IOP Conf. Series: Materials Science and Engineering **245** (2017) 022056 doi:10.1088/1757-899X/245/2/022056

Conversion of a Temporary Tent with Steel Frame into a Permanent Warehouse

Mircea Georgescu[1,2], Viorel Ungureanu[1,2], Daniel Grecea[1,2], Ioan Petran[3]

[1]The Politehnica University, CMMC Department, Str. IoanCurea, nr.1, Timisoara, Romania

[2]The Romanian Academy, Timisoara Branch, CCTFA, Bd. Mihai Viteazul, nr.24, Timisoara, Romania (part time)

[3]Technical University of Cluj-Napoca, Str. Constantin Daicoviciu, nr.15, 400020 Cluj-Napoca, Romania

mircea.georgescu@upt.ro

Abstract. The paper is dealing with the problem of a functional conversion (involving both architectural and structural issues) applied to the case of an industrial building. As well known, temporary tents, designed according to the European Code EN13782, represent a remarkable stake on the building market and a fast and practical solution for some situations. It is exactly the case approached by the paper, where the investor has initially decided to erect on his platform a provisional shelter for agricultural machines and subsequent staff, built of a light steel structure covered by PVC roofing and cladding. This temporary tent has been acquired from a specialized supplier in form of a series product. After using the tent for a number of years, the investor has decided to convert the existing structure from architectural and structural point of view by switching to a permanent structure designed accordingly. Important changes were thus imposed both to the architectural part (technological flows, openings, facades) and especially to the structural part where this switch imposed a re-design to the codes of permanent structures (especially as far as climatic loadings are concerned). The required architectural change implied the building of a 70 cm high concrete plinth and replacing the PVC membrane temporary roofing and cladding by permanent 60 mm thick PUR sandwich panels. Together with a new system of openings this has led to renewed facades of the buildings. As for the structural change, the required conversion has imposed a thorough checking of the existing steel structure (very slender and typical to a tent) in view of transforming it into a permanent structure. The consolidation measures of the existing galvanized steel structure are described, together with the measures applied at infrastructure level in order to implement the required conversion.

1. Introduction - General about tents

Temporary structures (also called “tents”) are provisional constructions built of a steel or timber structure covered by a PVC or textile membrane working as roofing / cladding system. The safety requirements prescribed in the field are meant to safe-guard persons and objects against damage caused by design, manufacturing and operation of these structures. These tents are intended to be installed repeatedly without loss of substance, temporarily as well as on short term or long-term basis (case of present paper) at any places, and multiple purposes. Owing to the interest of the market on such constructions, the different existing national regulations and guidelines were collected in the frame of a unified code at the level of the European Union [1] of which some specific provisions are hereby very briefly presented. The design documents shall include information for the verification of the stability, resistance and operating safety, especially a description of the construction and operation, the stability verification and design drawings as well as relevant documents concerning the burning behaviour.

The verification via design procedures shall follow the relevant part of EN1991-1-1 [2] and shall comprise the limit state analysis (according to theory of 1^{st} or 2^{nd} order), the stability limit states analysis (i.e. bar buckling and shell buckling), verifications of deformation limit states and verification of safety against overturning, sliding and lifting off. The mentioned verifications also imply the assessing of design loads values for tents, taking into account the possible operating conditions or installation alternatives (including special loads during erection). On this line of interest, a description of the applied loads might be of interest, especially if load features specific to tents are underlined.

Permanent actions shall be considered with their characteristic value denoted G_k but, depending on cladding material nature, the influence of dry or wet material conditions shall be recognized using G_{ku} or G_{ki}values respectively.

Life loads might also intervene with different values depending on tent function and operating conditions (i.e. tents with universal, public access or zones not open for public access). As this type of load does not appear in the studied case, no further reference will be made.

Wind loads shall be based on EN 1991-1-4 [3] however considering the special nature of the textile covers and also the geographic location, duration and period of installation, possibilities of protecting and strengthening. One should notice here that wind codes usually recommend load values to be applied on rigid surfaces of the buildings while tents exhibit flexible cladding / roofing surfaces. Some minimum load values are therefore prescribed depending on wind reference speed on tent location. If v_{ref}>28 m/s, the recommendation exists to verify the stability and resistance the usual way with the local wind conditions. However, if v_{ref}<28 m/s, some simplified procedure of assessing wind loads is prescribed using the data of table 1 and Figure 1. These values can be applied to closed structures.

Table 1. Wind loads for tents (simplified procedure) [1]

Height of the tent h [m]	Pressure Q [N/m^2]
h ≤ 5.0	500
5.0 < h ≤ 10.0	600
10.0 < h ≤ 15.0	660
15.0 < h ≤ 20.0	710
20.0 < h ≤ 25.0	760

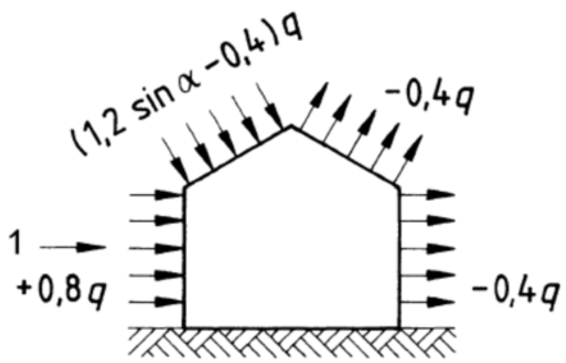

Figure 1. Aerodynamic coefficients for structures of conventional shape [1]

Snow loads shall be applied in accordance with EN 1991-1-3 [4]. Such loads are very important for any lightweight structure and especially for tents. Owing to the specific operation conditions of the tents, code [1] is offering the possibility of completely ignoring this load in certain conditions or to account for a reduced snow only (i.e. 0.2 kN/m^2). Snow loads need not to be taken into account for tents where there is no likelihood of snow, or the tent is operated during warm seasons only, or where snow settling on tent is prevented (by sufficient heating equipment inside, possibly started prior the snow to fall and acting in such a way that the whole roof cladding has an outside temperature of more than 2°C).Also, the cladding should be made and tensioned in such a way that pounding of water and any other deformations of the cladding cannot take place. The reduced snow loads for tents may be applied on the overall roof area provided that a snow height not exceeding h=8 cm can be assured at any time by removing snow. Any special conditions concerning the snow loads shall be stated in the tent book.

Seismic forces on tents may generally be not considered because of the flexibility and the light weight of the tent.

The load combinations shall be applied in accordance with [2]. Limit states assessment for tents shall be calculated with the following combinations:

$$\gamma_G G_k + \gamma_F Q_{k,1} \quad (1)$$

$$\gamma_G G_k + \sum \gamma_F Q_{k,i} \quad (2)$$

The partial safety factors in equations 1 and 2 take different values depending on the subsequent case i.e. γ_G=1.35 for unfavourable permanent actions, γ_G=1.0 for favourable permanent actions, γ_F=1.5 for a single variable actions while γ_F=1.35 for multiple variable actions.

Verifications of structural elements for resistance and stability, as well as verifications of the overall stability and equilibrium of the tens are further-on performed.

2. Existing tent in use of the client

At present time, an existing tent covered with textile membrane is in use by the client. An overall image of the existing tent is presented in figure 2.

Figure 2. Existing tent in use

The main frame of the tent under study is built of steel, based on a lattice frame pattern, for maximum economy in steel consumption. An image with the interior space of the tent, also showing the existing structure is given in figure 3.

Figure 3. Interior space of the existing tent

The presented tent has been designed, fabricated and supplied by a specialized Italian supplier, as a series product adapted to climatic loads specific to Romania but also looking at rules and provisions stated in [1]. The geometric characteristics of the studied tent structure are given in table 2.

Table 2. Geometry of the existing tent

Span of transversal frame =	14,0 m
Eaves height =	5,0 m
Ridge height =	7,0 m
Roof slope =	28,6%
Bay length =	5,0 m
Number of bays =	6
Overall length of the tent =	30,0 m

As the project of the existing steel structure was not available, a site measurement has revealed the actual dimensions of structural elements cross-section as presented in Table 3 (mostly square hollow section-SHS or rectangular hollow section-RHS).

Table 3. Cross section of the structural elements

Column of transverse frame =	SHS 120x120x6 mm
Upper and bottom chord of truss =	SHS 60x60x4 mm
Diagonal of the truss =	UPN 40x3,5 mm
Diagonal of the truss =	RHS 50x30x4 mm

In order to improve truss resistance under gravity loading and horizontal loading as well, a tapered shape vas chosen for the truss with maximum depths at mid-span and decreasing depth towards the lateral columns (see figure 3). Thus, the maximum depth of the truss under ridge resulted of 1,5 m while in the exterior thirds of the span, a 0,6 m depth was used.

A remarkable aspect in this case is the solution adopted for the infrastructure, which places the studied tent somewhere between provisional and permanent constructions. Usually, tents have a strong provisional character and therefore their supports use adequate solutions (laying direct on the ground, using various weight anchors or rod anchors and checking for stability and equilibrium of the tent under horizontal plus vertical loading). However, in this particular case the designers decided to provide under each column base permanent concrete foundations and 4xM24 anchoring bolts, very similar to an industrial hall. An image with the existing column base is given in figure 4.

Figure 4. Base plate of a column, with anchoring bolts

A further measure taken by the client in the attempt of improving tent function was the casting of a reinforced concrete plinth 25 cm thick and 70 cm high on the whole perimeter except the gate zone. By embedding the bottom zone of the SHS 120x120 columns, this is quite consistently contributing to the column base stiffness and also to the overall lateral stiffness of the transverse frame. An image with the plinth detail is presented in figure 5.

Figure 5 – Reinforced concrete plinth (detail)

3. Required conversion of the tent into an industrial hall and structural checking

As the activity of the client in his business field has improved and grown, the requirement appeared of transforming (if possible) the existing tent into a proper industrial hall. This proposal supposed changing the tent type roofing and cladding (built with a textile material) into a cladding built with polyurethane sandwich panels 60 mm thick, plus strengthening of the main frame where necessary according to codes provisions for permanent constructions.

When attempting this tent-hall conversion the existing structure shall be checked under regular permanent and climatic loads and NOT under the reduced loads indicated in [1]. A permanent load (resulting from Z purlins and 60 mm thick sandwich panels) equal to 0,35 kN/m^2 was applied on the existing structure. In addition, a characteristic snow load value of 1.5 kN/m^2 as per the Romanian national snow code [3] has been used. Snow loads (very important for industrial hall design) are quite high in Romania, as visible on the snow map in figure 6.

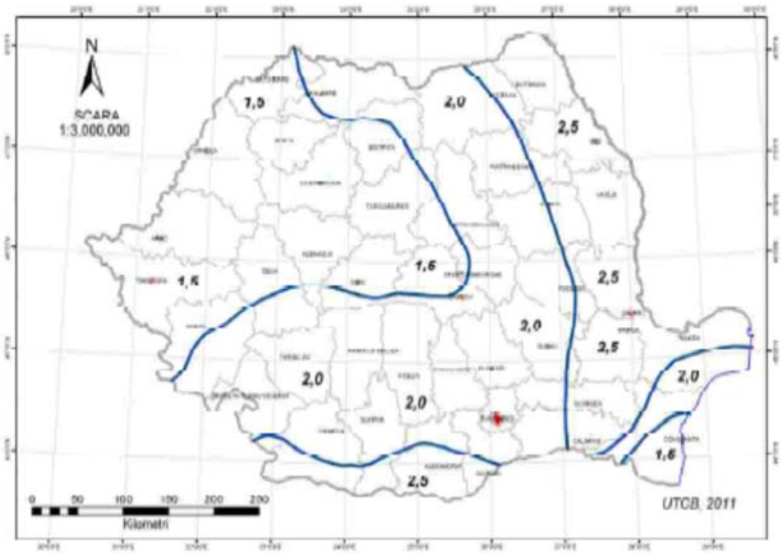

Figure 6. Ground level snow loads in Romania as per [3]

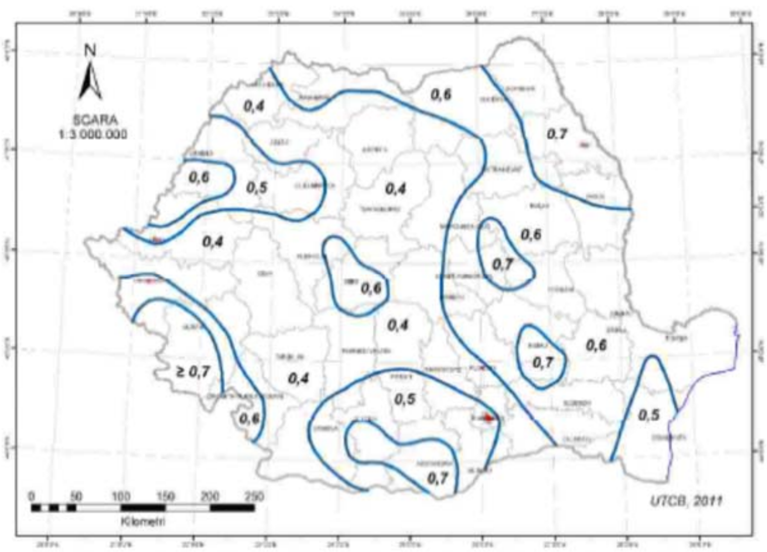

Figure 7. Reference values of wind dynamic pressure [kN/m^2] as per [4]

Wind is also a relevant load for such lightweight structures as in the studied case. The assessment of the wind load (this time applied on the rigid panel surfaces of the roofing and cladding) was performedas per national wind code [4]. The wind map indicating local values of the basic pressure in kN/m^{2}is presented in figure 7. A reference value of the wind pressure of 0,6 kN/m^2 was used to define local pressure and suction loads for longitudinal and transversal wind.

Earthquake load applies compulsory to usual hall structures, contrary to tents for which code [1] recommends total disregarding (zero load owing to low mass and provisional character). Therefore, an acceleration spectrum analysis was performed on the existing tent structure as per the national earthquake code [5]. The main parameters of the acceleration spectrum are peak ground acceleration a_g=0.20g (see the Romanian seismic map in figure 8), corner period T_c=0,7 sec and dynamic amplification factor β_0=2,5.

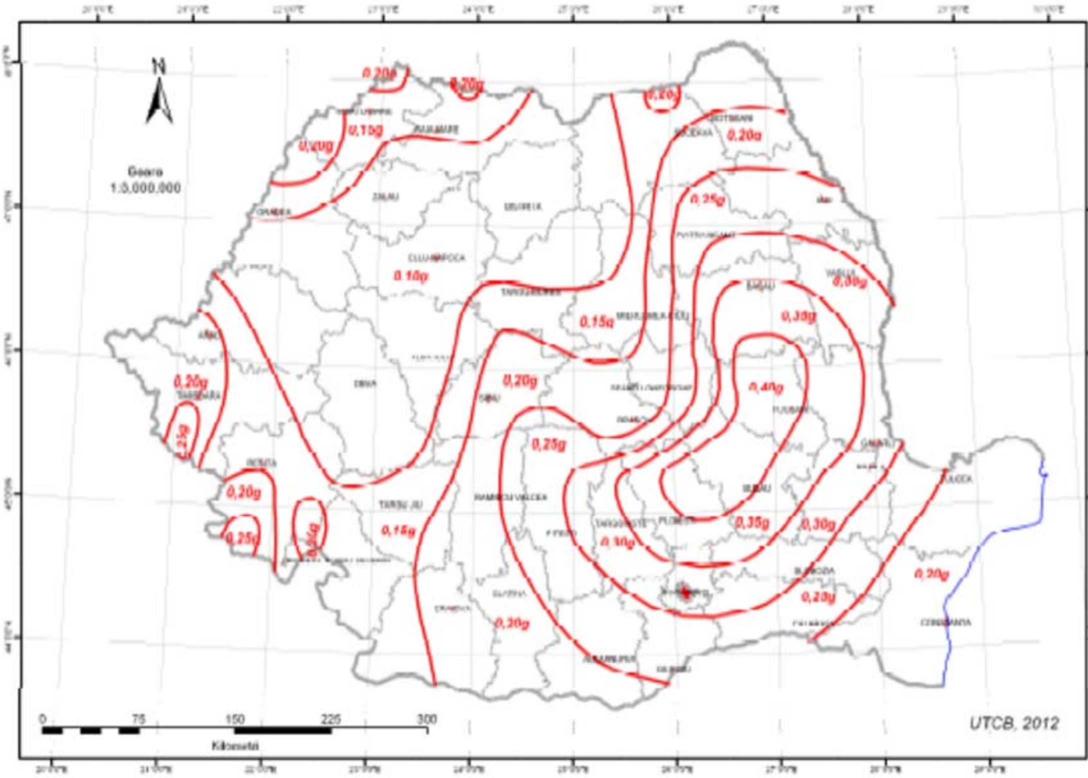

Figure 8. Peak ground acceleration map of Romania

The structural analysis was performed on a finite element model of the existing structure, built in SAP 2000 Nonlinear computer code. Load combinations for the analysis were defined according to [2]. As expected, the analysis results indicated the resistance of truss chords and diagonals being 20%-30% exceeded especially in the mid-span zone of the frame. After a number of strengthening attempts for the structure, the configuration in figure 9 finally resulted, fulfilling the ULS and SLS criteria. Actually, a longitudinal truss girder was inserted under the hall ridge, connected to all transversal frames, working as a central "spine" and practically reducing at a convenient level loads and stresses on previous exceeded zones. The longitudinal truss girder is supported by three pairs of intermediate columns, located in the gable walls and in the transversal frame at mid length. Thus, the longitudinal truss girder is working as a continuous beam with two spans of 15,0 m each, inserted within the 3D structure and unloading the previous vulnerable zones. Horizontal bracings were placed between the

IOP Conf. Series: Materials Science and Engineering **245** (2017) 022056 doi:10.1088/1757-899X/245/2/022056

bottom chord of the transversal frames and the longitudinal truss in order to improve structural behaviour in stability checking. Also the overall stability of the new structure was improved by inserting longitudinal X bracings of 24 mm diameter round steel (very effective under horizontal load) in bay 2 and bay 5 of the hall.

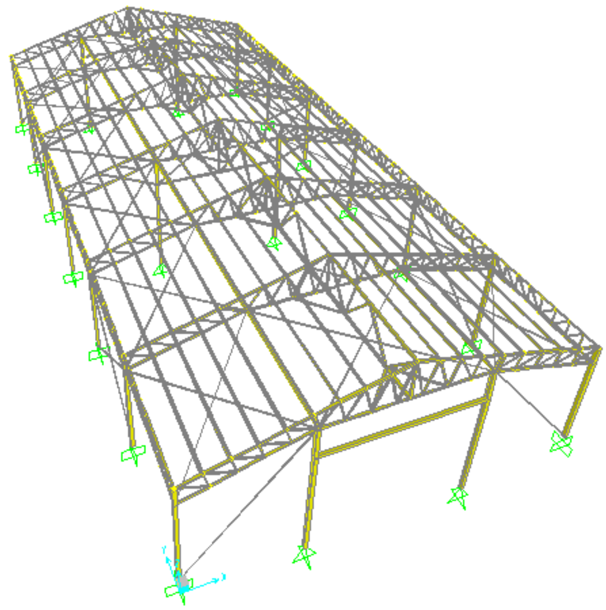

Figure 9. Strengthening scheme of the tent structure

4. Conclusions

An interesting and challenging request was stated by the owner of an existing tent, i.e. the attempt of converting the provisional structure into a permanent hall structure. A thorough examination of existing codes for provisional and permanent structures was performed by the authors in order to assess vulnerabilities and analysis directions. Appropriate strengthening measures were proposed in order to bring the provisional structure in the situation of fulfilling the ULS and SLS criteria corresponding to permanent structures.

References

[1] EN 13782 "Temporary structures – Tents –Safety". *European Standards, November 2005*

[2] J.A.Zuranski, A.Sobolewski "An Analysis of Snow and and Wind Loads. Combinations Based on Meteorological Data", *Archives of Civil engineering, ISSN (Online) 1230-2945, DOI: https://doi.org/10.1515/ace-2015-0117, volume 62, Issue 4 (Dec. 2016)*

[3] A.Michalski, D.Britto, P.Gelene, E.Hang "Computational Wind Engineering of Lightweight Structures" *Proceedings of the 6.th European and African Conference of Wind Engineering, www.iawe.org/Proceedings/EACWE2013/A.Michalski.pdf*

[4] T.Tomabechi, H.Yamaguchi, "Fundamental study of snow load on the roof from membrane structures" *Research Report on Membrane Structures, The Membrane Structures Association of Japan, 1993*

[5] P100-1 / 2013. Romanian National Earthquake Code. Provisions for Buildings.