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THE INFLUENCE OF SOLID DRY FRICTION DAMPING AT COLUMNS WITH COMPOUND SECTIONS

BY

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Abstract. An efficient way of dissipating the seismic energy is through solid dry friction. Friction dampers are very durable and have a very stable behaviour. Their incorporation in structures is usually made by using bracings provided with such devices. This is also a disadvantage because the space between some of the columns is blocked by the bracings. To avoid this phenomenon, “energy dissipative” columns are proposed. The intention is to absorb the seismic energy within the columns themselves. The aims of this paper are to evaluate how the dimensions of the contact elements influence the energy dissipation capacity and also to investigate the influence of the contact surface’s nature on the behaviour of the “energy dissipative” columns.

Key words: friction damper; energy dissipative columns; friction coefficient; hysteresis loop; compound section.

1. Introduction

Friction is a very convenient method of dissipating the seismic action by converting the kinetic energy into heat. On a much smaller scale, friction is also used in automotive brakes. In 1899, Emile Mors proposed the first

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frictional device, but in 1980 Pall was the first to build passive frictional dampers based primarily upon an analogy to the automotive brake. The purpose is to slow down the motion of structures "by braking rather than breaking" (Pall & Marsh, 1982).

The basic principle of frictional dampers is based on the following hypotheses:

a) the total frictional force developed is independent with respect to the apparent surface area of contact;

b) the total frictional force developed is proportional to the local normal force acting across the interface;

c) in the case of low relative velocities, the frictional force is independent with respect to that velocity;

d) the frictional force depends on the nature of the sliding faces (Budescu, 2005).

The modern theory of solid dry friction focuses on identification of the true contact area, the mechanisms involved in interfacial bonding and the localized inelastic deformation that occurs in the contact region (Pall & Marsh, 1982).

One inconvenient of dampers is that the space between some of the openings of the structure is blocked by such systems. In order to be able to use that space, "energy dissipative columns" are proposed. These columns have a compound cross-section. The seismic energy will be dissipated through friction which develops at the interface between the coupled profiles. The column considered is depicted in Fig. 1.

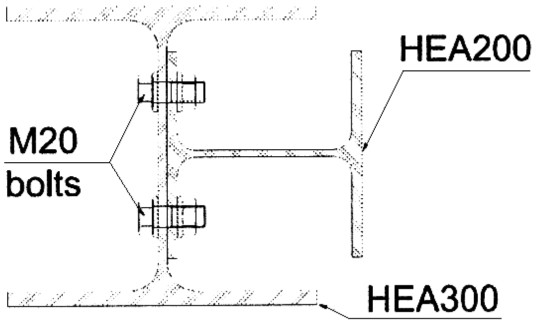


Fig. 1 – Energy dissipative column with compound cross-section.

2. Objectives and Scope of Work

The paper follows two main objectives. The first objective is to outline the influence of varying the flange and web thicknesses at the contact face of the steel profiles. The second objective is to investigate the influence of changing the nature of these contact surfaces.

3. The Analysis of Hysteretic Damping in a Coupling Area of the Column

ANSYS is the program used for the analysis. The simplified models consist of the following components: two steel plates of various thicknesses and one M20 bolt, as shown in Fig. 2. The steel plates are made of S235 steel grade and the bolt has a strength grade of 10.9. Plate *A* has the following dimensions: 120 × 200 × t_A , [mm] (t_A is the thickness of plate *A*) and is constrained at one end. The dimensions of plate *B* are 100 × 100 × t_B , [mm] (t_B is the thickness of plate *B*).

The contact between the plates is modelled as frictional. The friction coefficients considered are $\mu = 0.15$, $\mu = 0.25$, $\mu = 0.35$ and $\mu = 0.45$. The bolt is preloaded, as shown in Fig. 3 *a*, with a force equal to 14,700 daN. This is the maximum preloading force for a M20 bolt having a strength grade of 10.9 (Eurocode 3, 2003). Plate *B* is subjected to an imposed displacement of 0.45 mm according to the graph in Fig. 3 *b* and the direction is depicted in Fig. 4.

The values of the friction coefficients represent different ways of surface processing. These operations consist of wire-brushing, flame cleaning, sand blasting, shot blasting or applying different types of paint (ENV 1090-1:1996; Eurocode 3, 2003).

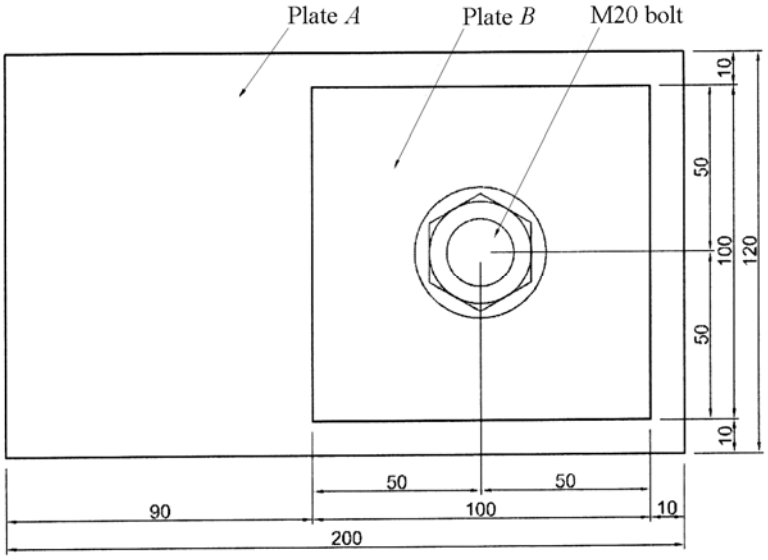
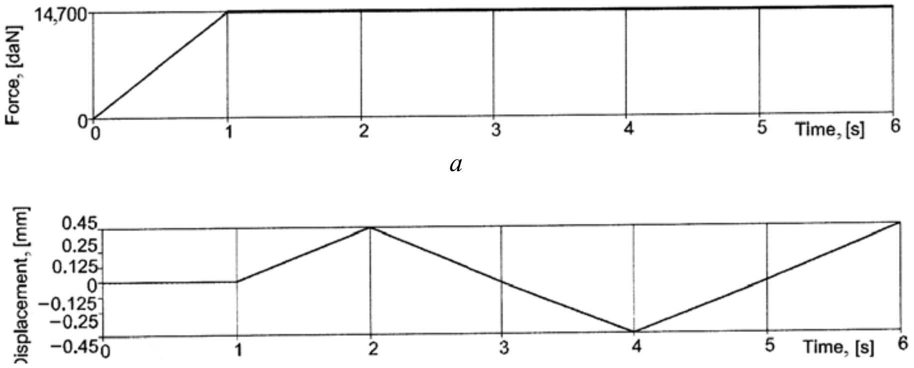


Fig. 2 – Top view of the model.

Two sets of models are considered. The parameter for the first set is the thickness of the plates, and for the second set, the parameter is the friction coefficient. The considered thicknesses for the first set of models are 10, 15 and 20 mm and the friction coefficient is $\mu = 0.35$. For the second set the friction coefficients are $\mu = 0.15$, $\mu = 0.25$, $\mu = 0.35$ and $\mu = 0.45$ and the thicknesses are t_A = 8.5 mm and t_B = 10 mm. These dimensions represent the web of the HEA300 euro-profile and the flange of the HEA200 euro-profile, respectively.



a

b

Fig. 3 – *a* – Preloading forces; *b* – imposed displacement (ANSYS, 2009).

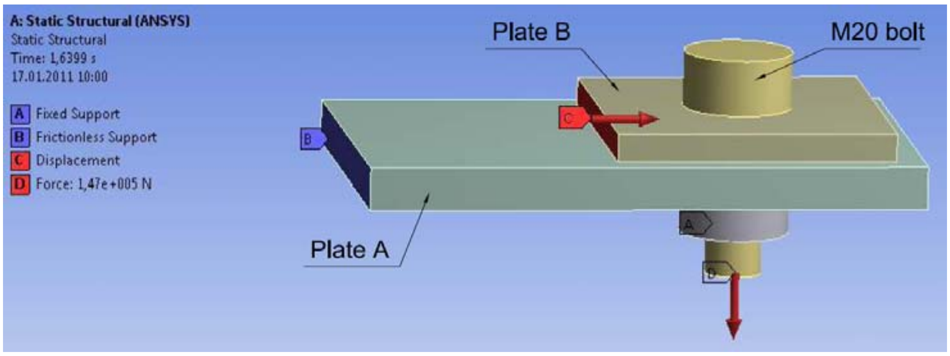


Fig. 4 – Model in ANSYS (ANSYS, 2009).

4. Results

The obtained results for both sets of models are exploited by graphs representing the relationship between the force and displacement.

4.1. The Influence of Varying the Thicknesses of the Plates

The steel plates thicknesses considered are hypothetical and do not represent actual web and flange dimensions of euro profiles. The value of the friction coefficient, $\mu = 0.35$, is for a surface treated with an alkali-zinc silicate paint applied after a shot blasting process (ENV 1090-1:1996; Eurocode 3, 2003).

The results are shown in Fig. 5 as hysteresis loops. An important aspect is the influence zone created by the preloaded bolt. These zones are different from one model to another due to the variation of the steel plate's thickness.

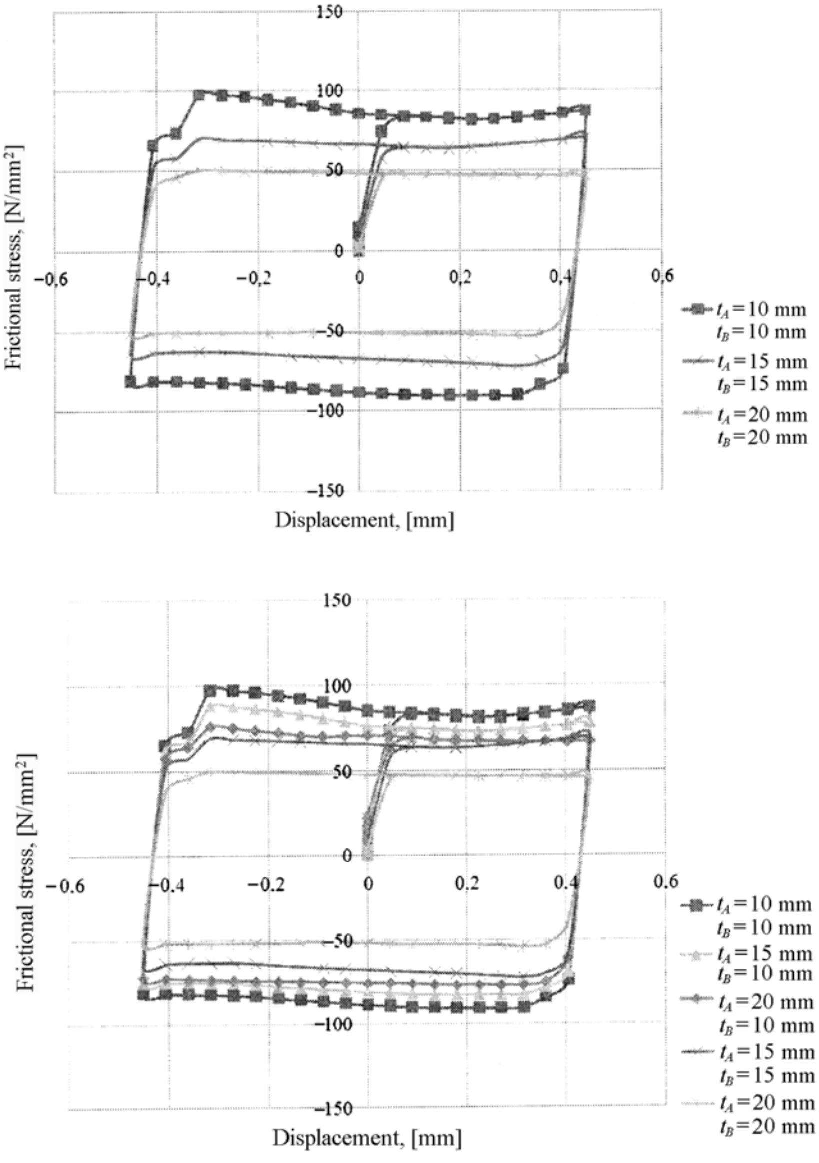


Fig. 5 – Hysteresis loops for the first set of models.

This difference is highlighted in Fig. 6. Another consequence is the variation of the normal stresses at the contact surface, also depicted in Fig. 6. If the plate thickness is halved, the normal stress increases by 67%.

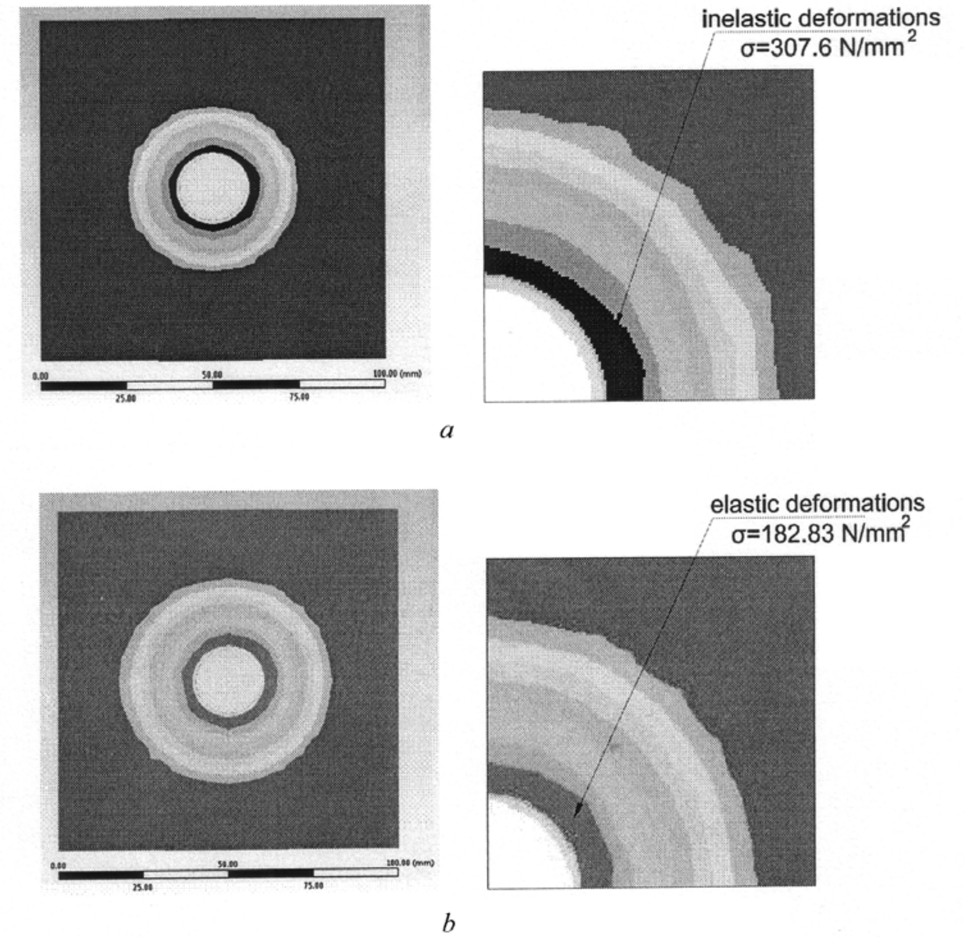


Fig. 6 – Influence zones for: *a* – $t_A = t_B$ = 10 mm; *b* – $t_A = t_B$ = 20 mm (ANSYS, 2009).

4.2. The Influence of Changing the Contact Surface's Nature

The values of the friction coefficients are, for all types of surfaces, from non-treated surfaces to shot or grit blasted surfaces with any loose rust removed (ENV 1090-1:1996; Eurocode 3, 2003). The results are shown in Fig. 7 as hysteresis loops. The variation of the frictional stress according to the friction coefficient is depicted in Fig. 8. This variation is non-linear, although all parameters, except the values of the friction coefficient, were kept constant.

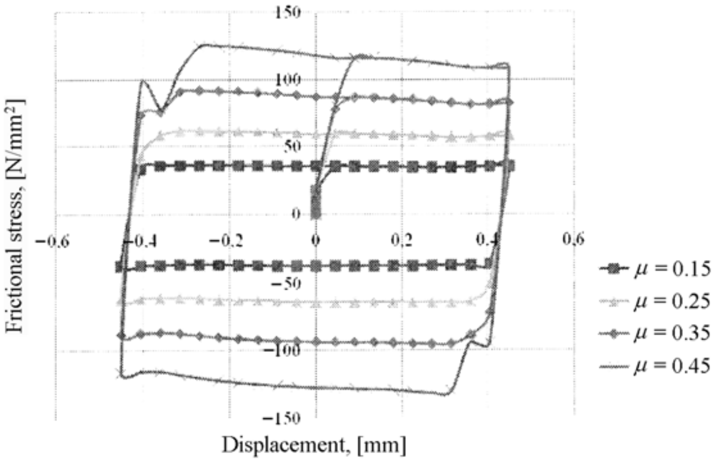


Fig. 7 – Hysteresis loops for the second set of models.

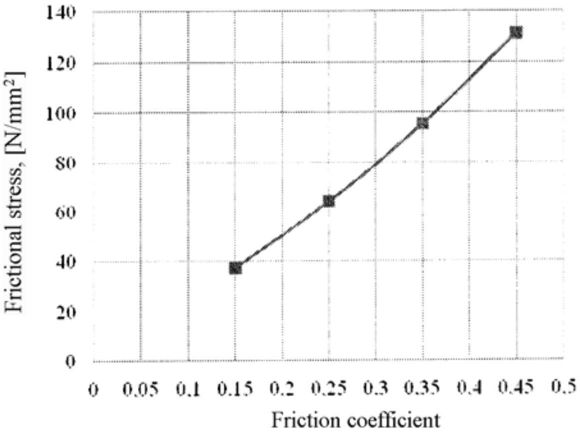


Fig. 8 – The variation of the frictional stress
according to the friction coefficient.

5. Conclusions

The graph in Fig. 5 reveals the fact that thick plates reduce the energy dissipation capacity of the friction damper. The distribution of stresses is made on a large surface, as shown in Fig. 6 *b*. The maximum value of the normal stresses at the contact surfaces is of 183 N/mm^2, which is situated in the elastic domain. In the case of using thinner plates, local inelastic deformations are present. The normal stress reaches the value of 307 N/mm^2. This is due to the distribution of stresses on a smaller surface, as shown in Fig. 6 *a*.

In the case of changing the nature of the surfaces, the hysteresis loops depicted in Fig. 7, outline the increase of energy dissipation with the increase of the friction coefficient.

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INFLUENŢA AMORTIZĂRII CU FRECARE USCATĂ LA STÂLPII METALICI CU SECŢIUNE COMPUSĂ

(Rezumat)

O metodă eficientă de disipare a energiei seismice o constituie amortizarea prin frecare uscată. Disipatorii cu frecare sunt durabili şi au o comportare stabilă în timp. Integrarea în structuri se face de regulă prin intermediul contravântuirilor prevăzute cu astfel de sisteme. În acelaşi timp această soluţie reprezintă un dezavantaj deoarece spaţiul ocupat de contravântuiri nu poate fi folosit. Pentru a evita acest dezavantaj sunt propuşi stâlpi „disipatori de energie”. Intenţia este de a disipa energia prin intermediul stâlpilor. Obiectivele acestei lucrări sunt evaluarea capacităţii de disipare a energiei prin schimbarea dimensiunilor elementelor care sunt în contact la suprafaţa de lunecare şi de a studia influenţa diferitelor metode de prelucrare a suprafeţelor asupra comportării disipatorului.