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ANALYSIS OF BEAM-TO COLUMN CONNECTIONS WITH DEMOUNTABLE ENERGY DISSIPATIVE PLATES, SUBJECTED TO CYCLICAL ACTIONS

BY

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Abstract. Connection behavior is the most important factor in the steel structure’s behavior subjected to cyclic actions. Structural ductility can be ensured following two methods: allowing plastic hinge to be formed in the beam by reducing section of the beam flanges, or by using dissipative elements in order to ensure plastic hinge formation in the connection. This paper presents and discusses results of parametric analyses un the behavior of dissipative beam-to-column connection using Finite Element (FE) modelling tools, and intelligent system artificial neuronal network. The analyses are made on a new type of beam-to-column connections with demountable dissipative plates which can be a new step in designing of beam-to-column connections for steel structures. The objective of introducing into the joint the dissipative plates presented in this article is to direct the plastic hinge into a “weak” element that can be easily replaced. The main objective of the analysis presented in this article is to study the state of tension and deformation of the dissipative plate. Models were analyzed with the ANSYS finite element analysis program. The main results obtained contain the hysteretic curves and state of tension. The artificial neuronal network program was used to analyze the area variation and distribution of plasticized material.

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Keywords: Non-linear analysis; finite element modeling; energy dissipative connections; parametric design; ductile design; plastic hinges; ANN.

1. Introduction

Research on seismic action on beam-to-metal joints and the metallic structures themselves have seen considerable advances, especially after the earthquakes in Northridge (1994) and Kobe (1995). The ductile failure requirement of joints and increased energy dissipation has been established. The "strong column-weak beam" principle, which means that the plastic joint develops at the level of the beams and at the base of the column was implemented in the case of semi-continuous joints, which are part of the moment-resistant frame (MRF) (Engelhardt & Husain, 1993), can be replaced as a principle of **"strong beam-weak element"** (Roeder *et al.*, 1993; Shneider *et al.*, 1993). That involves the dissipation of energy by degrading elements of the joint structure that can be easily replaced.

The beam-to-column joints with energy-dissipating can be conformed to this principle. This class of beam-to-column joints has a wide spread due to the relatively low cost of manufacturing, maintenance and the simple and easy replacement of damaged elements. At the same time, these joints have an increased seismic energy dissipation capacity and a stable and easy predicted behavior. A few examples of dissipative elements are the joints with PI-dampers (Koetaka *et al.*, 2005), slit dampers joints (Oh *et al.*, 2009), DST – Double Split Tee joints (Herrera *et al.*, 2013; Bravo & Herrera, 2014) (Latour & Rizzano, 2015; Tong *et al.*, 2016), and dissipative fusses joints (Calado *et al.*, 2013; Valente *et al.*, 2017a; Valente *et al.*, 2017b).

The ductile behavior of the joint is ensured by directing the formation of the failure mechanism into the beam or the end plate. The objective of introducing into the joint the dissipative plates presented in this article is to direct the failure mechanism into a "weak" element that can be easily replaced.

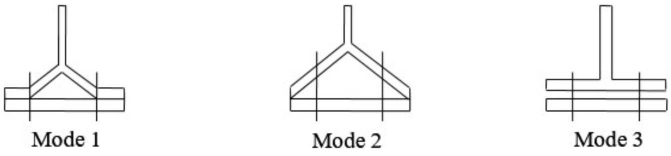


Fig. 1 – Modes of failure of the end plate.

2. Analyzed Models

The main objective of the analyzes presented in this article is to study the state of tension and deformation of the dissipative plate, but also the variation of these parameters depending on the shape of the dissipative plate.

The static scheme of the analyzed model is shown in Fig. 2. In order to simplify the model and optimize the computing volume, the analysis was reduced to the simulation of the dissipative plate and its components.

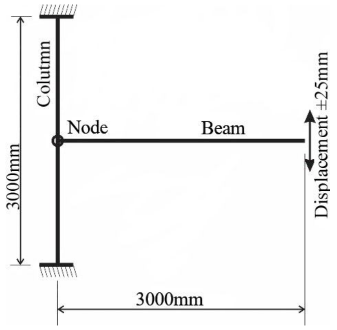
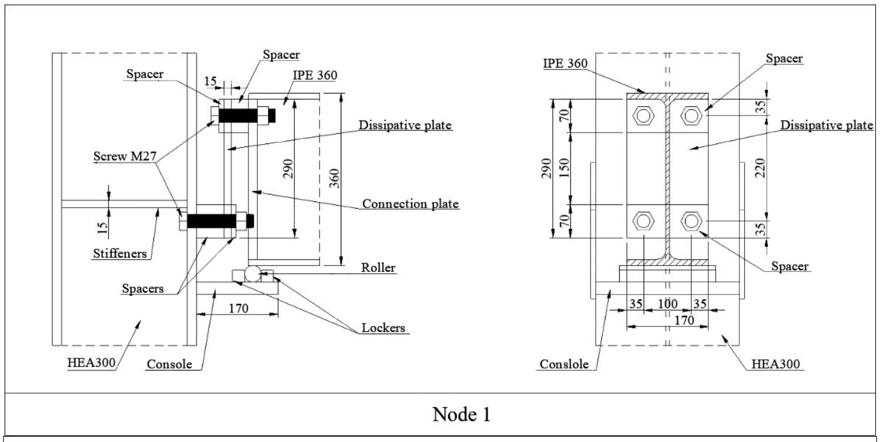
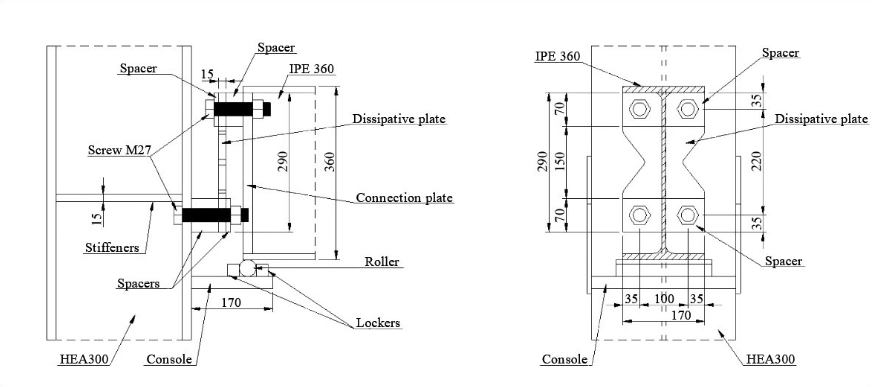


Fig. 2 – The static scheme of the analyzed models.



Node 1

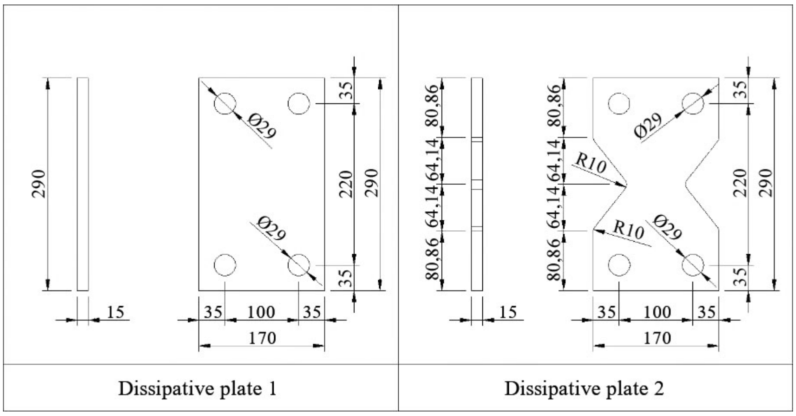


Node 2

Fig. 3 – Analyzed assemblies

The junction is composed of HEA300 column, IPE360 beam, M27 screws group 10.9, disposed 2 by 2 rows, 15 mm thickness dissipative plate and a series of spacing plates to facilitate deformation of the dissipative plate Fig. 3. The fastening assembly also includes a rigid console for efficient taking of the vertical forces on which a bearing bar is placed and two limiters/stoppers that prevent the bearing from excessive displacement. The contact surface between the bearing and the beam that supports it is the center of rotation of the joint. Transmission of stain efforts to the beam is achieved by means of stiffeners plates. The dimension for the analyzed dissipative plates are shown in Fig. 4. The steel grade for joint elements is S235.

Models were analyzed with the ANSYS finite element analysis program. The non-linear behavior of the materials was modeled with a simple bilinear characteristic curve Fig. 5. An 8 mm displacement was applied in both directions, on one of the spacer plates, at the opposite end being applied a fixed support Fig. 6.



Dissipative plate 1

Dissipative plate 2

Fig. 4 – Dimensions of dissipative plates analyzed.

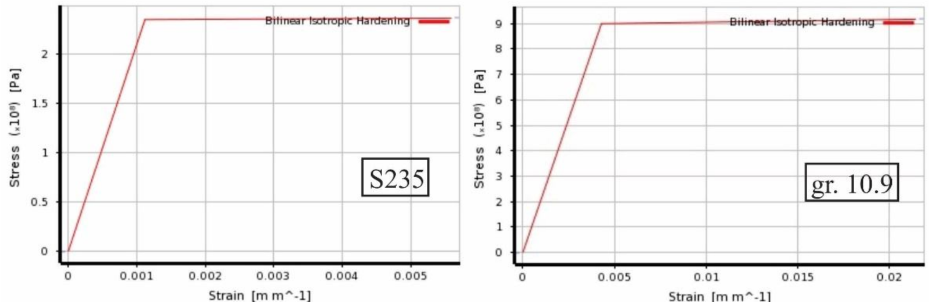


Fig. 5 – Non-linear patterns for materials in ANSYS.

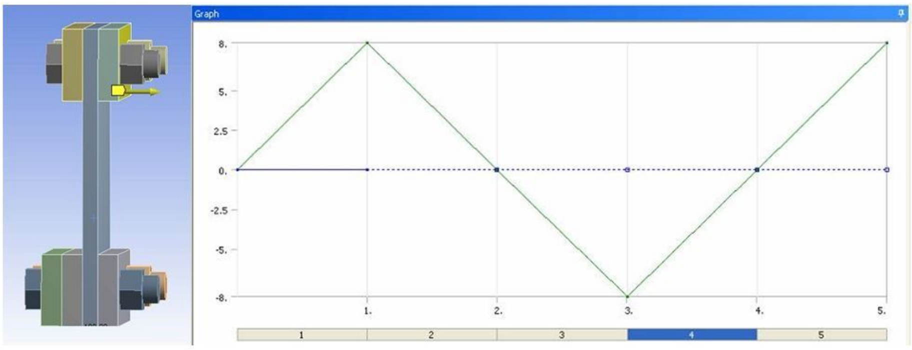


Fig. 6 – Applied displacement.

3. Results

The hysteretic curves for the dissipative plates 1 and 2 are shown in Fig. 7. The tensions developed in the dissipative plates are shown in Fig. 8.

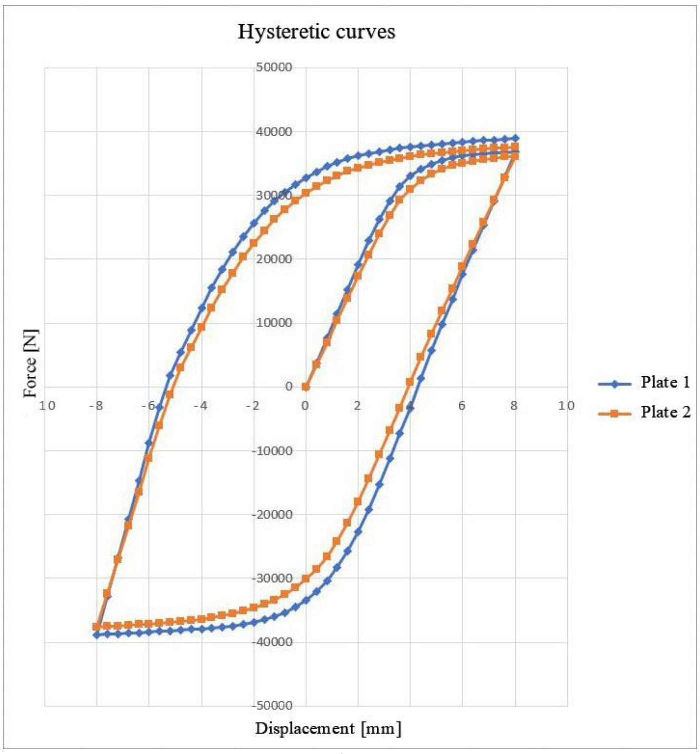
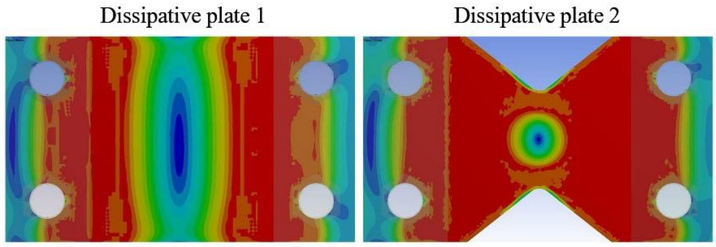
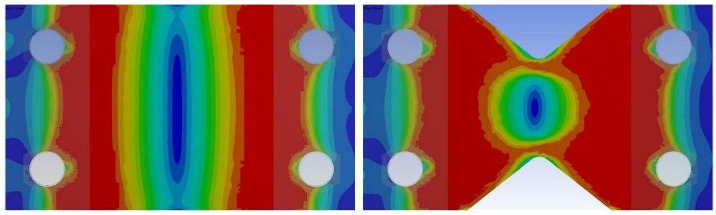


Fig. 7 – Hysteretic curves for dissipative plates 1 and 2.



Load step 1



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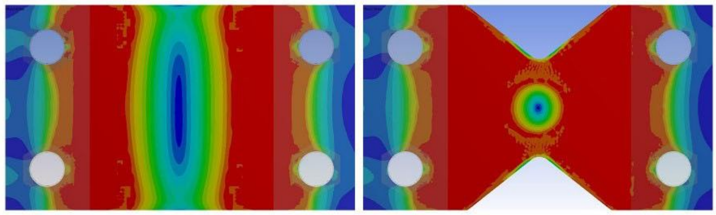

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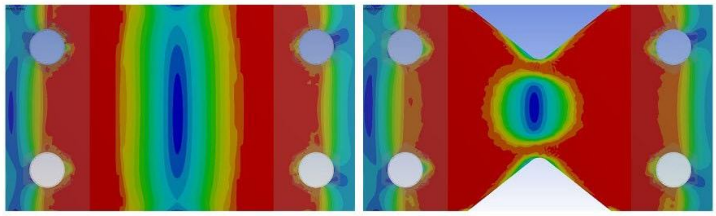
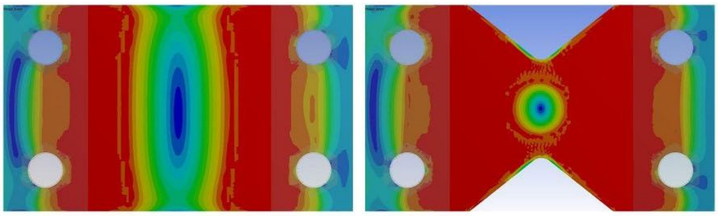


Load step 4



Load step 5

Fig. 8 – Von-Mises tensions in dissipative plates 1 and 2.

In Fig. 7 it is observed that both dissipative plates have an approximately identical behavior. The Von-Misses tension distribution maps were analyzed using the ISANNIF (Intelligent System Artificial Neuronal Network Internal Forces) program. The program processes images in various formats (.png, .jpg, .bmp, and .jpeg) using artificial neuronal networks to analyze the effort distribution in the plate (Pandelea *et al.*, 2017a). The surfaces of the dissipative plates and the surfaces of plasticized material (green color) are determined.

According to Table 1, it can be seen that the rectangular dissipative plate (plate 1) plasticizes approximately 35% of its surface with a maximum of 43.5% in the loading step 4. The hourglass shaped dissipative plate (plate 2) is plasticized in a proportion of 52.5% with a mode stable behavior.

Table 1

Areas of plasticized material

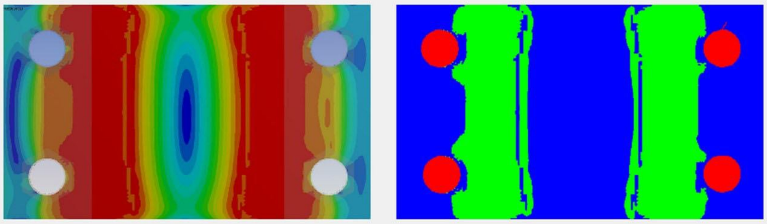
Dissipative plate / Loading step	Dissipative plate 1 S_{total} = 466.34 cm^2	Dissipative plate 2 S_{total} = 408.61 cm^2
Loading step 1	169.61 cm^2	215.05 cm^2
Loading step 2	167.04 cm^2	215.67 cm^2
Loading step 3	169.47 cm^2	216.48 cm^2
Loading step 4	203.04 cm^2	215.01 cm^2
Loading step 5	167.14 cm^2	215.75 cm^2

4. Conclusions

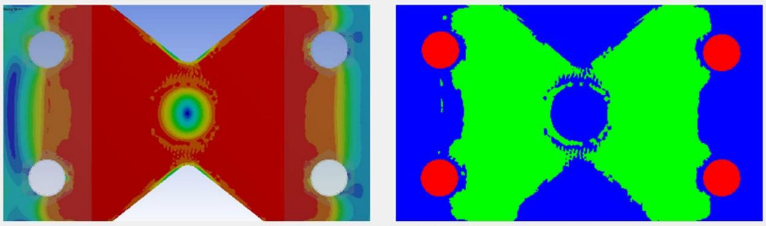
According to the results presented in Fig. 9 it is observed that the shape of the dissipative plate does not have a significant influence on the energy dissipation capacity of these joints. Instead, there is flattening of the stresses in the surface of the dissipative plate in the case of the hourglass shaped dissipative plate, due to the optimization of its section in terms of tension distribution over the section height.

Also, a decrease in the rigidity of the dissipative plate 2 can be observed due to the reduction in the material volume.

According to the results obtained with the ISANNIF program, it can be seen that the optimization of the dissipative plate shape gives an increase in the surface of plasticized material of approximately 25% compared to the rectangular plate. At the same time, the increase in the volume of plasticized material does not contribute to the seismic energy dissipation capacity, but the cutting of the material contributes significantly to the initiation of the plasticizing phenomenon of the dissipative plate.



Dissipative plate 1, Load step 5



Dissipative plate 2, Load step 5

Fig. 9 – Areas calculated with the ISANNIF program.

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ANALIZA COMPORTĂRII PLĂCUȚELOR DISIPATIVE DIN ÎMBINAREA GRINDĂ-STÂLP, SUPUSE LA ACȚIUNI CICLICE

(Rezumat)

Comportarea îmbinărilor este factorul cel mai important în comportarea structurilor supuse la acțiuni ciclice. Ductilitatea structural poate fi asigurată prin două metode: formarea articulației plastice în grindă prin reducerea secțiunii tălpilor sau inimii; sau prin utilizarea elementelor disipative care asigură formarea articulației plastice în îmbinare. Această lucrare prezintă rezultatele analizelor parametrice asupra comportamentului îmbinării grindă-stâlp cu elemente disipative, utilizând analiza cu element finit şi analiza cu rețele neuronale artificiale. Analizele se efectuează pe un nou tip de imbinare grindă-stâlp, care pot fi un nou tip pas în proiectarea îmbinărilor grindă-stîlp. Obiectivul introducerii în îmbinare a plăcilor disipative prezentate în acest articol este direcționarea articulației plastice într-un element "slab" care poate fi înlocuit. Obiectivul principal al analizei prezentate în acest articol este de a studia starea de tensiuni şi deformații a plăcii disipative. Modelele au fost analizate cu ajutorul programului de analiza cu element finit ANSYS. Principalele rezultate obținute conțin curbele histeretice şi hărțile de tensiune. Cu ajutorul rețelelor neuronale artificiale au fost analizate variația distribuției materialului plastificat în plăcuța disipativă.