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Comparative analysis of two seismic energy dissipation solutions in the case of a steel structure

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1. INTRODUCTION

The present paper aims at the comparative analysis of two seismic energy dissipation solutions for a steel structure in frames. We opted for non-braced frames and centrally braced frames. In the case of unbroken frames, the resistance structure consists of steel beams and columns. Potential plastic areas are formed mainly at the ends of the rulers and, to a lesser extent, in columns. Horizontal actions are mainly taken by bending the structural elements. In order to ensure the most efficient observance of the rigidity requirements for lateral actions, the solution of rigid beam-column joint is required. The use of the concept of weak beam - strong column leads to the appearance of plastic joints in the beams, close to their joints with the columns. Centrically braced frames are able to take over the horizontal actions, which are manifested in their plane, through axial forces. Energy dissipation occurs mainly by plasticizing the extended diagonals. The comparative analysis consists in highlighting the results obtained from the structural calculation with the help of a commercial automatic calculation program for the two solutions: non-braced frames and centrally braced frames. An office building with 2 levels was analyzed, located in Constanța, where the two types of staff were provided in turn. The obtained results will be compared from the point of view of the amount of steel used, so from the economic point of view. Another comparison refers to the displacements to SLS and SLU and to the seismic energy dissipation capacity.

Last but not least, another possible comparison refers to the over-resistance of the structural system

2. Case study of metal structure in non-braced frames

1. *Verification of the strength and general stability of the beams*
2. *Calculation of the super resistance of the structural system (Tabel 1)*
3. *Verification of the strength and general stability of the columns*
4. *Checking the beam-pillar joints*
5. *Vibration modes*
6. *Check displacements to SLS and SLU (Tabel 2)*

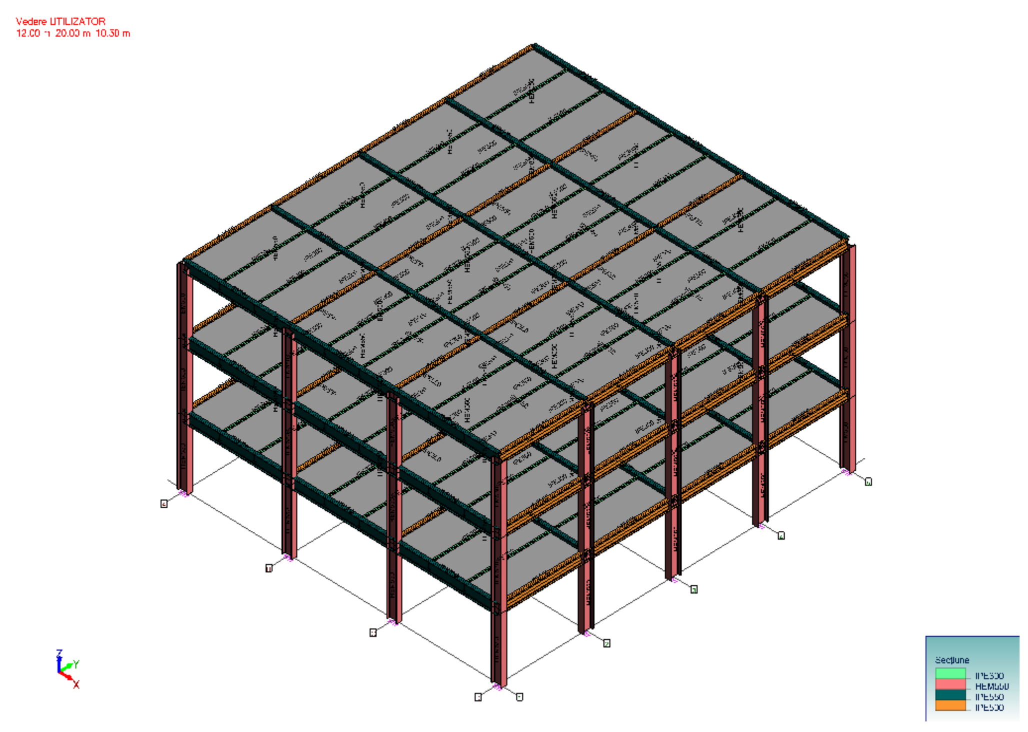

Figure 1.3D model of the structure non-braced frames

Tabel 1. Super-resistance calculus Ω_T , X direction

Opening	Level	M_{Ed}	$M_{pl,Rd}$	M_{Ed} / $M_{pl,Rd}$	$\Omega_i^M = M_{pl,Rd}/M_{Ed}$	Ω^M	$\Omega_i^M - \Omega^M$	$\Omega_i^M - \Omega^M$ (%)	Ω_T
A-B	2	146.02	696.75	0.210	4.772	3.40	1.37	28.76	4.86
	1	194.9	696.75	0.280	3.575		0.18	4.91	
	P	204.71	696.75	0.294	3.404		0.00	0.12	
B-C	2	129.24	696.75	0.185	5.391		1.99	36.94	
	1	174.45	696.75	0.250	3.994		0.59	14.89	
	P	183.33	696.75	0.263	3.801		0.40	10.55	
C-D	2	145.39	696.75	0.209	4.792		1.39	29.06	
	1	195.39	696.75	0.280	3.566		0.17	4.67	
	P	204.96	696.75	0.294	3.399		0.00	0.00	

The super resistance Ω_T Y direction is 3.98

The structural calculation is performed with the Advance Design 2020 (Graitec) automatic calculation program (Figure1).

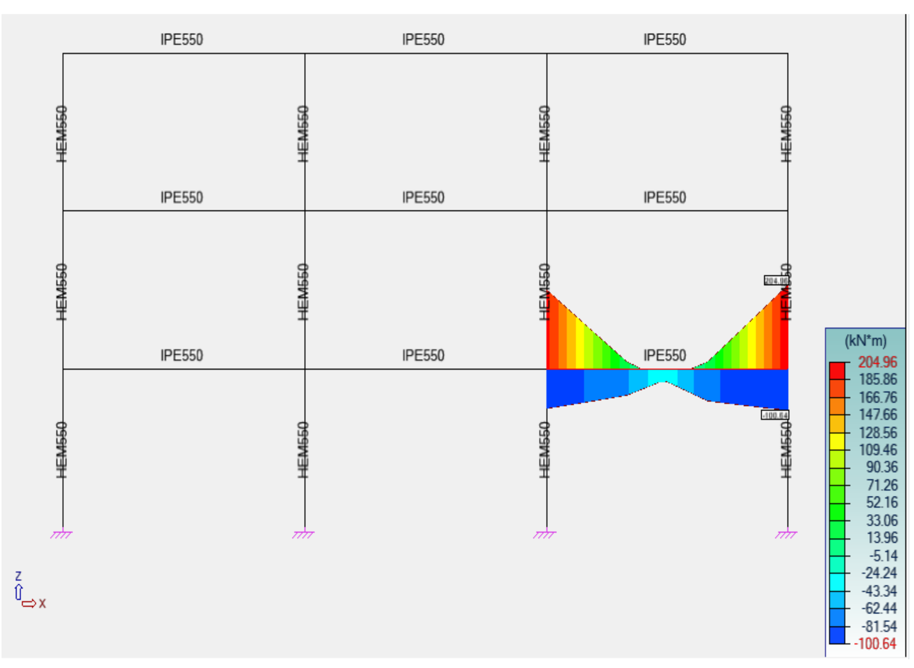

Figure 2. The bending moment diagram of the most requested beam

Tabel 2. Check displacement at last limit state **(SLU)**

	d_{re}				d_r^{ULS}			check	
level	DirectionX	Direction Y	c	q	Direction X	Direction Y	$d_{r,a}^{ULS}$	Direction X	Direction Y
floor 2	0.0115	0.0001	1.074	4	0.0494	0.0004	0.0875	ok	ok
floor 1	0.0131	0.0002	1.074	4	0.0563	0.0009	0.0875	ok	ok
Ground floor	0.0099	0.0004	1.074	4	0.0425	0.0017	0.0875	ok	ok

3. Calculation of strength and stability of the structure in centrally braced frames

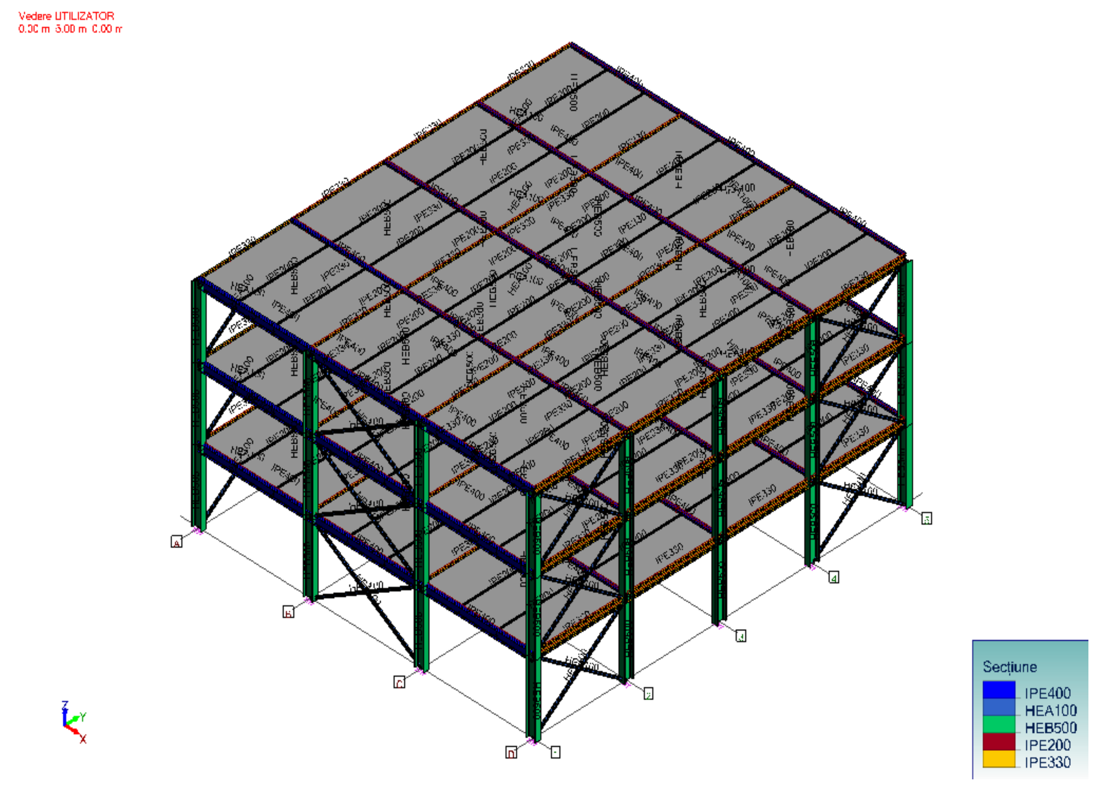

Figure 3. The spatial model of the non-braced structure in the calculation program

The structure, which is to be analysed, is made up of a centrally braced X-shaped frame arranged in the transverse axis 1 and 5 (X direction) and in the longitudinal axes A and D (Y direction).The stell frame has 2 floors, 3 openings and 4 open beams.

The diagonals were dimensioned according to Eurocode and was calculated of the super resistance of the structural system.

Tabel 3 Calculation of the super resistance Ω_T , on the X direction

Opening	Level	N_{Ed}	$N_{pl,Rd}$	N_{Ed} / $N_{pl,Rd}$	$\Omega_i^N = N_{pl,Rd}/N_{Ed}$	Ω^N	$\Omega_i^N - \Omega^N$	$\Omega_i^N - \Omega^N$ (%)	Ω_T
B-C	2	117.22	531	0.221	4.53	3.00	1.53	33.87	4.28
	1	177.27	531	0.334	3.00		0.00	0.00	
	P	143.21	531	0.270	3.71		0.71	19.21	

The super resistance Ω_T Y direction is 6.01

The difference between the maximum and minimum ratio Ω_i^N is less than 25% for each direction of the structure. In the X direction this difference is 19.21%, and in the Y direction it is 13.21%.Exceptions to the rule make diagonals to the 2nd floor, which results in being oversized.

Other calculations made refer to: the buckling of the column; compression and bending verification; calculation of joints of dissipative elements (bracing).

4.Conclusion

One of the principles of anti-seismic design is the imposed of a favourable structural mechanism for energy dissipation (plasticization mechanism) under high-intensity seismic actions, thus preventing the collapse.

In the case of the centrally braced structure, the dissipative zones are located, in particular, diagonally, when they are stretched.

For steel structure in non-braced frames were used steel profiles HEM550 for columns, IPE 550 for main transverse beams, IPE500 for longitudinal main beams, and IPE 300 for secondary beams, resulting in a total weight of 124 tons.

In the case of the centrally braced structure, the dissipative zones are located, in particular, diagonally, when they are stretched.

For the metal structure in centrally braced frames, HEB500 metal profiles were used for columns, IPE 400 for main transverse beams, IPE330 for main longitudinal beams, IPE 200 for total beam and for diagonal beams, and HEA100 for bracings resulting in a total weight of 81 tons.

The structure in unbroken frames will have a better behaviour to the seismic action, it presents a high ductility, ensuring the dissipation of a large amount of energy, but it does not require larger sections of the elements. It is preferred by architects as it does not condition the positioning of gaps for windows on the facade.

The centrally braced structure has a limited ability to dissipate seismic energy. The existence of diagonals makes the beam sections smaller, and therefore an advantage in terms of economic value. It is not preferred by architects as it conditions the positioning of the gaps for windows on the facade.

References:

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