STRAINS AND STRESSES IN TWO METAL STRUCTURES FOR STORAGE

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Abstract: *The paper performs a numerical analysis with the RDM 6 software concerning the behaviour under loading of some beam structures. The maximal stresses and deflections, reaction and internal forces were determined. Solutions were proposed to optimize the stress distributions and to increase the general stability of the structures.*

Key words*: strains, stresses, metal structures, stability, finite element*

1. GENERAL CONSIDERATIONS

Metal structures are formed of separate assembled elements, representing tridimensional systems with the purpose to satisfy the specific features of working under load.

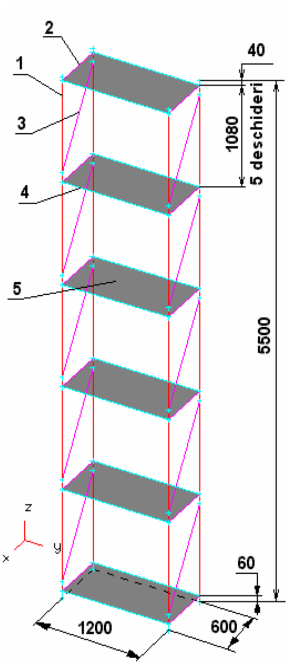


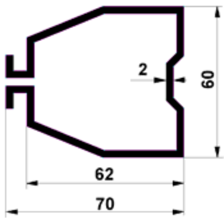
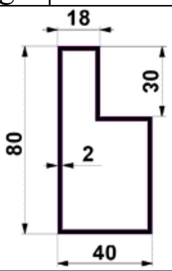
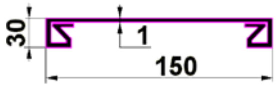
Fig.1 General view of the metal stand "B60".

The metal structures' strain and stress calculation in each of its elements that have a part in bearing the given loads has the goal of ensuring a high reliability of the spatial assembly using the minimum weight condition – [1,4].

Out of the great variety of metal furniture used for industrial storage (beams, pipes, different rolled metals cross-sections, plates, rods etc.) or commercial storage of goods – stands, shelves, etc. – two types of spatial structures are examined further on.

a *The metal stand "B60"* (Figure 1) consists of two lateral legs 1, with sleepers, 2, and cross bars, 3, connected with bearing sleepers, 4, that support the shelves, 5. Table 1 contains the cross-sections and sizes of all the components of the stand, plus the types of load they bear.

Table 1. Cross-sections of the components for the metal stand "B60"

Crt.nr.	*Component*	*Cross-section*	*Load*
1	Leg	 	Own weight
2	Sleeper	Ring - ϕ21.3x2.3mm	Own weight
3	Cross bar	Ring - ϕ21.3x2.3mm	Own weight
4	Bearing sleeper	 	Own weight
5	Shelf	 	Own weight and a load of 3.41 N/mm

The stand legs are fixed with anchor bolts to the foundation (floor). The cross bars, 3, and the sleepers, 2, and, 3, are connected with bolts to the legs. All joints are considered to be rigid with the exception of the cross bar – leg connection, that is an articulated joint (Y - axis of rotation) – figure 1. Shelves, 5, are simply supported on the bearing sleepers 4.

The lower sleepers are situated at 65 mm from the floor, while the upper sleepers - at 40 mm from the upper end of the leg. The spacing between the lower and the upper sleepers is equally devided in five intervals.

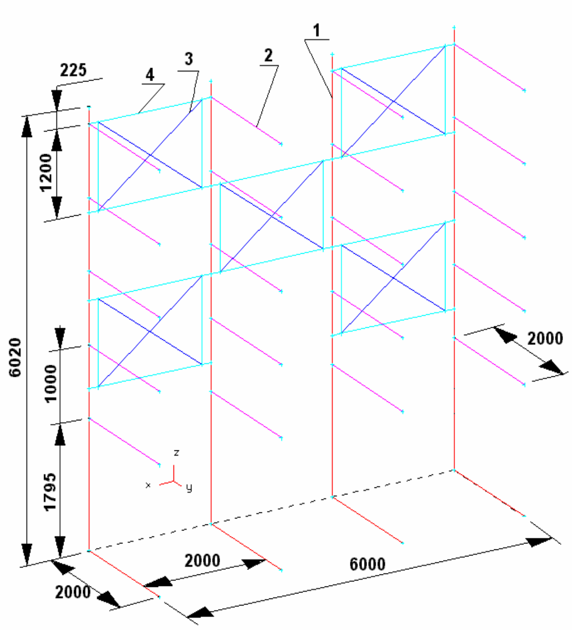
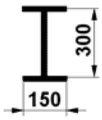


Fig.2 General view of the metal creel "P".

b. *Metal creel "P"* - this kind of metal structure allows the creation of continuous storage surfaces that are well adapted for the traditional means of load carryal, such as forklift trucks, overhead cranes, etc. It has a single access side and is designed to be positioned by the wall, considering the specific form with cantilever bearing beams. The metal creel is composed of columns, 1, cantilevers, 2, and stiffness elements, 3, and, 4 – Figure 2.

In the considered case, the columns are not fixed in any way to the walls. All the elements are considered to be rigidly joined. Table 2 contains the cross-sections of all the elements for the considered creel.

Table 2 Cross-sections of the elements for the metal creel "P"

Crt. nr.	***Component***	***Cross-section***	***Load***
1	Column	**I** shape - 	Own weight
2	Cantilever	**I** shape - IPE 120	Own weight and a load of 1.5 N/mm
3	Stiffness sleeper	Square shape ring (side/wall thickness) – 80/8.0 mm	Own weight
4	Stiffness cross bar	Square shape ring (side/wall thickness) – 22/2.3 mm	Own weight

The strength calculation of these structures has the following goals [1,3]:

1. Determination of the internal forces generated in the component elements as a result of the action of the carried loads;

2. Checking or sizing of the component elements;

3. Calculation of system's maximal displacements (strains) and/or foreseeing the measures for maximal displacements limitations.

The metal structure may be broken in two of the following situations:

- the exhaustion of the strength capacity (i.e. the breaking of the most stressed element) or the stability loss of a component (or even of the entire structure);
- exaggerated displacements.

2. STRUCTURE MODELLING

The metal structures are schematized for the strength calculations. The simplifications refer to the geometrical form of the structure, the distribution mode of the loads and supports, as well as to the behaviour of the structure and material under the load. The basical statics principle is used in the analysis: the whole metal structure, as well as any of its components – should remain in statical equilibrium under the action of exterior loads and internal forces.

The schematization used can be followed in figures 3 and 4, where additionally the distribution of loads and supports is shown. The strength calculations were made using the finite element program "RDM" with the 3-D bar structural analysis "OSSATURE" module – [2,5].

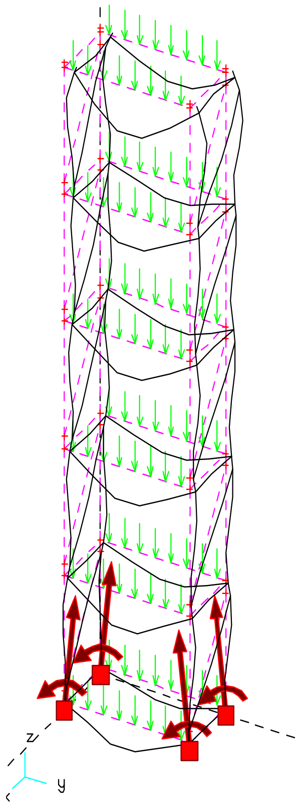


Fig.3 Deformed shape, reactions and loads on the metal stand "B60".

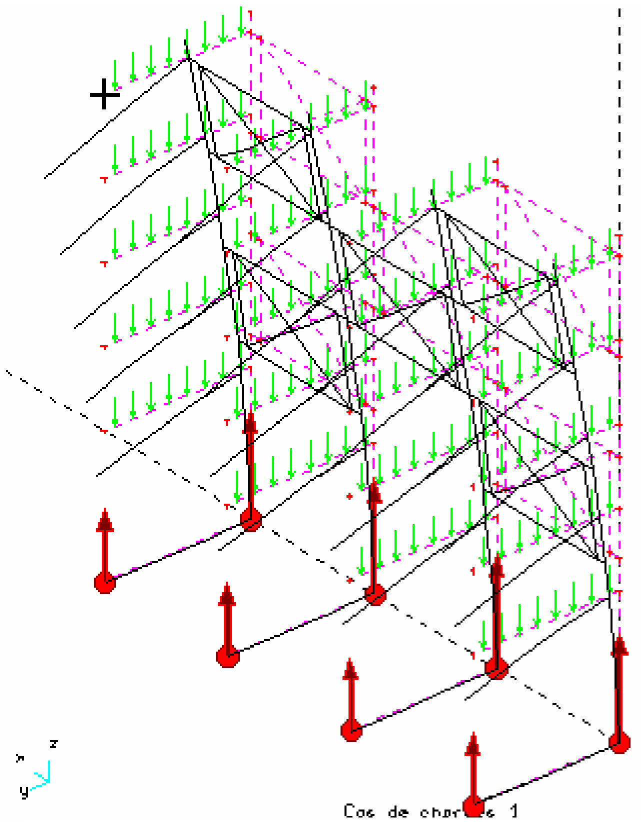


Fig.4 Deformed shape, reactions and loads on the metal creel "P".

Static loads applied to the structures are composed of:

- Own weight of the bars – oriented in the negative direction of OZ axis, calculated by the program considering the mass of the components of the structure;
- Exterior loads, considered uniformly distribuited over the length of the bearing elements – Fig.3 and Fig.4.

The numerical computation of the problem is based on the use of finite elements of "bar" type, with 2 nodes, each node having 6 degrees of freedom. The RDM program does the meshing of the structure automatically.

3. RESULTS AND OPTIMIZATION POSSIBILITIES

As a result of the computation, the finite element program gives: the reactions in each support; the internal forces in every component (axial, shearing, bending and torsional); the displacement of every point of the structure (including the maximal displacement(s) and the position of that point (Figures 3 and 4)), normal stresses resulting from axial and bending loads, separated or combined (Figures 5 and 6). One can obtain also the buckling mode of the structure, as well as the buckling coefficient K_f (defined as the ratio between the critical buckling force F_{cr} and the computation force F_c – K_f=F_{cr}/F_c) (Figures 7 and 8).

The following results were obtained for the metal stand "B60":
After the numerical computation, without plotting the shelves (simply supported, that have no influence over the stiffness of the system), whose loads were redistribuited on the bearing sleepers 4, one can see that the maximal normal stresses $\sigma_{max4}=109.24$ MPa, are at the ends of the lower pair of the sleepers 4. The structure has a general buckling coefficient $K_f=15.3$, being obvious that the crushing load is limited by the strength (breaking) capabilities of the most stressed component. For the cross bars 2 and sleepers 3, maximal normal stresses are $\sigma_{max2,3}= 6.01$ MPa, which shows that their current cross-section is overdimensioned. For the legs 1 $\sigma_{max1}= 82.5$ MPa.

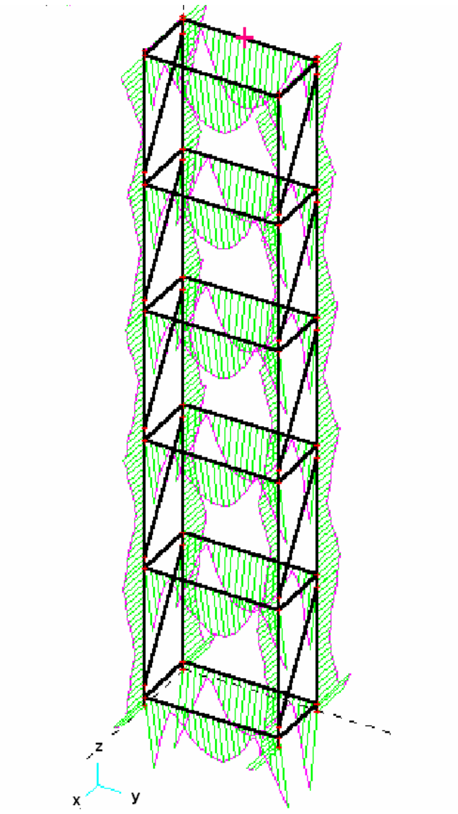


Fig.5 The diagram of the normal stresses in the elements of the metal stand "B60"

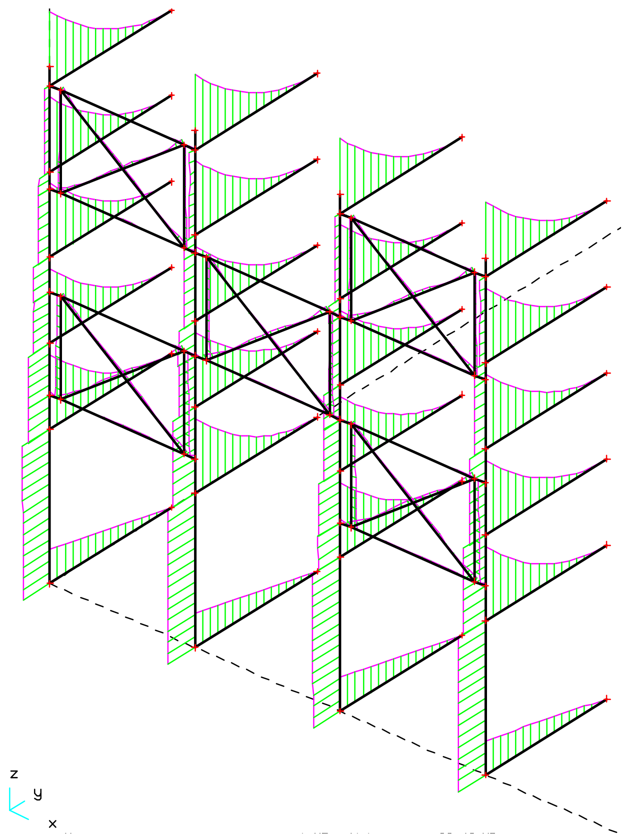


Fig.6 The diagram of the normal stresses in the elements of the metal creel "P"

Because of the great stability reserve of the structure and its mode of buckling (figure 7), it was possible to "optimize" the metal stand by removing the cross bars 2. As a result, the weight of the structure is reduced by 5.84%, while the buckling coefficient is still enough ($K_f=2.47$). The new optimized structure of the metal stand as well as its buckling mode is shown in figure 9.

Table 3 contains some comparative data for the initial and optimized structure of the stand "B60".

Table 3. Comparative data for the initial and optimized structure of the stand "B60".

Reference input	***Initial structure***	***Optimized structure***
Maximal displacement, mm	1.85	1.53
Cross-section of the cross bar 3,mm	ϕ21x2.3/steel	--
Maximal normal stresses/position	109.24/ends of lower sleepers 4	109.14/ ends of lower sleepers 4
Buckling coefficient, K_f	15.3	2.47

For the single-sided metal creel – considering it not bounded in any way to the nearby wall (simply supported at the lower end and free at the upper end), with the given loads, the deformed shape, shown in figure 4, distribution of normal stresses in every component – figure 6 and the buckling mode, plotted in figure 8 were calculated.

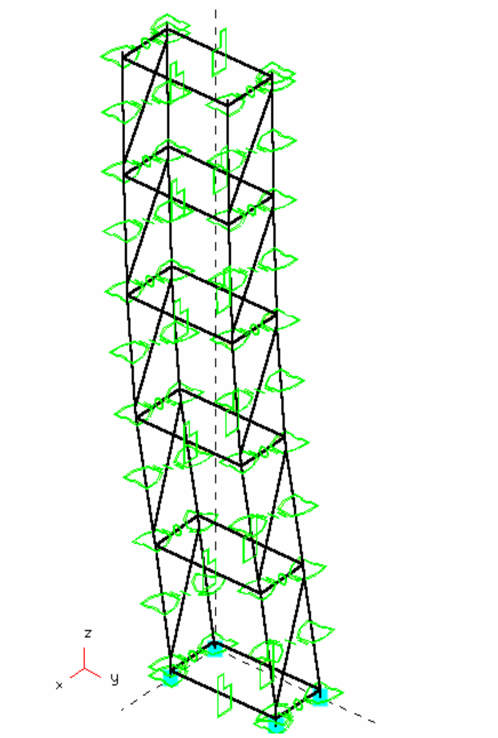


Fig.7 Buckling of the "B60" stand and the shapes and orientation of the cross-sections of the component elements.

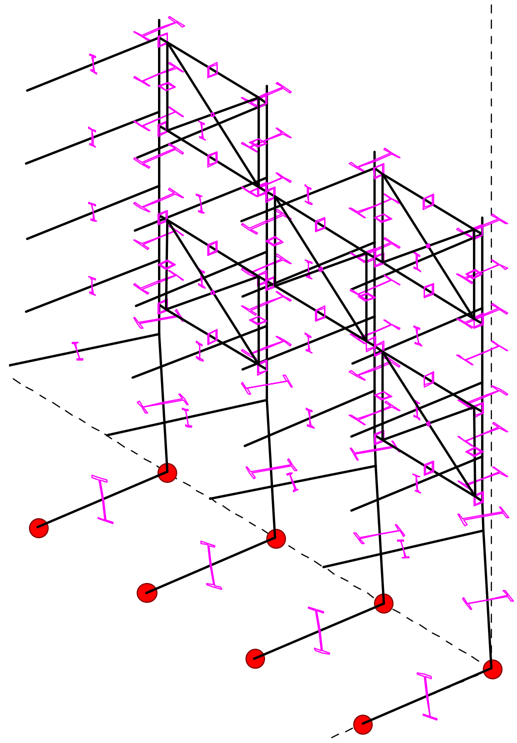


Fig.8 Buckling of the "P"creel and the shapes and orientation of the cross-sections of the component elements.

As one can see, the analysis performed on the metal creel, with the components layout shown in figure 2, the maximal normal stresses appear at the cantilevers 2 and columns 1 joints - $\sigma_{max2}= 60.16$ Mpa; the maximal vertical displacements of the cantilevers 2 free edges - $\delta_z=12.6$ mm and horizontal displacements (Y axis) $\delta_y=15.4$ mm. It can be noticed that even though the maximal normal stresses in the columns 1 ($\sigma_{max1}= 31.1$ MPa) and in the cantilevers are smaller then the allowable values, the obtained displacements at the cantilevers free edges are rather high (as absolute values). That is why, if there is need to store any kind of plates that require plane supports, the cross-section of the cantilevers (or columns) cannot be reduced. Instead, one can observe the great stability reserve of the metal assembly (table 4); so there is a posibility to obtain a structure with the same general characteristics of strength, but with a smaller buckling coefficient. With a view to that, all the cross bars were removed, while the stiffness sleepers 4 were redistribuited (and their cross-section - modified); the new resulting structure (with the maximal buckling coefficient) is shown in figure 10.

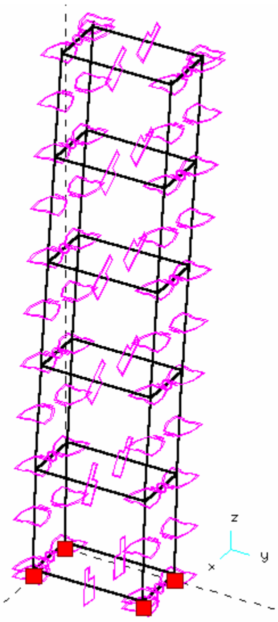


Fig.9 Optimized form of the metal stand "B60".

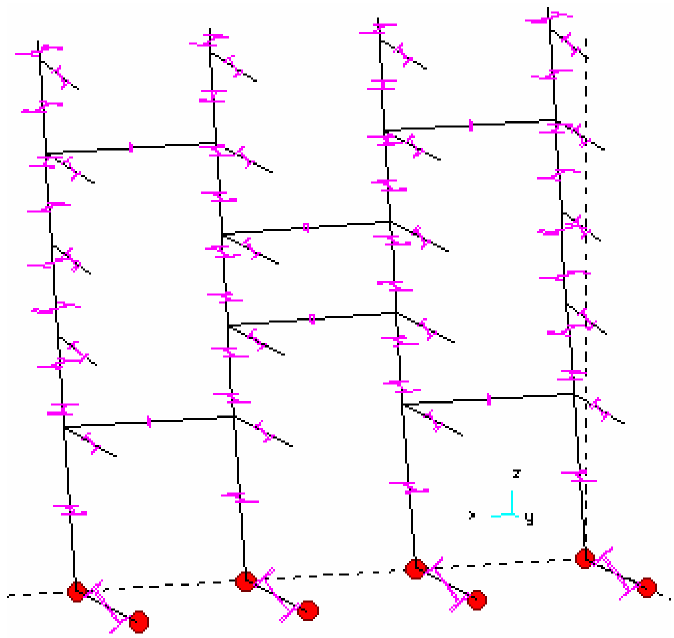


Fig.10 Optimized form of the metal creel "P".

Table 4 shows the comparative effect of the optimization upon the metal creel.

Table 4. Comparison data for the metal creels – initial and optimized structures.

Metal creel considered	***Cross-section of the stiffness sleeper 4***	***Buckling coefficient, K_f***	***Weight of the structure, N***
Fig. 2	Square ring shape 80x8 mm	12.45	25790
Fig. 10	Square ring shape 45x3.2 mm	2.84	20240

As a result, a net weight reduction of about 21.5% is gained, with an acceptable reserve to buckling.

4. CONCLUSIONS

The use of the finite element method through specialized RDM software, dedicated to 3-D bar structures such as the OSSATURE module, proved to be an efficient way of solving the analized spatial structures in this paper. The large number of computed cases in a short period of time allows one to take optimal decisions towards the improvement of a structure's behaviour under complex loading and support.

Processing of the acquired results gives the opportunity to generate functional solutions of maximal safety in operation, eliminating even the danger of elastic stability loss of the analized structures.

5. REFERENCES

[1] **Baikov V.**, and others. Calcul des structures. Moscou, Éditions Mir, 1984.

[2] **Debard Y.**, RDM – Calcul des structures par méthode des eléméntes finis, version 6.2. Institut Universitaire de Technologie du Mans, 1999.

[3] **Ferry Borges I., Castanheta M.** Siguranța structurilor. Bucureşti, Editura tehnică, 1974.

[4] **Mestat Ph.** et autres. Calcul des ouvrages en interactions. Paris, Éditions Hermès Sciences, 1999.

[5] **Țerna I., Dudescu C., Abrudan S., Crețu A.** Studiul comportării sub sarcini a unei rampe-suport pentru bărci de salvare. In „Lucrările Sesiunii de Comunicări Ştiintifice a Universității „Petru Maior" from Târgu-Mureş", 27-28 oct. 2000, pg. 209-216.