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OPTIMIZATION METHODS OF ENERGY DISSIPATIVE COLUMNS

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Abstract. In seismic areas the shallow composite flooring systems like Slimdek present some disadvantages. The most important is the low energy dissipation capacity. Embedding the beams in concrete eliminates the occurrence of plastic hinges, which are the mechanisms of absorbing the seismic energy. In order to correct that, energy dissipative columns are proposed. The columns studied so far showed a good energy dissipation capacity for high relative storey displacements. In this paper several methods are considered of improving these columns subjected to small displacements. Also, a case study is made. A multi-storey building is analysed in order to obtain a relative storey displacement, which was used as the action for the studies regarding methods of optimization of energy dissipative columns.

Key words: dampers; Slimdek; energy dissipative columns; finite element analysis; hysteresis.

1. Introduction

Shallow composite floors consist of resting the steel decking on the bottom flange of asymmetric section beams. These types of systems are mostly

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used for their many advantages. One type of shallow composite flooring system is called Slimdek (2001) and it is presented in Fig. 1. Fast construction time, low craneage needs and the fact that the decking acts as a permanent shuttering (Hicks *et al*., 2001; Venghiac *et al*., 2011) are very attractive advantages for engineers, but this system also presents a big disadvantage. Their behaviour to dynamic loads is close to a flat slab. The fact that the beams are embedded in concrete eliminates the occurrence of plastic hinges which absorb the seismic energy. In this case dampers are needed.

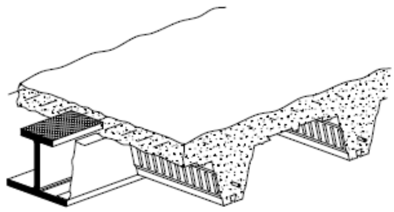


Fig. 1 – Slimdek composite flooring system.

2. Objectives and Scope of Work

The main objective of this paper is to study several methods of improving the energy dissipative columns in case of small storey drifts. A multi-storey building is considered as a case study to determine a storey drift.

3. Finite Element Modelling

The computer program used for the case study is SAP2000. The building is a steel frame structure with shallow composite floors and the adopted flooring system is SLIMDEK. The structure has the following characteristics:

a) the building has a ground floor and eight storeys;

b) the storey height is 3 m;

c) two openings of 6 m and two bays of 4 m;

d) the structural members have euro-profile sections;

e) the concrete grade is C32/40;

f) the steel grade is S235.

The loads considered for the analysis are the following:

a) the structure own weight (it is automatically evaluated by the software);

b) finishings: 100 daN/m^2;

c) live load: 400 daN/m^2.

The parameters of the spectral analysis used to simulate the seismic action are the following:

a) the peak ground acceleration: a_g = 0.20g (g = 9.81 m/s^2);
b) the control period: T_c = 0.7 s.
The maximum relative storey displacement obtained is 10 mm.

The energy dissipative column models consist of two or more HEA180 euro-profiles placed at a distance of 500 mm one from the other. The steel grade is S235 and the action is an imposed displacement equal to 10 mm. The finite element computer programmed used for the analysis is ANSYS (2009).

4. Finite Element Analysis

Analyses conducted so far showed a good behaviour of the energy dissipative columns subjected to big storey displacements. The columns studied and presented in a previous paper (Venghiac *et al.*, 2010) were subjected to a displacement equal to 25 mm. Applying a displacement of 10 mm to these columns reduces their capacity to absorb the seismic energy. This is due to the fact that the actual displacement induced on the active steel plates, which absorb the energy by yielding, is approximately ten times smaller. This causes the yielding to occur at high relative storey displacements. The difference between a 10 mm and a 25 mm storey displacement is presented in Fig. 2.

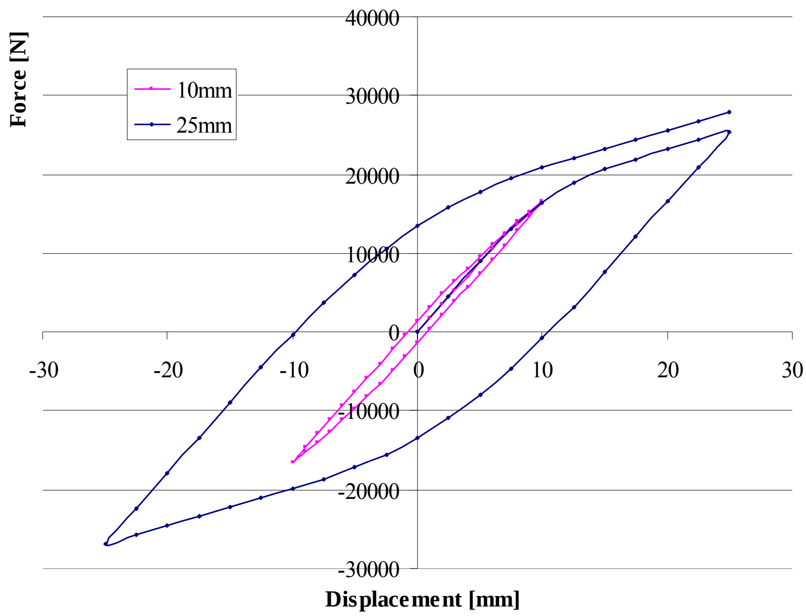


Fig. 2 – Hysteretic loops for the 10 mm and the 25 mm storey displacements.

Yielding starts at a displacement value of approximately 8 mm. In order to correct this problem, the following measures are considered:

a) increasing the displacement on the active steel plates;
b) increasing the stiffness of the active steel plates.

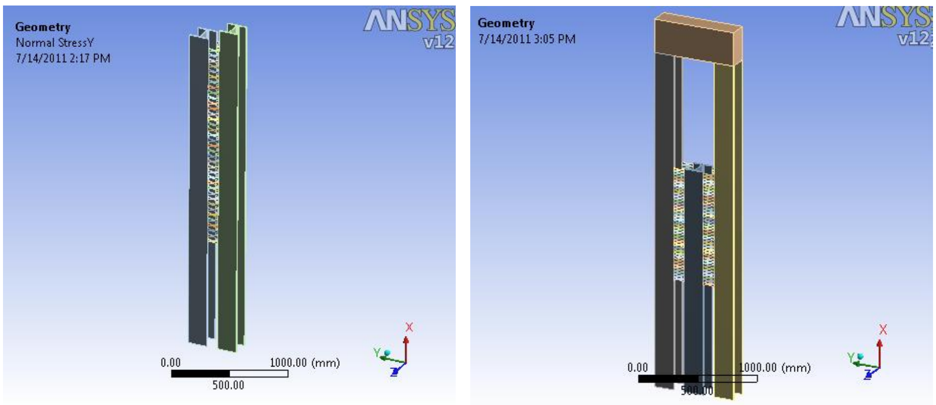
4.1. Increasing the Displacement on the Steel Plates

Two methods of increasing the displacement on the steel plates are studied.

The first one is to free the end of one of the columns. The models are presented in Fig. 3. The models consist of two HEA180 euro-profiles linked with parabolic shaped steel plates. The energy is dissipated through the yielding of these steel plates. The hysteretic loops for these models are presented in Fig. 4 and the strain energies in Table 1.

Table 1
Strain Energy

Model	Strain energy, [J]
a	374
b	699



Model *a* Model *b*

Fig. 3 – Models geometry in ANSYS.

The second method is to create a special mechanism which increases the local displacement. The models are similar with the previous ones. The mechanism is presented in Fig. 5 and the stresses in the steel plates of the considered models are presented in Fig. 6. The hysteretic loops are shown in Fig. 7 and the strain energy is presented in Table 2.

The contact surfaces of the mechanism joints are considered to be frictionless. To make a comparison between friction and frictionless contacts, model *b* has been modified with friction contacts. The friction coefficient is μ = 0.2. The difference made by friction is very small. One way of improving this mechanism is to use HSFGB (High Strength Friction Grip Bolts) at the joints.

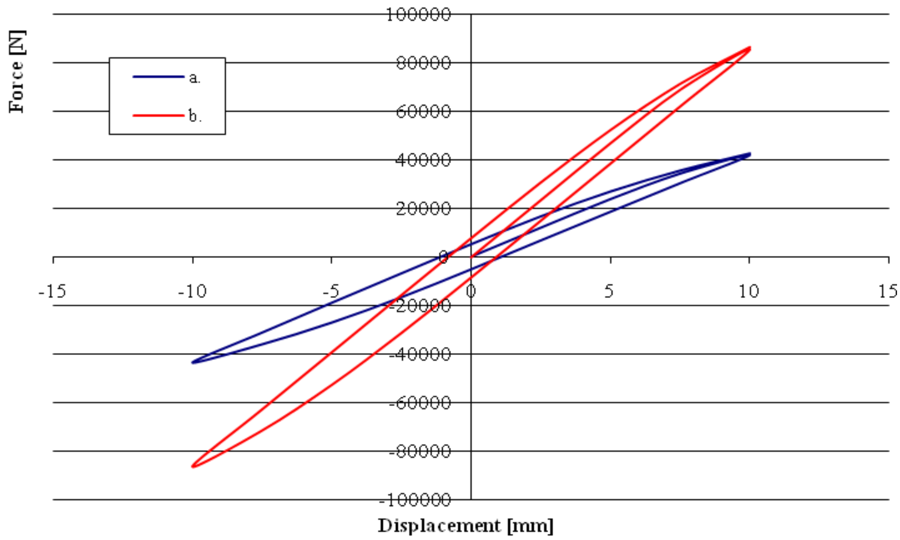


Fig. 4 – Hysteretic loops.

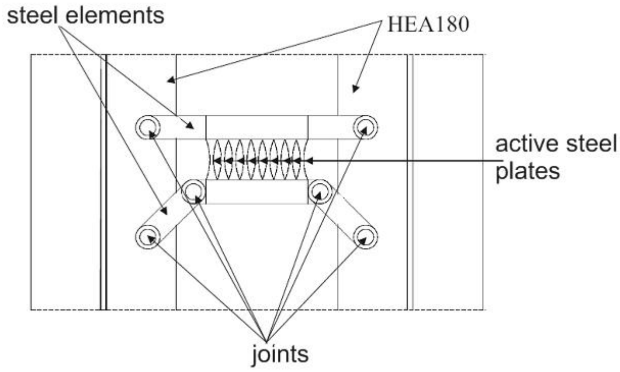
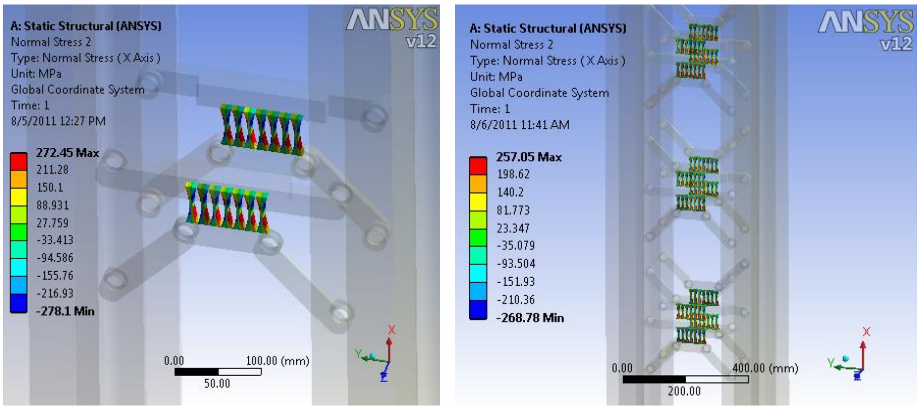


Fig. 5 – Mechanism for amplifying the local displacements.

Table 2
Strain Energy

Model	Strain energy, [J]
a	153
b	396



Model *a* Model *b*

Fig. 6 – Stresses in the active steel plates of the mechanism (User's Manual..., 2009).

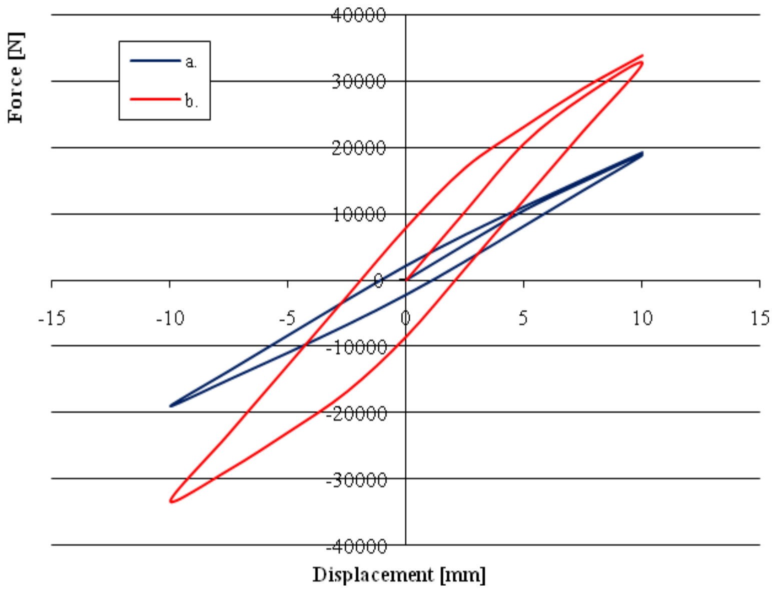
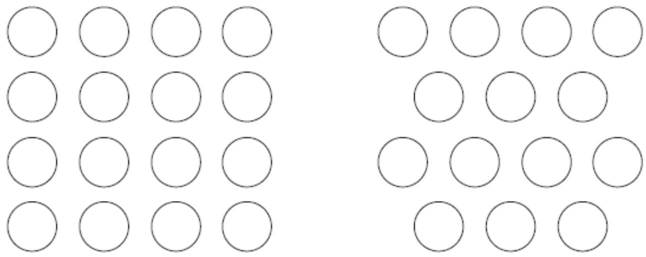


Fig. 7 – Hysteretic loops.

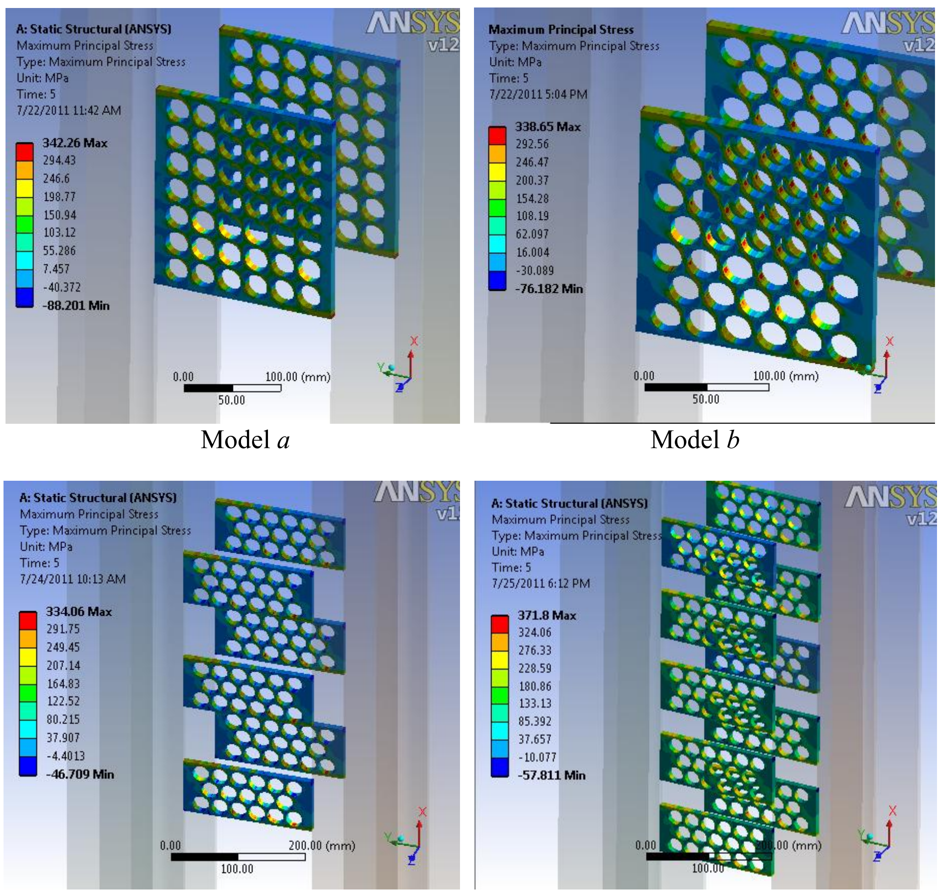
4.2. Increasing the Stiffness of the Steel Plates

The rigidity of the active steel plates can be increased by modifying their geometry. Instead of using the singular parabolic steel plates, rectangular plates with circular holes are adopted. The thickness of the plates is equal to 10 mm and the circular holes have a 25 mm diameter. The arrangement of the holes has been made in two ways and it is presented in Fig. 8. The plates are placed at the middle height of the columns.



a *b*

Fig. 8 – Types of holes arrangement in the steel plates: *a* – type *A* arrangement; *b* – type *B* arrangement.



Model *a* Model *b*

Model *c* Model *d*

Fig. 9 – Stresses in the active steel plates (User's Manual..., 2009).

The studied models are presented in the list bellow:
a) model *a*: 2 plates with type *A* arrangement (7 hole lines);
b) model *b*: 2 plates with type *B* arrangement (7 hole lines);
c) model *c*: 6 plates with type *B* arrangement (3 hole lines);
d) model *d*: 10 plates with type *B* arrangement (3 hole lines).

The stresses in the active steel plates are presented in Fig. 9, the hysteretic loops in Fig. 10 and the strain energy in Table 3.

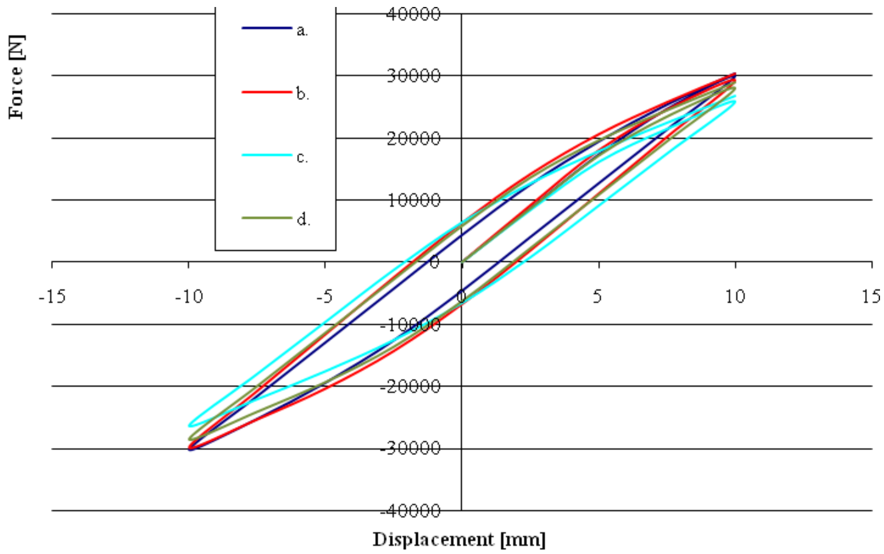


Fig. 10 – Hysteretic loops.

Table 3
Strain Energy

Model	Strain energy, [J]
a	283
b	335
c	313
d	360

5. Conclusions

The main conclusion that can be drawn is that the concept of the energy dissipative columns works best with big storey displacements, as seen in Fig. 2. For small storey displacements several measures must be taken into consideration in order to absorb the seismic energy more efficiently. The best method obtained so far is to increase the stiffness of the active steel plates. These plates have the advantage of simple construction.

In the case of the mechanism represented in Fig. 5, the resisting forces are lost within the mechanism itself. The forces are decomposed at the hinges. Another disadvantage of this mechanism is that it can be difficult and complex to build. The advantage is that after a major earthquake the damaged active steel plates can be easily replaced.

Further research will be carried out on ways to improve the energy dissipation capacity of these columns.

REFERENCES

Hicks S.J., Lawson R.M., Rackham J.W., Fordham P., *Comparative Structure Cost of Modern Commercial Buildings*. Sec. Ed., The Steel Constr. Inst., Ascot, 2003.

Venghiac V.M., Ciongradi I.P., Budescu M., *Steel Structures with Composite Floors and Energy Dissipative Columns*. Internat. Symp. „Computational Civil Engineering 2010", Iaşi, România, 2010.

Venghiac V.M., D'Mello C., Ciongradi I.P., Budescu M., *A Parametric Study Regarding the Dynamic Behaviour of the Slimdek Composite Flooring System*. Proc. of the Internat. Conf.: DEDUCON – „Sustainable Development in Civil Engineering". Edit. Soc. Acad. „Matei-Teiu Botez", Iaşi, România, 2011.

* * * *Better Value in Steel – Composite Flooring – Floors Using Steel Decking*, The Steel Constr. Inst., Ascot, 2001.

* * * *Engineered Flooring Solution*. SLIMDEK, Corus, Scunthorpe, North Lincolnshire, 2001.

* * * *Integrated Finite Elements Analysis and Design of Structures*. SAP2000, Tutorial Manual, Comp. A. Struct., Inc., Berkley, California, USA.

* * * *SLIMDEK Manual*. http://www.corusconstruction.com.

* * * *User's Manual*. Revision 11, ANSYS, Inc., Canonsburg, PA, USA, 2009.

METODE DE OPTIMIZARE A STÂLPILOR DISIPATORI DE ENERGIE

(Rezumat)

Sistemele de planşee compozite subţiri, cum ar fi cele SLIMDEK, prezintă anumite dezavantaje în cazul folosirii acestora în zone seismice. Cel mai important dezavantaj îl constituie capacitatea redusă de disipare a energiei. Înglobarea grinzilor în beton elimină apariţia articulaţiilor plastice, care sunt mecanisme de disipare a energiei seismice. Pentru a corecta acest inconvenient sunt propuşi stâlpii disipatori de energie. Stâlpii studiaţi până acum prezintă o bună capacitate de disipare a energiei la deplasări relative de nivel mari. În lucrare sunt studiate câteva metode de îmbunătăţire a acestor stâlpi supuşi la deplasări relative de nivel reduse. De asemenea, se efectuează şi un studiu de caz. S-a analizat o structură multi-etajată pentru a determina o deplasare relativă de nivel, care a fost folosită ca acţiune în studiile metodelor de îmbunătăţire a stâlpilor disipatori de energie.