the design principle "strong column – weak beam" shown in Fig. 1. (Eurocod 3. SR EN 1993-1, 2006). The reasons of premature and brittle failure on steel beam-to-column joints were analysed in a series of papers such as (Mahin, 1998; Miller, 1998; Hedayat & Celikag, 2009).



a) Steel frame structure

b) Steel frame structure after the formation of plastic hinges

Fig. 1 – "strong column – weak beam" principle.

Research was carried out to improve the behaviour of the steel beam-to-column joints and implicitly of the structure. The results of the research were outlined in two categories of methods for improving the behaviour of beam-to-column joints, namely:

- the geometric modification of joint elements;
- the implementation of additional dissipative elements.

The geometric modification of joint elements consists in stiffening the joint through additional elements or increasing their size (Engelhardt & Husain, 1993). Another approach to geometry modification involves reducing the section of the beam RBS (Engelhardt *et al*., 1996) or RWS (Tsavdaridis & Papadopoulos, 2016).

The steel beam-to-column joints with dissipative elements may be classified into three categories:

- joints with hysteretic dampers with plastic deformation of metal,
- joints with visco-elastic hysteretic dampers,
- joints with hysteretic dampers based on friction.

Hysteretic dampers with metal plastic deformation are the most used in beam-to-column joints due to the relatively low cost of manufacturing, maintenance and the simple and easy replacement of degraded elements (Staşcov & Veghiac 2017). Some of the advantages of this type of dampers are the high capacity of seismic energy dissipation and the fact that they have a stable and relatively easy way to predict the structural behaviour.

The experimental program presented in this paper relates to the analysis of the behaviour of the structure with joints with torsion-bent bar hysteretic damper. The main objective of this program is to describe the parameters that influence the behaviour of the joint.

2. Literature Review

Due to the fact that the experimental tests on the seismic platform involve substantial costs and performant equipment, their number is reduced. The experimental set-up was based on previous shake table tests carried out on reinforced concrete frames at the Faculty of Civil Engineering and Building Services in Iaşi. The test results allowed the authors to draw a series of eloquent conclusions about the behaviour of the structure subjected to seismic actions.

3. Description of the Experimental Program

The aim of the proposed experimental program is to describe the behaviour and mechanisms of energy dissipation of the dissipative joints in steel frame structures. For this purpose, a spatial model was developed (Fig. 2), which involves the testing of three sets of torsion-bent beam type dissipative elements (Budescu, 2005), adapted to the clamping and bearing conditions of the beam-to-column joints, shown in Fig. 3.

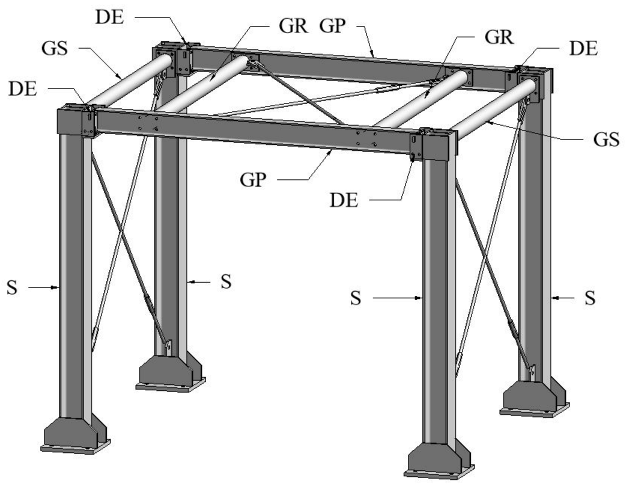


Fig. 2 – Experimental model.

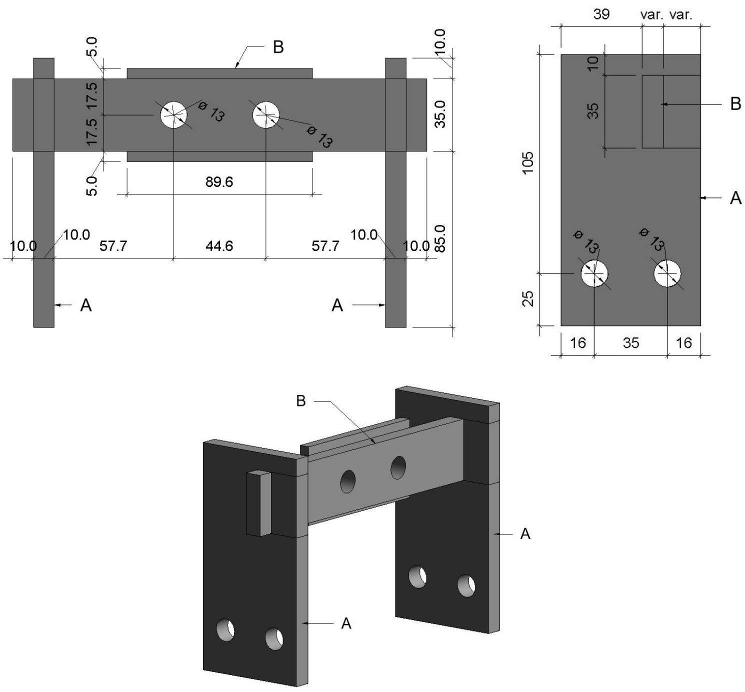


Fig. 3 – Torsion-bent bar type dissipative elements.

The three sets mentioned above are differentiated by the thickness variation of the “B” element:

- The first set of dissipative elements has the thickness of the dissipative element “B” equal to 6mm;
- The second set has thickness of the dissipative element “B” equal to 8mm;
- The third set has the thickness of the dissipative element “B” equal to 10mm.

The linear elements of the model are made of S235 steel. The dissipative elements are made of S235 steel subjected to the annealing process. The screws utilised for the experimental model are M12, class 10.9.

GP – the main beam - is an IPE 120 profile; GS – the structural beam - is a tubular profile 76.1 × 5; S – Column HEA 140 profile; GR – beams for supporting the load concrete slab - are a tubular profile 76.1 × 5; DE – dissipative elements. The model is equipped with bracings in the transverse direction to the load to strengthen the model.

For the seismic action testing, the seismic platform ANCO R250-3123, shown in Fig. 4 is used. The platform is powered by three servo-hydraulic actuators, which induce three-dimensional motions. At the bottom of the platform there is an air bearing that supports the platform and test model.

The characteristics of the platform are:

- three-dimensional action (two horizontal and one vertical),
- three 70-ton servo-hydraulic actuators with 6 joints to create three-dimensional action,
- three torque cylinders with 18 joints to guide the platform movement and prevent pitch, yaw and rotation motion,
- displacement peak-to-peak: 350mm,
- maximum speed: 0,8m/s,
- maximum acceleration (with a 10-ton model): 3.0g,
- maximum weight of a test model: 16ton,
- maximum torque of a test model: 150kN*m,
- platform dimensions: 3.05m x 3.05m with a 20x20cm grid of M24 threated holes,
- maximum frequency: 50Hz….100Hz; function of mass of the tested model (ANCO R250-3123 tri-axial vibration shake table, 2004).

Fig. 4 – ANCO R250-3123 tri-axial vibration shake table.

After the model has been assembled on the seismic platform, it is equipped with four linear displacement transducers (D1, D2, D3, D4), eight accelerometers, a pair of transversals at each measurement points (A1, A2, A3, A4) and four inclined transducers disposed at 45° (L1, L2, L3, L4), as shown in Fig. 5. Strain gauges are mounted on the dissipative elements. The applied action is the sinus beat type.

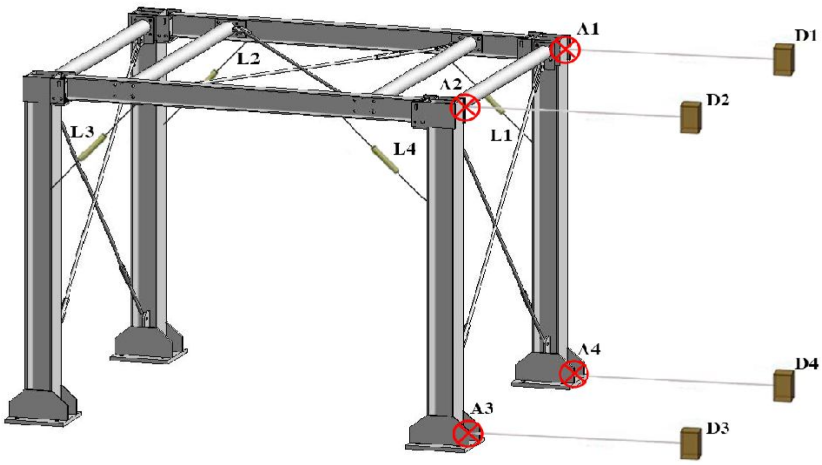


Fig. 5 – Mounting the transducers on the model.

All transducers are connected to the DAQ ESAM Traveller data acquisition system.

4. Conclusions

This paper presents the experimental set-up of a study aiming to describe the behaviour of dissipative elements in beam-to-column joints. The preparation and instrumentation of the steel frame model with joints with dissipative hysteretic dampers was extensively detailed. The experimental program focuses on the main parameters that characterize the behaviour of the dissipative elements in beam-to-column joints, the stress-strain and acceleration-displacement hysteretic curves. Additionally, the rotation of the beam-to-column joint can be measured. Based on result of this experimental program, the validity of the existing analytical and numerical models can be verified and, if necessary, corrections or new models can be proposed.

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RĂSPUNSUL STRUCTURAL LA ACŢIUNE SEISMICĂ AL UNUI CADRU DE OŢEL CU NODURI CU ELEMENTE DISIPATIVE
Organizarea programului experimental

(Rezumat)

Această lucrare prezintă etapele de pregătire şi instrumentare pentru un studiu experimental privind comportarea îmbinărilor metalice grindă-stâlp cu elemente disipative. Trei seturi de disipatori histeretici cu deformaţie plastică a metalului de tip bară torsionat-încovoiată au fost proiectate şi fabricate pentru acest studiu, al carui scop este de a analiza parametrii care înfluenţează comportarea îmbinării. Aspecte importante privind eficienţa disipării energiei în îmbinare pot fi obţinute şi analizate prin realizarea programului experimental descris în această lucrare. Aceste aspecte fac referire la caracterizarea modurilor specifice de cedare, la identificarea forţelor capabile ultime şi la caracterizarea stării de tensiuni – deformaţii specifice.