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14. Analysis of the Industrial Metallic Halls under Lateral Force Action Generated by an Earthquake in the Danube Delta Area

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Abstract: This paper presents the results of a seismic simulation for an industrial metal hall located in Sfantu Gheorghe locality in the Danube Delta. Seismic simulations have an important contribution when it is desired to design a metallic hall because, through them, we can better compute and stiffen the resistance structure. For this purpose, the behaviour of the metal construction to the action of the lateral forces was studied with the help of the automatic calculation for structure programs SCIA Engineering. The results obtained with the help of the structural modeling software are presented in the form of displacement diagrams in different viewing forms, thus providing an overview of the entire metal structure.
Keywords: metallic hall, lateral force, displacement, loads

INTRODUCTION

The pace of the industrialization of our country's economy determines the proper development of the construction sector and mainly the typing of the buildings. Among these buildings the industrial ones have a significant share, as for example: industrial halls ground floor or storey, warehouses, tanks, water chambers, silos, bunkers, chimneys, cooling cannons, etc.

The name of the industrial metal hall defines a large production area in the plan, ground floor or split. The overall composition of a hall is depending on the conditions of deployment the productive activity, the machinery and installations used in the manufacturing process, the necessary means of transport, the circulation and storage spaces, etc.

A detailed analysis of these factors has led to the conclusion that industrial requirements can be met, in all the cases of industrial halls type, which allows the promotion of industrialization of the elements and of the section types. The main industrialization path of these constructions is the prefabrication of the elements and the type of the sections. In order to reduce the weight of the buildings, it is necessary to use materials with high resistance, which contribute to the reduction of the dimensions of the bearing elements and thus of their weight. For metal constructions, it is recommended to extend the use of OL44 (S 275) and OL52 (S 355) high-grade steels.

The structural elements ensure the strength and stability of the construction. They need to be dimensioned and properly executed for the purpose of retrieval and transmission to their load systems. They can be grouped into horizontal structural elements (strips, plates, beams or combinations thereof) and vertical structural elements (columns, walls or combinations thereof). The foundations are also structural elements of construction. Non-structural elements perform certain functions that ensure the normal operation of the building, for example, non-bearing elements of closure, partitioning, finishing elements (floors, ceilings, etc.), ornamental elements, etc. The

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resistance structures for industrial halls can be classified according to several criteria as illustrated in Figure 1.

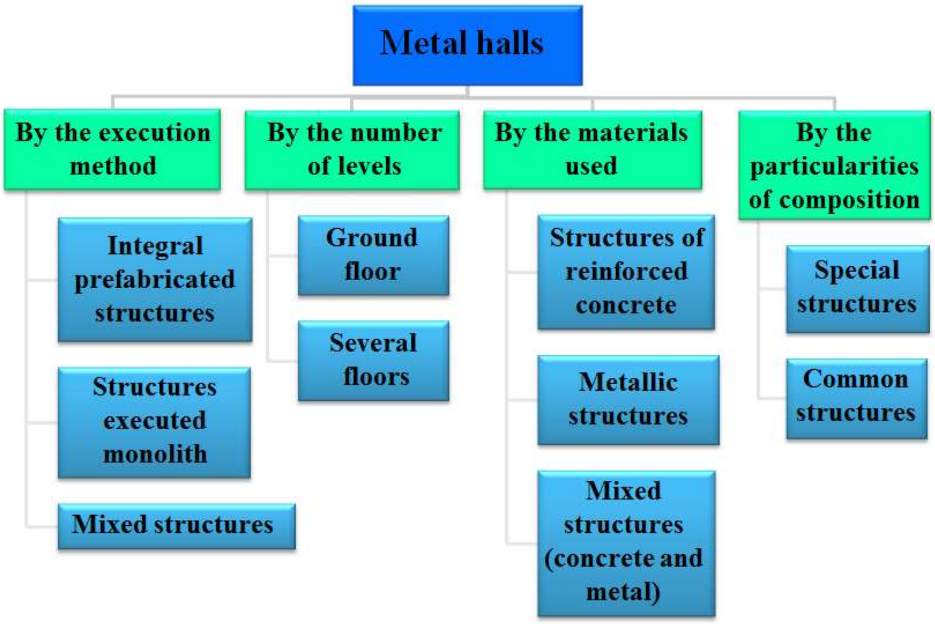

Figure 1. Classification of the structures of resistance for industrial buildings

The industrial halls ground floor provides functionally productive activities with technological flow taking place on a single level and, as a rule, along a single direction, along the hall. The gauge elements that geometrically define an industrial hall are the opening of the hall and the bay. The opening of the hall represents the distance between the axes of the columns, in the transverse direction. The bay represents the distance between the axes of the columns, in the longitudinal direction. The free height represents the distance from the finished floor surface of the hall until to the inner face of the roof elements.

Multi-storey industrial halls are recommended in all cases where the technological flow is mainly vertical with a reduced equipment weight. The execution of the multi-storey industrial halls is also indicated in situations where the production activity at one level is independent of the other levels and does not require gauge elements (openings, bays, free heights). Multi-storey industrial halls are structurally designed from transverse and longitudinal frames with rigid knots, ensuring the continuity of strains and deformations (Mahesh and Panduranga, 2014).

The ground floor industrial halls are the most important category of industrial buildings in terms of the number of objects and the size of the surfaces built in all areas of the country with a characteristic determined by their wide range of use.

In ordinary cases, for ground floor metallic halls, the plasticizing mechanisms of the metal structures, mobilized under the action of the earthquakes associated with the requirement of life safety, implies for each sense of the action of the earthquake the formation of plastic joints with the same direction of rotation at the ends of the beams.

MATERIALS AND METHODS

The calculation of the building elements and structures implies the consideration of combinations of the most unfavourable, of different loads. These combinations are represented by load groups. Building a structure involves dimensioning the elements of resistance under a certain degree of safety that takes into account any possible deviations that may occur in design, execution, and exploitation.

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These deviations may occur due to the following factors: in designing, schematizations are used of the resistance structure (static schemes), as well as the simplifications in the assessment and distribution of the loads, at execution, the quality of the materials, the dimensions of the elements may differ from the design, in exploitation, appear differences to the project. In some cases, the destination of the building may be changed over time or new tasks may arise due to the modernization of technological processes (machinery and installations, etc.), which alters the initial design assumptions (Toderascu and Rusu, 2013).

The loads acting on the structure of the industrial halls come from the weight of the building elements, the climatic actions (wind, snow, temperature variations), lifting and transporting equipment (cranes, suspended bridges, console cranes, etc.) or technological platforms that reside on the structure of the hall, etc. In some cases, some exceptional actions are also considered, such as loadings in technological failure situations, the settlement of foundations, seismic actions, etc (Balaji and Selvarasan, 2016; Onea and Rusu, 2014).

The transverse frame of the metal hall shall be calculated separately at each load. The determination of the effort is made in the elastic stage which allows overlapping in the most unfavourable groups. In special cases, the calculation can be adopted taking into account the development of plastic deformation in metallic elements.

The loads on the roof which belongs to the metal hall can be considered for frame calculation as uniformly distributed, although some of these are transmitted via panes. On the columns, some loads can also be transmitted from the weight of the suspended walls as well as from the weight of the columns. Depending on the height of the hall, the weight of the columns can be considered between 2 and 12 tonnes and sometimes even more; of which 10…30% represents the upper part (Bahador et al, 2012).

The action from the snow becomes determinant for elements of the roof strength structure in metal-structure halls, especially when the wrapper is light. Snow agglomerations, which generally occur at longer intervals, can lead to significant increases in stresses in some elements of the roof structure. Taking into account the fact that these actions occur at longer intervals and that they represent maximum possible loads it is admitted that the dimensioning of the metallic elements to be done with reduced safety coefficients.

The actions from the wind are manifested by the pressure exerted on the direct-acting face of the construction and through suction on the opposite face. Wind action on building elements produces forces whose components are normal and tangential (friction).

The seismic action in the case of metal halls is manifested through development in seismic motion of the contact area: construction-land. The action is spreading across the surface of the construction resulting in a phenomenon of oscillatory solicitation, chaotic, spatial.

For the design of the industrial metallic halls to seismic action, the territory of the country is divided into seismic hazard zones.

On the land surface, at a certain point, the seismic action is given elastic response spectra for absolute accelerations. The seismic force acting horizontally in the design of the metal halls is classified into two orthogonal components of independent seismic action between them. The seismic action is a function of time variation of acceleration when the dynamic structural calculation is performed (Mahesh and Yogesh, 2015).

In this paper, there is conceived an industrial metal hall with an opening of 14 meters on the transverse axis and 5 bays of 6 meters long on the longitudinal axis – Figure 2. The metal hall was dimensioned in SCIA Engineering automated computing program, having as input data: columns HEA280 (material S 275), frame beams IPE360O (material S 275), wind bracing HFLeg 90x90x9

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(material S 275), secondary beams IPE120 (material S 275), marginal beams IPE330O (material S 275), bundle IPE200 (material S 275), elbow roof RO57X16 (material S 275). The height of the metal columns on the Z axis is 5 meters. The seismic area chosen is Sfantu Gheorghe locality in the Danube Delta. The peak acceleration of the land is thus determined as 0.20g as illustrated in Figure 2.

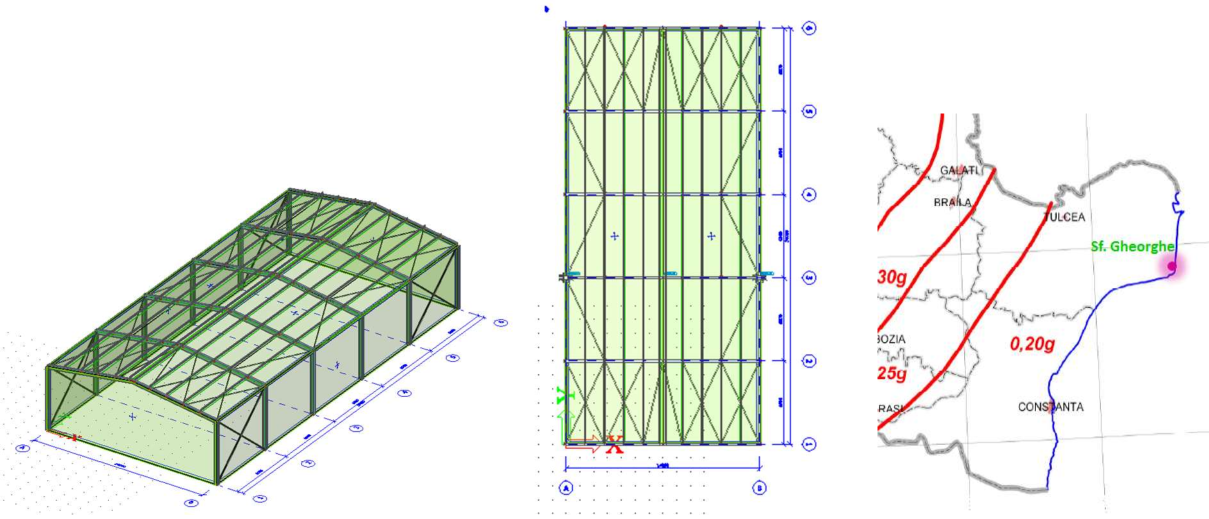

Figure 2. 3D view, plan view, location view – Industrial metal hall

SCIA Engineering is a software that performs the automated calculation of the structures. Generally, in our country, the structures are driven by static and/or dynamic loads, in compliance with the national and international norms in force.
When we want to model the structural elements for a metal hall, we must keep in mind that the modelling is based on the finite element method even if they do not work with finite elements but with self-contained entities which can be discredited with the help of the automated software before making the calculation. With the help of the SCIA calculation program, it is possible to dimension and calculates linear elements, i.e. linear finite elements or finite elements that are flat (curved surfaces, walls, floors). In the program can be introduced types of uploads. They are included in load cases for proper use in defining load combinations (Banescu et al, 2017).
The methodology used in Figure 3 analyzes the behaviour of the metal hall under the action of the side force caused by the occurrence of an earthquake in Sfantu Gheorghe locality in the Danube Delta. The structure is represented in a tri-orthogonal view considering a Cartesian system defined by the axes X, Y, Z in the plane.

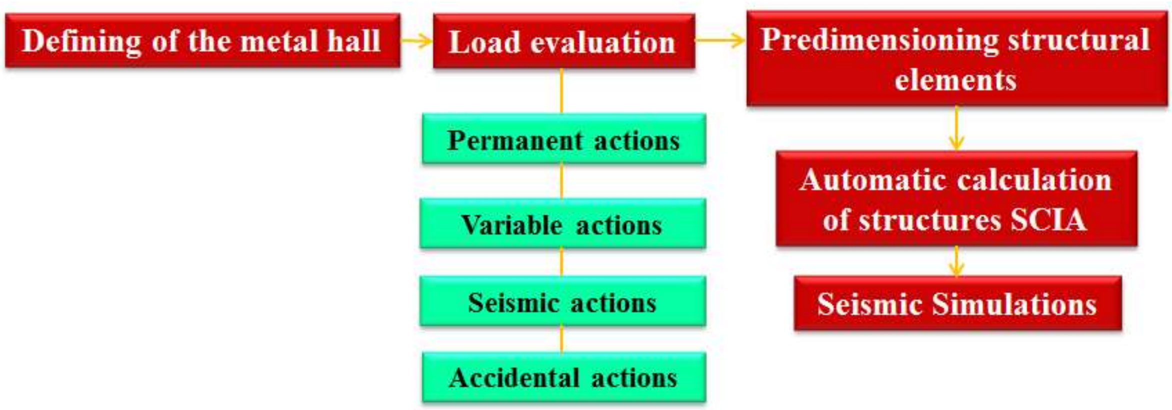

Figure 3. Schematic description of the methodology applied for generating the seismic simulations

The superstructure is conceived as a model of spatial frames, the columns being embedded in isolated foundations. In the modal calculation method, the side force action is evaluated on the basis

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of the response spectra corresponding to the unidirectional translational motion of the terrain described by accelerograms (Sultan and Peera, 2015).

The seismic risk is generally given by the highest value of the horizontal seismic acceleration of the field. It is determined for an average reference range, called the design field acceleration. The basic cutting force corresponds to its fundamental mode, for each main horizontal direction considered in the calculation of the metal hall. The basic cutting force is determined as follows:

$$F_b = \gamma_{I,e} \, S_d(T_1) \, m \, \lambda \quad (1)$$

Where $\gamma_{I,e}$ represents the factor of importance of the construction, $S_d(T_1)$ represents the ordered response spectrum for design corresponding to the fundamental period, m represents the total mass of the construction and λ represents the correction factor.

In the calculation, we will consider our own vibration modes with a significant contribution to the total seismic response, this being met if the sum of the effective modal masses for your own considered modes represents 90% of the total mass of the structure and were considered in the calculation all its own modes with effective modal mass more than 5% of the total mass (Banescu et al, 2017).

RESULTS AND DISCUSSIONS

The results presented hereunder are seismic diagrams corresponding to the analyzed metal hall. Figure 5 shows the behaviour of the metal hall when the side seismic force acts in the left direction, and Figure 6 describes the behaviour of the metal hall when the earthquake acts in the right direction.

In the definition of the load cases are introduced: wind loads, snow loads, structural weight and seismic load. After the load cases have been defined, the load masses have been generated – Figure 4.

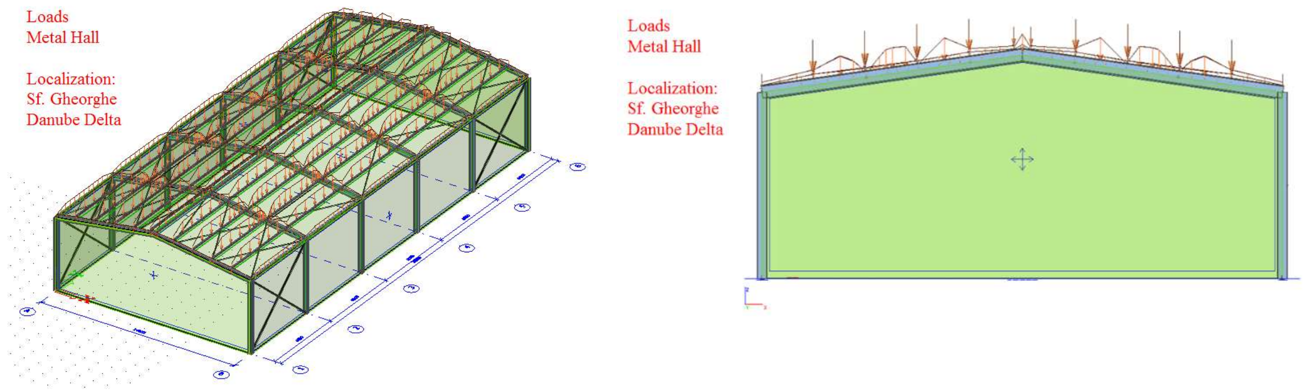

Figure 4. Snow loads on the metallic hall – 3D view, section view

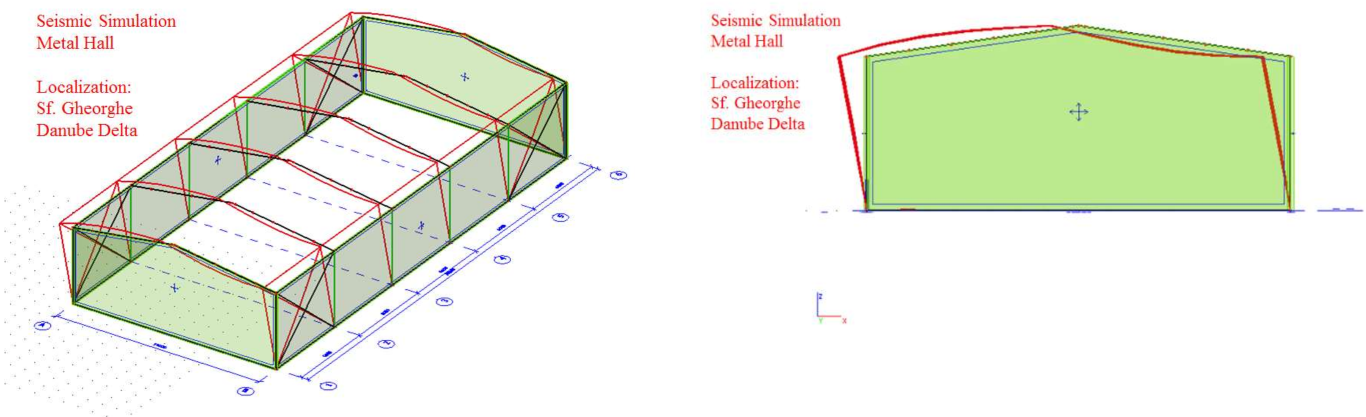

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Figure 5. Seismic simulation in the (left) direction – 3D view, section view – Industrial metal hall

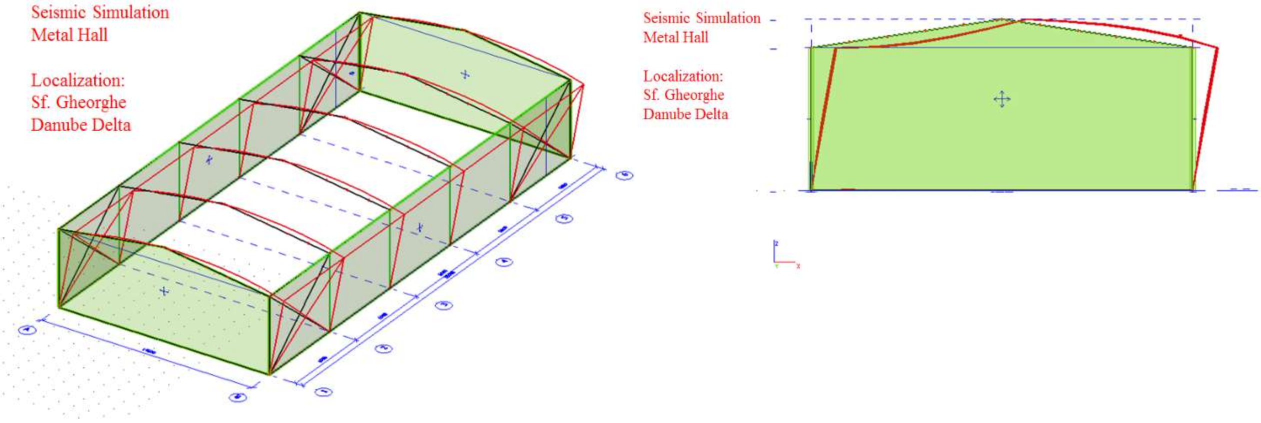

Figure 6. Seismic simulation in the (right) direction – 3D view, section view – Industrial metal hall

Below the 3D displacement diagrams are shown for the industrial metal hall in 2 phases: undeformed structure and deformed structure – Figure 7 and Figure 8.

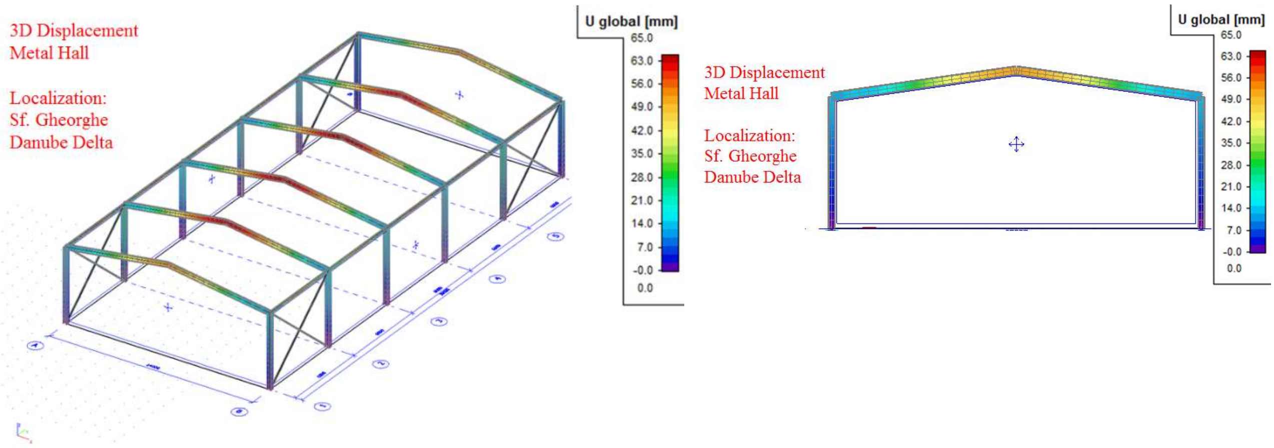

Figure 7. 3D Displacement of the undeformed structure – 3D view, section view – Industrial metal hall

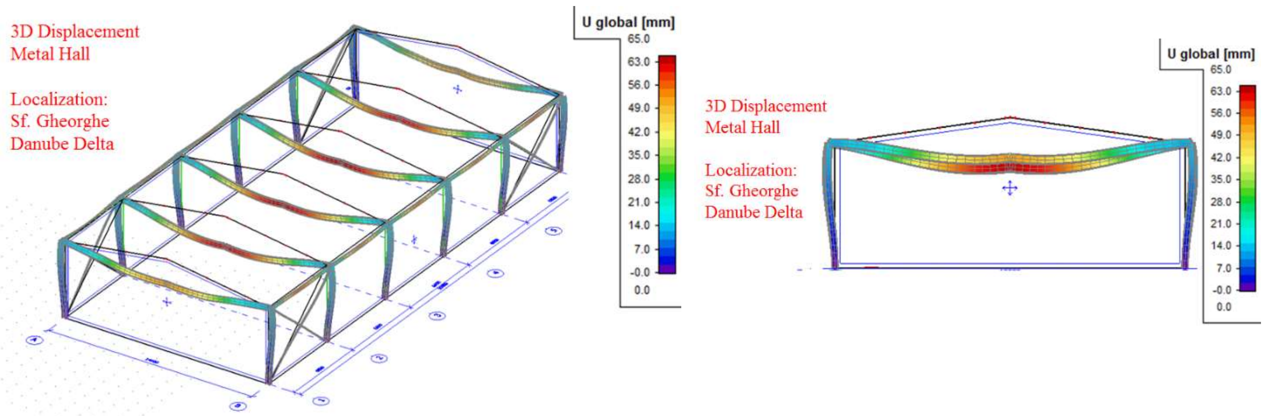

Figure 8. 3D Displacement of deformed structure – 3D view, section view – Industrial metal hall

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The global displacements for the industrial metal hall vary in different areas of the structural elements from value 0 mm to value 65 mm. Global displacements are largely concentrated for the most part on the central transverse frames 2-2, 3-3, 4-4 and 5-5 – Table 1. Marginal transverse frames (1-1 and 6-6) benefit from lower displacements compared to other frames with values up to 53 mm. This is due to the wind bracing system.

Table 1. Displacements of the structural elements – Industrial metal hall

	Transverse frame 1-1	Transverse frame 2-2	Transverse frame 3-3	Transverse frame 4-4	Transverse frame 5-5	Transverse frame 6-6
Column displacements [mm]	0-14	0-16	0-18	0-18	0-16	0-14
Beam displacements [mm]	14-53	16-63	18-65	18-65	16-63	14-53

Characterizing the type of behaviour of a structure, dissipative or non-dissipative, for the calculation, in the case of application of elastic calculation methods (with equivalent static forces or based on response spectra) is done through the behaviour factor. The total value of the behaviour factor can be expressed as the product of the over-resistance and the reduction factor due to ductility. In principle, any conforming structure and dimensioned correctly possesses over-resistance, due to the partial safety coefficients used to define the calculation resistors and uploads used in design (Diaconu and Rusu, 2013, Sharma and Maru, 2014).
The average value of the steel fluxion limit is in general higher than the nominal one and depends on the steel brand and the type of siderurgical product. The joints with screws of the structural elements who participate in the processing and to the transmission of seismic action (beams and columns for the frames which are not stiffened between them in the form of x, respectively beams, columns which are stiffened between them in the form of x) will be projected with high-strength screws. The stiffening in x form of the frames is represented by the wind bracing system.

CONCLUSIONS

The results of the present work lead us to some conclusions that can be outlined as follows.
The structural elements that make up the resistance structure of the metal halls provide the strength and stability of the construction. For this, the structural elements must be suitably dimensioned and built in order to be able to retrieve and forward farther the load systems.

The most important category of industrial buildings is the ground floor metal halls, having a characteristic determined by the wide range of usage.
The main forces acting on the strength structure of the metal halls are their own weight of building elements, wind force, snow force, the strength of the machinery that resides on the structure of the hall and the seismic force.
The lateral seismic force is manifested in the case of the metallic halls by introducing it in the seismic motion, the land-construction contact area.
The resistance capacity and stiffness of the frames who do not have a system of wind bracing (frames 2-2, 3-3, 4-4 and 5-5) required for the seismic action is ensured, in the main, of resistance and bending stiffness of the beams and columns, as well as the ability to transmit bending moments at the joints between beams and columns respectively of the joints between columns and foundations.
The frames that have wind bracing system (frames 1-2 and 5-6) in the form of x is generally more flexible. The vertical bar system of liaison ensures the uniformity axial efforts from the wind bracing system on the height of the structure.
A well-conformed structure overtaking the seismic actions must ensure by composition, calculation, sizing and constructive details a balance between resistance, stiffness and the ductility of the structural elements and their joints.

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