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THE IMPROVEMENT OF BEHAVIOR TO VERTICAL FORCES FOR STRUCTURAL ROOF ELEMENTS BY RECONFIGURING THE STATICS SCHEME. CASE STUDY

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Abstract: *The service level of safety is a main indicator for a building's structural performance. The non-fulfilment factors of this criterion are multiple. An important component is constituted by the increase of the loads intensity. In this context, the case study presented in this paper was conducted on a industrial building "type ground floor" and highlights the growth of strains in the roof trusses elements, higher than the initial ones witch ware considered, as a result of modification of prescriptions contained in the norms for vertical loads evaluation.*
In this situation, the fulfilment of the service safety to vertical loads was considered to be ensured by trying to redistribute the strains as a result of changing the supports.

Key words: *steel truss, strain, vertical load, restrain, beam.*

1. Introduction

The concept of safety in exploitation refers to a whole structural assembly and for an element or for a steel structure it is studied through the close-up view of the notions of bound state and the assurance level. In the present context, where a big part of the already built foundation has been designed and executed previous to the adoption of the new design rules in civil engineering, the question arise about the way of implementation of the safety level in exploitation for the structures designed after old norms.

1.1. General Presentation Data

The construction representing the focus of the case study belongs to a group of buildings with the end use of „ spaces of production", specific to the beneficiary's area of activity.

The inquired construction area is tooled up with bathrooms intended for the surface treatments specific to certain helicopter components, resulting due to the chemical substances used during the technological flow, in an aggressive environment for the construction elements that define the production space.

1.2. Presentation Data of the Inquired Construction

The inquired building, entitled „Surface treatments" is part of a production covered market, with a type ground floor.

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It has three spans of 24 m and 20 bays of 6m. Structural assembly has the following components: isolated foundations, reinforcement concrete columns by precast on site, transversal truss beams with an opening of 24.0m, with bearing on concrete column and on truss with opening of 12 m, alternating. The surface elements of the roof are coffer type of 1.50 x 6.00m, mounted at the superior bloom level of the transversal metal beams (Figure 1).

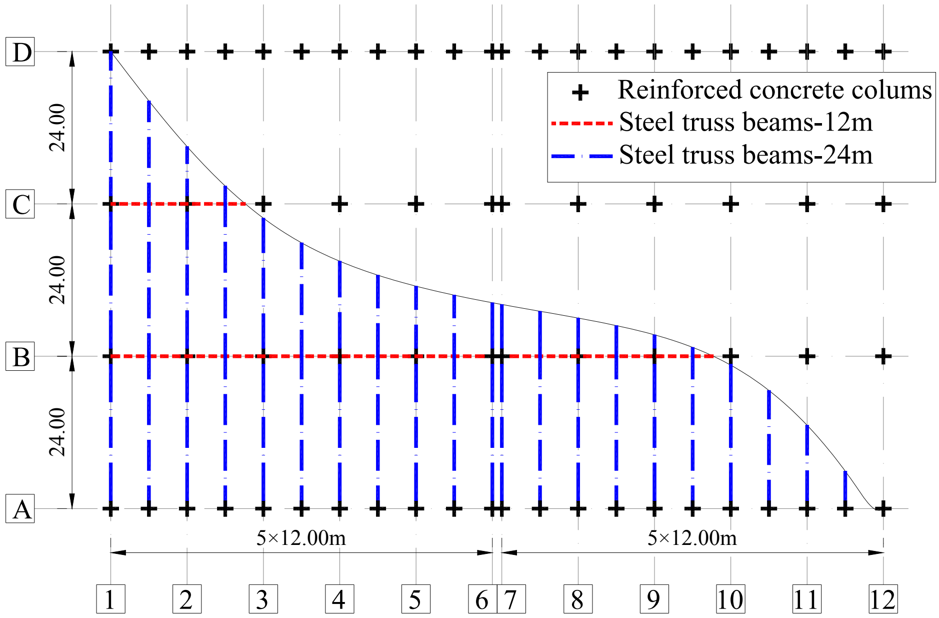


Fig. 1. *Structural elements arrangement*

1.3. Roof Elements Description

The steel trusses with a bay of 24 meters have the rails with an integrated section formed by two U profiles supported with small boards. The shape of these trusses is trapezoidal. The steel trusses with a bay of 12 meters are of rectangular shape with parallel chords [1]. This cross beam represents a prop for the truss of 24 meters and in turn it props up on the reinforcement concrete columns (Figure 2).

Taking into consideration the building's end use, namely „bathrooms for the surface treatment" of helicopter components, at the roof level there has been a steam release with a considerable corrosive substance content [2]. Among the substances heavily corrosive present in the building, there were: nitric acid, hydrofluoric acid, hydrochloric acid, sulphuric acid [2].

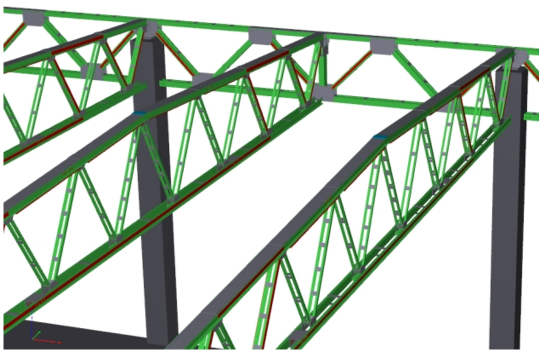


Fig. 2. *Structural system for roof*

2. The Case Study's Description

The investigated building presents different degradation stages for the structural and non-structural elements and many forms of manifestation of these, according to the materials, the location in the building, the type and transport mechanism of the aggressive agents.

The degradation state investigation followed the level of depreciation of the physic-mechanic characteristics of the structural elements, in order to determine the level of safety in exploitation these elements provide to the buildings structure, mostly following the endurance, stability and stiffness demanding fulfilments.

The investigation processes targeted structural elements, mostly roof trusses, and consisted in: the visual investigation of the degraded areas; the verification of the structural geometric dimensions using measurements; running non- destructive tests like spectral analysis; running destructives tests like traction on extracted specimens; local scraping.

The findings detached during the investigations, the results obtained after the measurements, the laboratory and on site determinations are presented for the roof structures elements in this study.

The investigations performed for the roof trusses revealed a relative good state of the component elements, without obvious section reductions produced by corrosion (Figure 3), noting some points and stains unsearchable by the rust in the steel structure, which penetrated only the protection layer, weld cords faulty executed, the absence of some bracings, deposits of dirt as special on the elements intersections, on the superior side of the horizontal elements, and on the supports.

On the trusses supports was noticed that not all the nuts wore adequate tight, the lack of some nuts, rusted screws, dirt deposits and support defects of the metallic trusses ends.

By clearing the surface, wasn't noticed any texture modifications in steel's structure and any geometrical modifications of the structural elements.

Fig. 3. *On site measurements of the elements geometry*

The spectral analysis result of the material highlighted that the chemical composition of the initial steel was kept, Table 1.

The chemical steel composition Table 1

Measured values	C%	Si%	Mn%	P%	S%	Cu%
Specimen 1	0.159	0.198	0.76	0.02	0.0025	0.171
Specimen 2	0.149	0.35	0.85	0.028	0.0030	0.245

Using the traction tests on specimens extracted from the steel structures elements (Figure 4), the steel's mechanic characteristics used for the trusses were determined. The specimens were extracted according to the technical norms and their dimensions respected SR EN 10025[4].

Fig. 4. *Steel specimens for traction tests*

The obtained results showed a satisfactory behavior of the steel, without a significantly deterioration of the elastic and mechanic properties (Figure 5). After the analysis of the characteristic curve of the material obtained on steel specimens a adequate behaviour can be observed. The steel has a 30-35% elongation and a rate between the maximum stress and yielding stress of 1.35.

To consider the materials ageing effect, a 10% reduction of mechanic characteristics of the steel of the structural elements was considered.

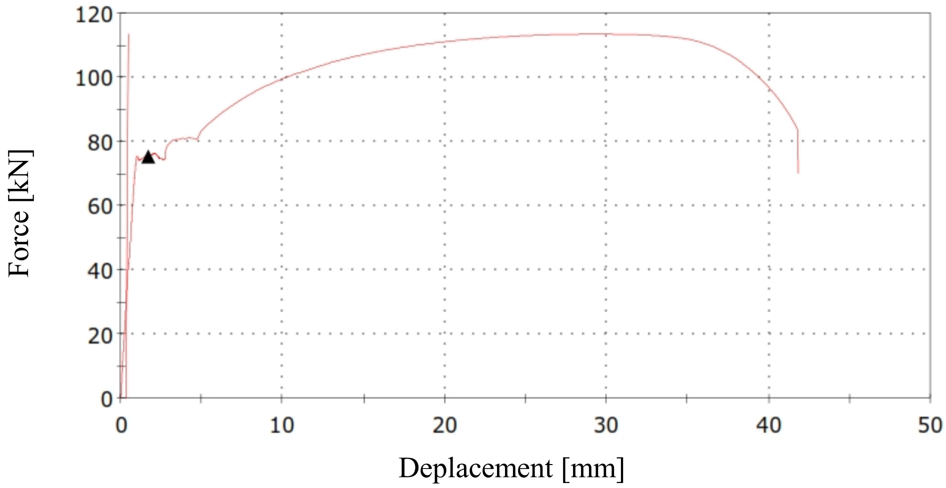


Fig. 5. *The load- displacement curve*

2.2. The Structural Analysis of the Metallic Roof Trusses

With the purpose of obtaining the safety levels, therefore of the level of accomplishment of the resistance and stability demanding for each element component of the metallic roof trusses, both buildings were modelled using the automatic analysis program Axis VM 9.

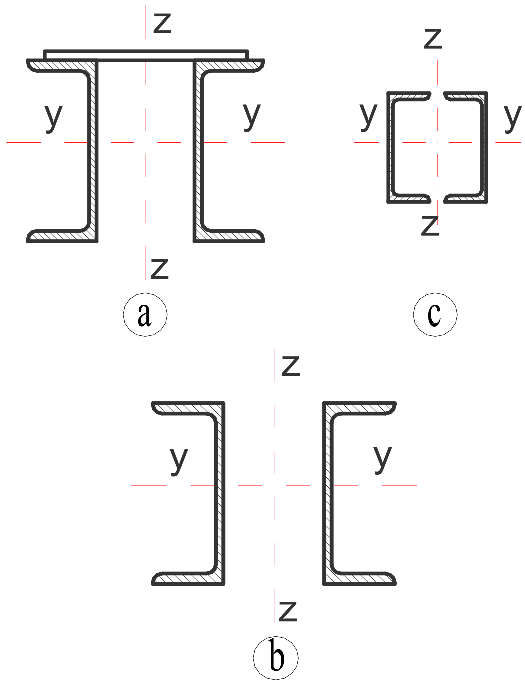
For the roof steel trusses having a span of 24.0 m, representing the transversal's frame beams, two distinct situations were considered:

- The trusses are considered freely supported beam;
- The trusses are considered continue beams on three equal spans of 24.0 m;

The purpose followed was to obtain a comparative analysis of the two distinctive situations and so to establish a solution of consolidation which will involve minimal financial costs and the necessity to intervene to a minimum number of elements.

For designing the trusses, U shape sections and steel plate were used and the articulated grip in the end of the elements was built with double brackets and welding cords.

The geometry of the elements is presented in Figure 6.



a) The upper chord cross section;
b) The lower chord cross section;
c) The cross-bracing cross section;

Fig. 6. *The cross sections of the elements*

For every element of the steel truss with a traction strain were established [3]:

- The value of the plastic strain in the raw cross section:

$$N_{t,Rd} = N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} \tag{1}$$

where:
A = area of the raw cross section;
f_y = yielding stress;
γ_{M0} = partial coefficient of safety for the resistance of the cross sections indifferent of the sections class;

For every compressed element of the steel truss were established [3]:

- The value of cross sections resistance to compression:

$$N_{c,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} \tag{2}$$

- The value of cross sections resistance to buckling:

$$N_{b,Rd} = \frac{\chi \cdot A \cdot f_y}{\gamma_{M1}} \tag{3}$$

where:
χ = the reduction factor for the buckling form considered;
γ_{M1} = partial coefficient of safety for the resistance of elements to buckling;

The trusses schematization and the knots numbering is represented in Figure 7 and strains obtained for simply supported beam and continue beam on three equal spans are presented in Table 2.

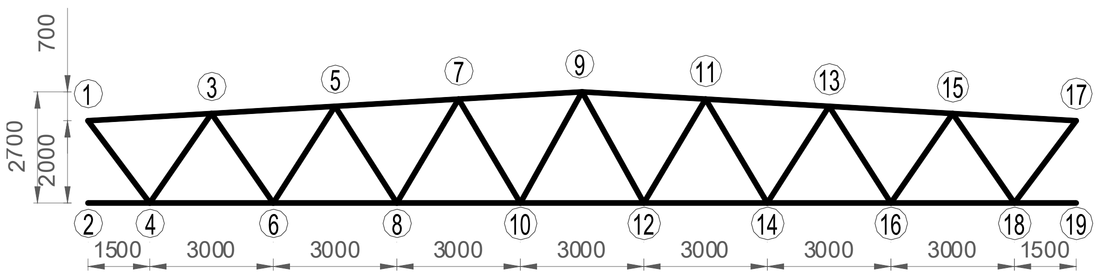


Fig. 7. *The numbering of the trusses knots*

Mechanic characteristics, strains and insurance coefficients for the 24 m span roof trusses

Table 2

Nr. crt.	Elements	Elements type	Slenderness coeffcient λy	λz	Reduction factor χ	The design forces resistance of cross sections: Tension $N_{t,Rd}$	Buckling $N_{b,Rd}$	**Freely supported beam** – Maxim strains: Tension $N_{t,Ed}$	Compression $N_{b,Ed}$	Degree of safety N_{Rd}/N_{Ed}	**Continue beam** – Maxim strains: Tension $N_{t,Ed}$	Compression$N_{b,Ed}$	Degree of safety N_{Rd}/N_{Ed}
						[kN]	[kN]	[kN]	[kN]		[kN]	[kN]	
0	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1;3	The upper chord	46	81	0.599	1409	845	0	432	1.96	-545	0	2.58
2	3;5		46	81	0.599	1409	845	0	1026	0.82	0	352	2.40
3	13;15		46	81	0.599	1409	845	0	1081	0.78	0	609	1.39
4	15;17		46	81	0.599	1409	845	0	496	1.70	-82	74	11.4
5	5;7		47	84	0.599	1665	999	0	1387	0.72	0	786	1.27
6	11;13		47	84	0.599	1665	999	0	1436	0.70	0	937	1.07
7	7;9		47	56	0.785	1665	130	0	1561	0.84	0	102	1.28
8	9;11		47	56	0.785	1665	130	0	1607	0.81	0	110	1.19
9	1;4	Support's diagonal	54	34	0.785	724	569	-713	0	1.02	-853	0	0.85
10	17;18		54	34	0.785	724	569	-824	0	0.88	-817	0	0.89
11	3;4	The diagonal	46	36	0.843	724	611	0	621	0.98	0	742	0.82
12	15;18		46	36	0.843	724	611	0	612	1.00	0	600	1.02
13	3;6		68	36	0.712	470	335	-429	0	1.09	-534	0	0.88
14	15;16		68	36	0.712	470	335	-424	0	1.11	-418	0	1.12
15	5;6		57	38	0.785	574	451	0	657	0.69	0	519	0.87
16	13;16		57	38	0.785	574	451	0	411	1.10	0	405	1.11
17	5;8		89	37	0.569	385	219	-254	0	1.52	-342	0	1.13
18	13;14		89	37	0.569	385	219	-249	0	1.55	-244	0	1.58
19	7;8		76	39	0.662	470	311	0	246	1.27	0	332	0.94
20	11;14		76	39	0.662	470	311	0	241	1.29	0	236	1.32
21	7;10		94	39	0.539	385	208	-97	33	3.98	-177	0	2.17
22	11;12		94	39	0.539	385	208	-101	35	3.81	-88	43	4.37
23	9;10		99	41	0.512	385	197	-36	68	2.91	0	156	1.27
24	9;12		99	41	0.512	385	197	-131	2	2.95	-152	0	2.53

25	2;4	The lower chord	22	13	0.984	1193	117	0	0	OK	0	115	1.02
26	4;6		43	75	0.662	1193	790	777	0	1.53	0	251	3.15
27	6;8					1193	0	1246	0	0.96	-451	0	2.64
28	8;10					1398	0	1507	0	0.93	-780	0	1.79
29	10;12					1398	0	1561	0	0.90	-898	0	1.56
30	12;14					1398	0	1557	0	0.90	-896	0	1.56
31	14;16					1193	0	1300	0	0.92	-673	0	1.77
32	16;18					1193	0	838	0	1.42	-257	0	4.64
33	18;19		22	13	0.984	1193	117	0	0	OK	0	642	1.83

The graphic representation of the results after the processing and interpretation of the results is represented in Figure 8.

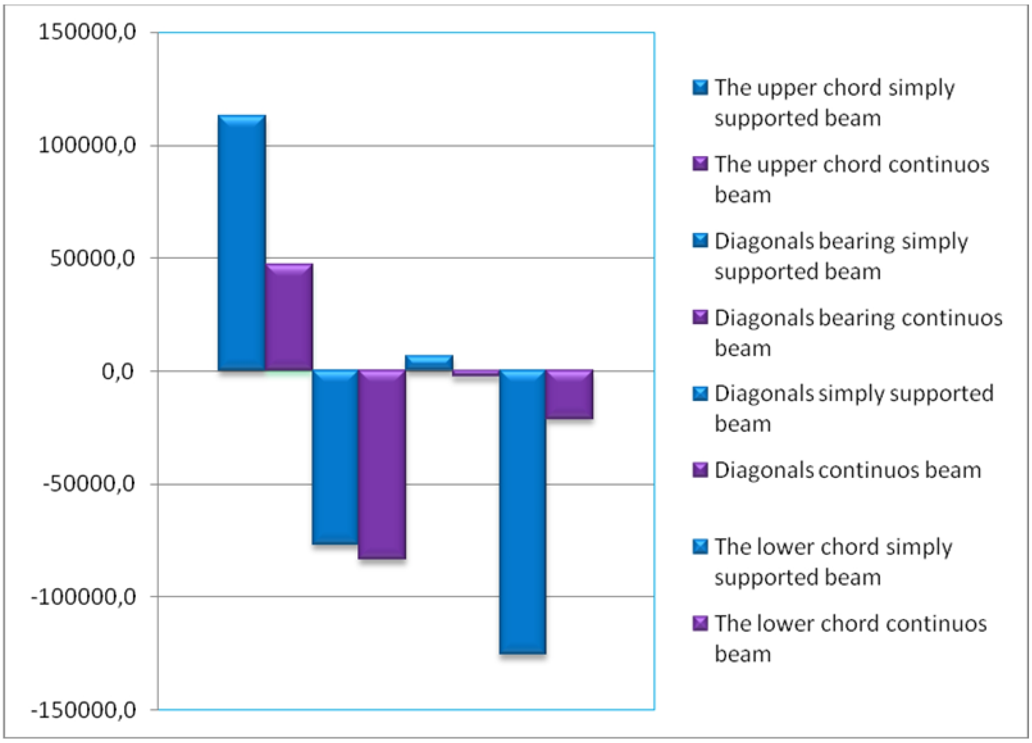


Fig. 8. *The graphic comparative representation of strains in trusses elements*

2.3. Improvement Solutions of Structure Behaviour of the Roof Steel Trusses

From the comparative analysis of the data presented in Table 2 results the benefit effect for the axial strains for some elements by the modification of static scheme from the freely supported beam to continue beams on three equal spans of 24.0 m.

The configuration of the static scheme was obtained by insuring the continuity connection between the chords of the trusses. The configuration of the static scheme leads to a diminution of the axial strains obtained for the vertical loads to 60% for the upper chord and current diagonals and 80% to the lower chord. An exception is the support's diagonal, who's strain is increasing after the change of the static scheme.

Choosing this solution implies a few interventions on the mechanic connections in the end of the elements, allowing the transmission of the axial strains from one chord to the other for two successive trusses, as well as the transmission of the axial strains from the lower chord to the concrete column.

The solution of improving the roof trusses for vertical loads by changing the static scheme leads to the modification of the strains in the component elements in intensity and in direction, as is shown in Table 2.

For the purpose of restoring the resistance capacity of the steel trusses, a few intervention measures can be adopted:

- changing the static scheme;
- increasing the cross sections;
- changing the mechanic connection at the end of the elements;
- prestressing some elements, etc;

The modification of the static scheme does not ensure the complete restoration of the bearing capacity [5]. For this reason it has to be applied simultaneous with other consolidation solutions. In this case study the enlargement of the cross section was applied.

3. Conclusions

Consolidation of component solutions to restore full bars bearing capacity aimed minimal intervention measures carried out under exploitation, without interrupting the production process. Following processing and interpretation of data obtained from the case study made that reconfiguration statics scheme by the modification truss steel solution "simply supported "with" continuous beam" leads to redistribution favourably internal forces by vertical loads and nature strain, registering reduce calculation values approx. 60%.

Through this type of operation has ensured substantial reduction intervention works and time to execution.

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