Reaction of a Sandwich Type Structure to Static Stress Under the Action of the Snow

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Structural elements of special industrial constructions can be often subjected to time variable stresses. One of the main stress is the snow action, which is considered to be one of the most severe tests. In the study, the static snow action on a tank cover from a pickling plant on the ArcelorMittal Galaþi platform is analysed. The material structure of the cover is sandwich type with skins made of steel /layered composite and core made of polystyrene foam. The purpose is to determine, by FEM analysis, the deformation mode and the stress condition of the cover under the action of load, for two models of sandwich type structures, steel-polystyrene-steel, respectively composite-polystyrene-composite, with different faces thicknesses and cores. Panels are applied simulative a load of snow of different thickness, the distribution of snow on the surface of the panels being considered uniform in order to determine an optimum combination of faces and core thickness as well weight and economic cost too. Numerical analysis models with finite elements of SHELL 3L sandwich type structures are used.

Keywords: finite element method, sandwich panel, buckling, static action

In the pickling tanks, the oxidized surface created during the hot rolling of steel is removed, with the help of acids (hydrochloric, sulphuric, hydrofluoric, etc.), at high temperatures. Some steels have higher pickling times compared to normal, with low carbon steel content, a fact that makes these special industrial tank type constructions of particular importance [1]. Their protection and especially of those of very high volume, must correspond to all areas of use: fire resistance, resistance to attack of chemical and environmental agents - temperature variations, solar radiation, snow action, etc. [2, 3].

In the study, it is described the way of replacing the metallic cover, degraded, of an existing pickling equipment found on the ArcelorMittal Galati platform, with a similar dimensional structure, analysed from the point of its loading with different amount of snow. This structure is associated with a roof in two slopes where snow load is considered, in this case, to be a fixed and static action expressed as load per square meter of horizontal projection of the support and only in cases of exceptional snow agglomeration, the load can be considered accidental and variable [4-6].

To determine the own weight of this element of construction, has been considered the dimensions of the element as well as the material of which it is made, represented in the calculations by the apparent specific weight [7]. In order to determine the load capacity, the finite element analysis method is often used, most often for the purpose of determining deformations and equivalent stress, depending on the nature of the material of the faces, the core and the thickness of the layers, correlated with their dimensional values, but also depending on the way to apply the tasks [8-10, 14].

The study proposes the analysis of two sandwich type structures, made up of metallic materials faces, respectively, of polyester resin composite material and bidirectional fiber glass fabric. From the weights calculation, it was decided to realize a sandwich type structure with two 2 mm thickness, core of extruded polystyrene with 20 mm thickness, and respectively 50 mm. Given the structural simplicity, the weight-strength ratio, the exceptional anticorrosive properties, such a structure, widely used in most industrial fields, can be considered optimal in terms of elasticity, thickness, weight and cost properties [11-13].

Therefore, for ease of physical realization of the structure, it initially started from modelling performed in the graphical environment Autodesk Inventor (fig. 1).

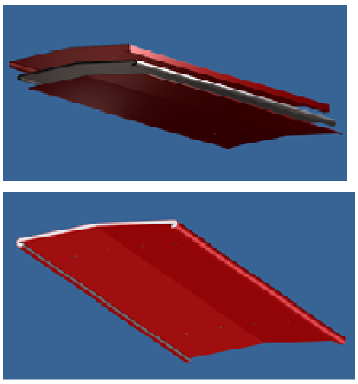

Fig. 1. Sandwich type structure modeled in Autodesk Inventor graphical environment

Since the initial reservoir cover type structure is relatively large (3m x 2.5m x 0.22m), it requires a hydraulic lifting system in a position that allows it to be opened up to 90°, with the possibility of locking the cover in the open position by the help of safety devices (fig. 2). The opening is made in the vertical plane with the help of a hydraulic system, comprising the operating cylinders and the hydraulic pump, the closing being accomplished by releasing the hydraulic oil from the cylinder.

Finite element modeling of the sandwich type structure

In the study, the cover is statically analysed when the load given by snow, of 2.5 kN/m² [4], in the form of surface pressure, has the following values: $p_1 = 7.66 \cdot 10^3$ N/m²; $p_2 = 9.58 \cdot 10^3$ N/m²; $p_3 = 11.5 \cdot 10^3$ N/m².

The numerical analysis was performed on sandwich type structural composite plates, simply supported on two sides at 3000 mm x 0.07 mm. The loading was carried out with a uniformly distributed pressure on each rectangular surface of 3000 mm x 1277 mm. To determine the displacements and stresses of sandwich composite plates,

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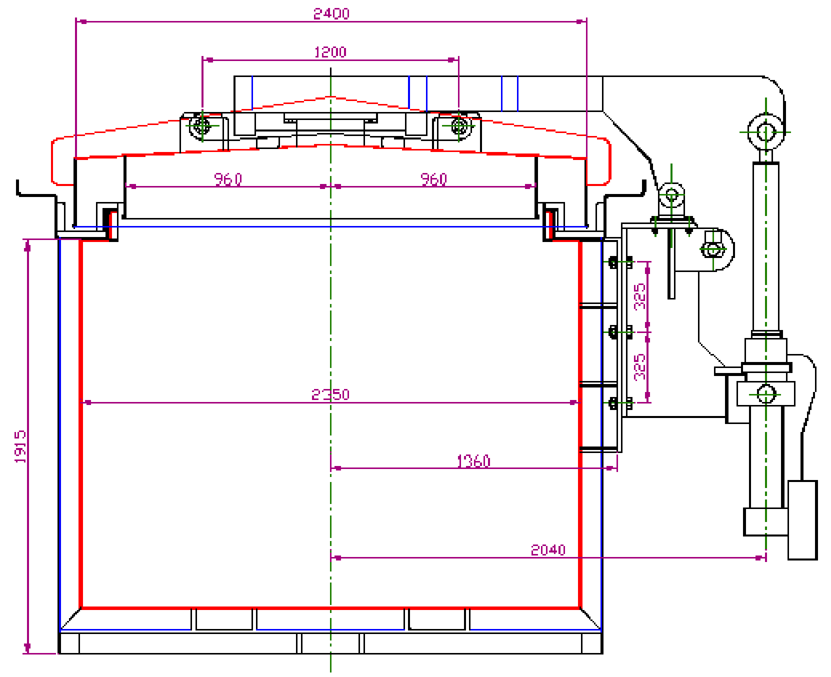

Fig. 2. Lifting mechanism for pickling tank cover

Table 1
MATERIALS USED IN MODELING

M1 The faces of the sandwich structure	Steel	E_x=2.1·10^{11} Pa; μ_{xy} =0.3
	Epoxy - E-glass	E_x=3.5·10^{10} Pa; E_y=E_z=9·10^9 Pa; μ_{xy}= μ_{xz} =0.28; μ_{yz}=0.4 G_{xy}= G_{xz} =4.7·10^9 Pa; G_{yz}=3.5·10^9 Pa
M2 Core of the sandwich structure	PVC - Foam_80 kg/m^3	E_x=1.02·10^8 Pa; μ_{xy}= 0.3; G_{xy}= 3.9·10^7 Pa
	PVC - Foam_60 kg/m^3	E_x=7·10^7 Pa; μ_{xy}= 0.3 G_{xy}= 2.69·10^7 Pa

there were used SHELL3L elements to make the FEM model. There were analysed structures with both steel and Epoxy - E-glass composite faces, with the extruded polystyrene core of 20 mm and respectively 50 mm thickness (table 1).

Figure 3 shows the meshing, the connections and loading of the structure, and figure 4 defines the bonding and deforming conditions of the cover under the action of the load p_1. Due to geometric symmetry and the loading, the structure was analysed in half, imposing specific symmetry conditions.

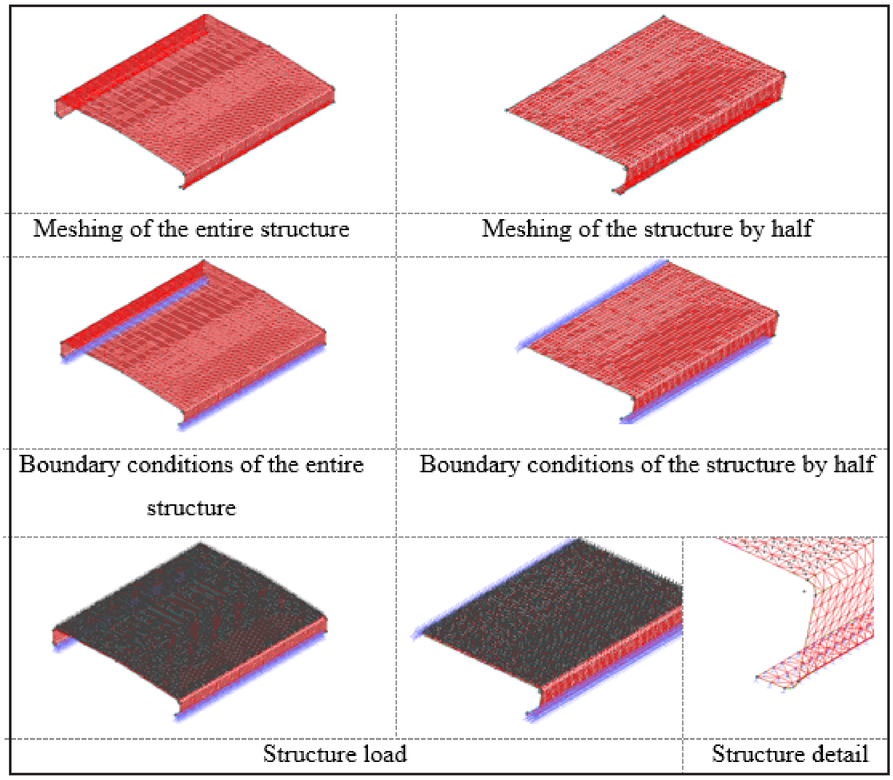

Fig. 3. Meshing, boundary conditions and loading of the structure

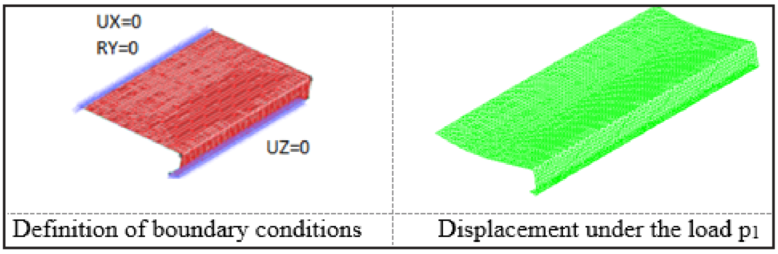

Fig. 4. Definition of the boundary and deformation conditions of the cover under the load p_1

Table 2
CHARACTERISTICS OF MATERIALS USED IN FEM ANALYSIS

Coding	Face type	Face thickness [mm]	Core type	ore thickness [mm]	Weight [kg]
ST_PVC_80_50_G1	STEEL	2	PVC_80	50	177.518
ST_PVC_60_50 _G2	STEEL	2	PVC_60	50	172.509
ST_PVC_60_20_G3	STEEL	2	PVC_60	20	163.493
ST_PVC_80_20_G4	STEEL	2	PVC_80	20	148.844
CO_PVC_80_50_G5	COMPOSITE	2	PVC_80	50	57.102
CO_PVC_60_50_G6	COMPOSITE	2	PVC_60	50	52.093
CO_PVC_80_20_G7	COMPOSITE	2	PVC_80	20	45.081
CO_PVC_60_20_G8	COMPOSITE	2	PVC_60	20	43.077

In table 2 are presented, coded, the specific elements used in the finite element analysis.

Figure 5 shows the variation in the weight of the cover depending on the composite structure from which it is made.

In the modeling with finite elements, the symmetry condition is used to determine the displacement maps and the von Mises stress. Thus, in figure 6 there are represented the displacement maps for the p_1, p_2 and p_3 loads and in figure 7 - the von Mises equivalent stress maps.

After the analysis of the displacement maps for the studied cases, under the actions p_1, p_2 and p_3, the variations of the vertical displacements (arrows) are defined in figures

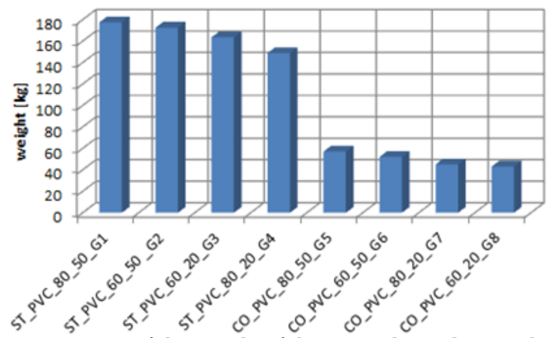

Fig. 5. Variation of the weight of the cover depending on the used composite structure

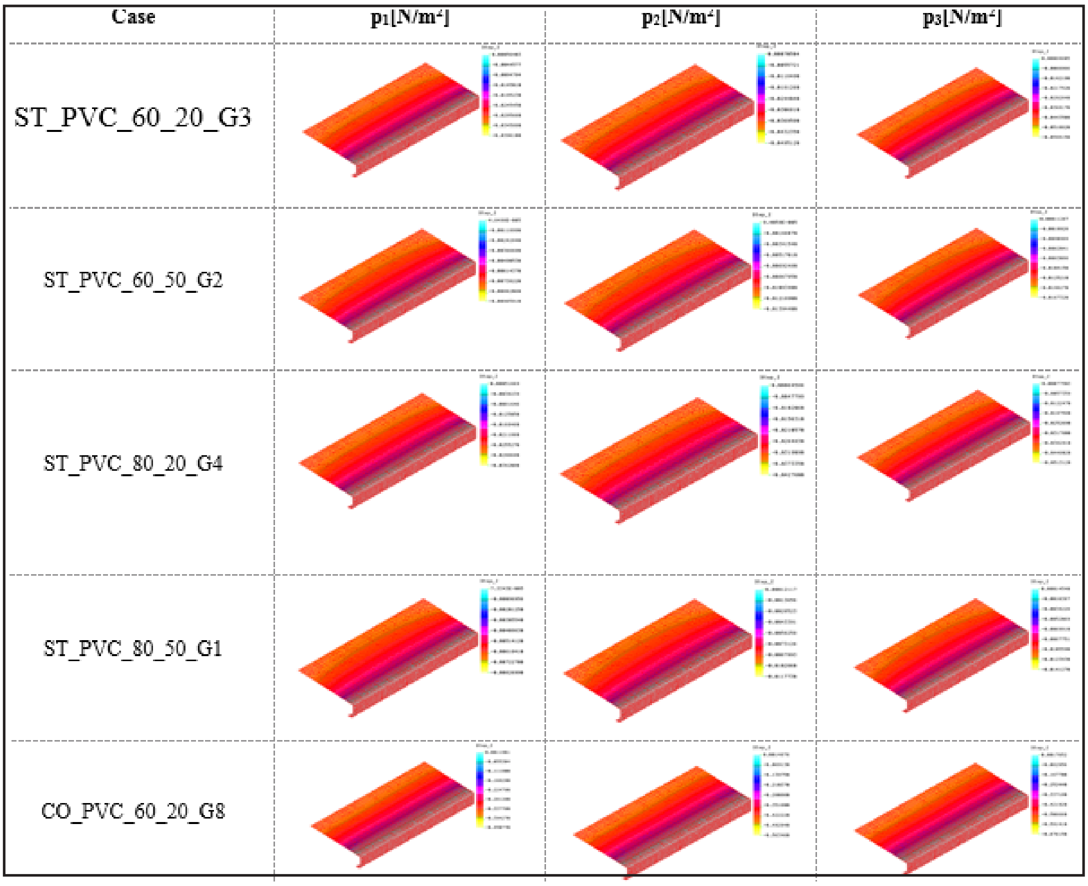

Fig. 6. Maps of displacements [m]

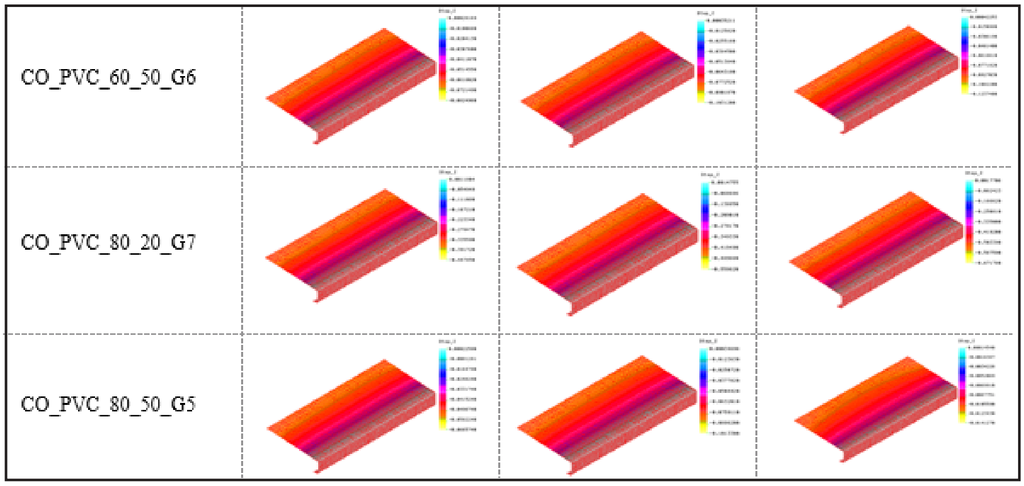

Fig. 6. Continuated

Fig. 7. Maps of von Mises stresses [Pa]

8÷13 and in the figures 14÷19, the variations in the maximum equivalent stress.

From the vertical displacement chart (arrow) with the load on the sandwich type structure having PVC foam core - 60 kg/m^3, figure 8, it can be seen that the variation between load and displacement is directly proportional and the variation between displacement and weight is inversely proportional. The steel with faces structure has a larger

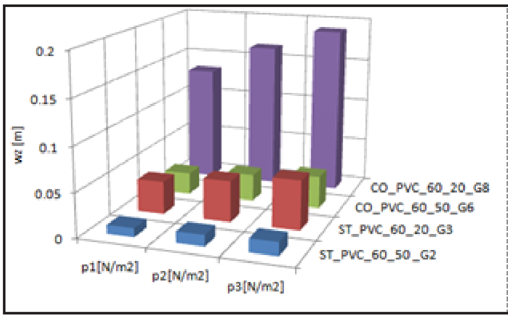

Fig. 8. Variation of vertical displacement - PVC core - Foam_60 kg/m^3 at loads p_1, p_2, p_3

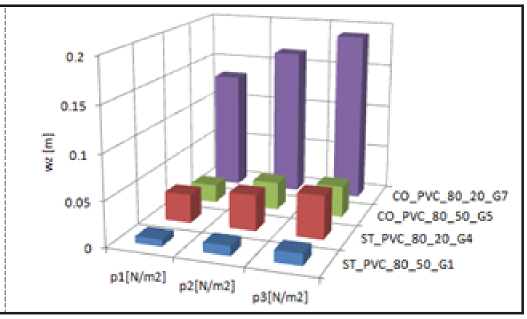

Fig. 9. Variation of vertical displacement - PVC core - Foam_80 kg/m^3 at loads p_1, p_2, p_3

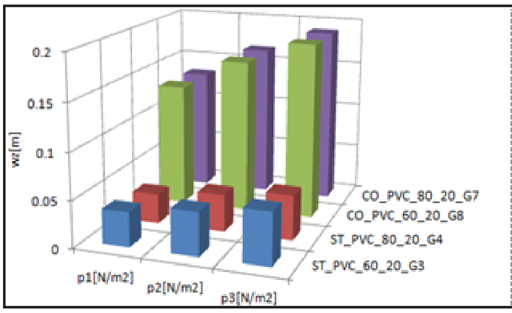

Fig. 10. Variation of vertical displacement - 20 mm thickness core, at loads p_1, p_2, p_3

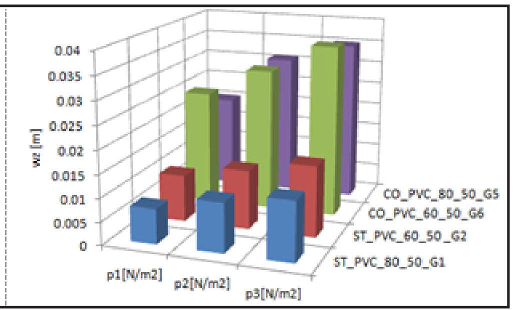

Fig. 11. Variation of vertical displacement - 50 mm thickness core, at the loads p_1, p_2, p_3

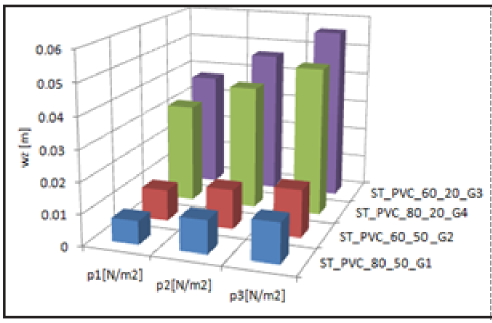

Fig. 12. Variation of vertical displacement - steel faces, at loads p_1, p_2, p_3

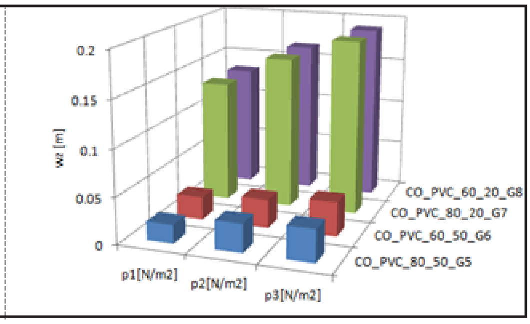

Fig. 13. Variation of vertical displacement - Epoxy-E-glass faces, at loads p_1, p_2, p_3

weight than the one with Epoxy-E-glass faces. The structure with steel faces has a smaller displacement than the structure with Epoxy-E-glass faces.

From the vertical displacement chart (arrow) with loading for the sandwich structure with the PVC foam core - Foam_80 kg/m^3, figure 9, it can be seen that the variation between load and displacement is directly proportional and the variation between displacement and weight is inversely proportional.

The steel with faces structure has a larger weight than the one with Epoxy-E-glass faces. The structure with steel faces has a smaller displacement than the structure with Epoxy-E-glass faces.

From the vertical displacement chart (arrow) with loading for the 20 mm thickness sandwich type structure, figure 10, it can be seen that the variation between load and displacement is directly proportional. The sandwich structure with steel faces is less displaceable than the Epoxy-E-glass sandwich structure. The sandwich structure with PVC core - Foam_80 kg/m^3 with 20 mm thickness has a smaller displacement than the PVC core - Foam_60 kg/m^3 sandwich type structure of the same thickness.

From the vertical displacement chart (arrow) with loading for sandwich structure with a 50 mm core thickness, figure 11, it can be seen that the variation between load and displacement is directly proportional. The sandwich type structure with steel faces is less displaceable than the Epoxy-E-glass sandwich structure. The PVC core sandwich type structure - Foam_80 kg/m^3 with 50 mm thickness has a smaller displacement than the PVC core - Foam 60 kg/m^3 sandwich type structure of the same thickness.

From the vertical displacement chart (arrow) with loading for the sandwich structure with steel faces, figure 12, it can be seen that the variation between load and displacement is directly proportional. The sandwich structure with a 50 mm thickness of core has a lower displacement than the 20 mm thickness sandwich type structure. The sandwich structure with PVC core - Foam_80 kg/m^3 with a thickness of 50 mm, has less movement than sandwich structure with the PVC core - Foam_80 kg/m^3 with a thickness of 20 mm. The sandwich structure with PVC core - Foam 60 kg/m^3 thickness 50 mm has less movement than the PVC core sandwich structure - Foam_60 kg/m^3 with a thickness of 20 mm.

From the vertical displacement chart (arrow) with the load in case of the Epoxy-E-glass sandwich structure faces, figure 13, it can be seen that the variation between load and displacement is directly proportional and the variation between displacement and weight is inversely proportional. The 50 mm thickness sandwich structure has a smaller displacement than the 20 mm thickness sandwich structure. The sandwich structure with PVC core - Foam_80 kg/m^3 with a thickness of 50 mm, has less movement

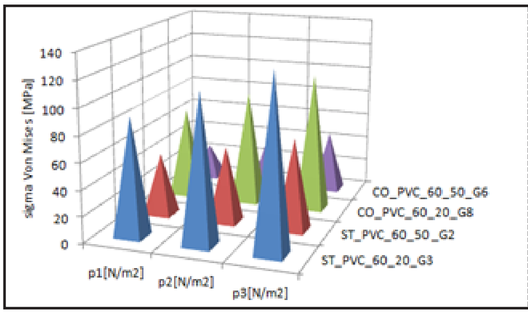

Fig. 14. Variation of equivalent stress - PVC core - Foam_60 kg/m^3 at loads p_1, p_2, p_3

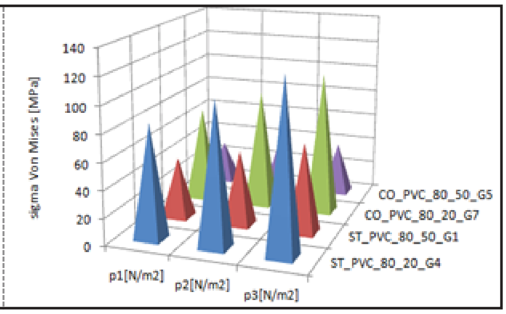

Fig. 15. Variation of equivalent stress - PVC core - Foam_80 kg/m^3 at loads p_1, p_2, p_3

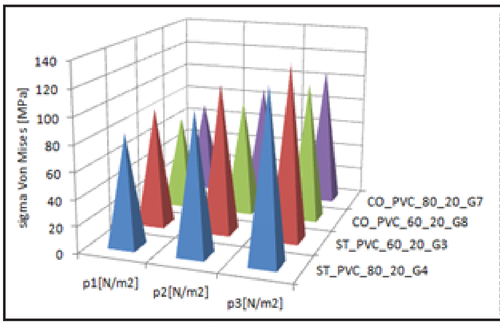

Fig. 16 Variation of equivalent stress - 20 mm thickness core, at loads p_1, p_2, p_3

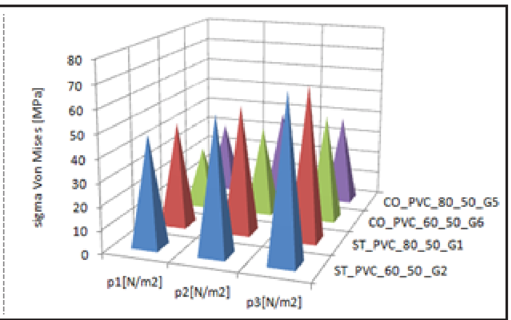

Fig. 17 Variation of equivalent stress - 50 mm thickness core, at loads p_1, p_2, p_3

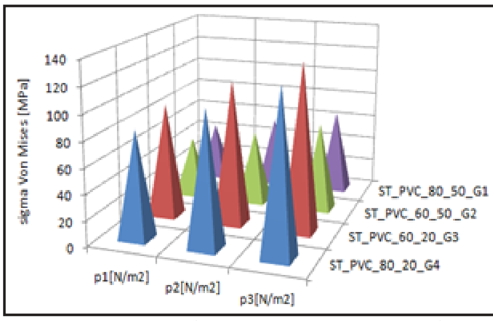

Fig. 18. Variation of equivalent stress - steel faces, at the loads p_1, p_2, p_3

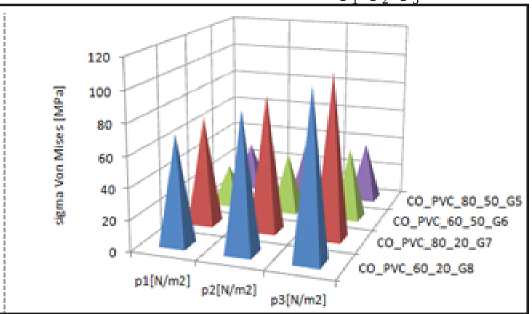

Fig. 19. Variation of equivalent stress - Epoxy-E-glass faces, at the loads p_1, p_2, p_3

than the PVC sandwich structure PVC core Foam_80 kg/m^3 with a thickness of 20 mm. The sandwich structure with PVC core - Foam 60 kg/m^3 50 mm thickness has less movement than the PVC sandwich structure - Foam_60 kg / m^3 with a thickness of 20 mm.

From the chart of the equivalent stress to loading in the case of PVC core sandwich structure - Foam_60 kg/m^3, figure 14, it can be seen that the variation between the load and the equivalent stress is directly proportional. Structure with steel faces has a higher equivalent stress than the Epoxy-E-glass faces structure. Structure with steel faces and 20 mm thickness of core has the equivalent stress larger than the 50 mm core structure. The Epoxy-E-glass faces structure and 20 mm core thickness has the equivalent stress of the 50 mm core structure.

From the chart of the equivalent stress to loading in the case of PVC core sandwich structure - Foam_80 kg/m^3, figure 15, it can be seen that the variation between the load and the equivalent stress is directly proportional. Structure with steel faces has a higher equivalent stress than the Epoxy-E-glass face. Structure with steel faces and 20 mm thickness of core has the equivalent stress larger than the 50 mm core structure. The Epoxy-E-glass face structure and 20 mm core thickness has the equivalent stress of the 50 mm core structure.

From the chart of the equivalent stress to loading in the case of sandwich structure with core thickness of 20 mm, figure 16, it can be seen that the variation between load and stress is directly proportional. The sandwich structure with steel faces has the same equivalent stress as the Epoxy-E-glass sandwich type structure. The PVC sandwich structure - Foam_80 kg/m^3 20 mm thickness core has the equivalent stress larger than the PVC core Foam_60 kg/m^3 sandwich structure of the same thickness.

From the chart of the equivalent stress to loading in the case of sandwich structure with core thickness of 50 mm, figure 17, it can be seen that the variation between load and stress is directly proportional. The sandwich structure with steel faces has the equivalent stress larger than the Epoxy-E-glass sandwich type structure. The sandwich structure with PVC core - Foam_60 kg/m^3 with a thickness of 50 mm has the equivalent stress larger than the PVC sandwich structure - Foam_80 kg/m^3, with the same thickness.

From the chart of the equivalent stress to loading in the case of sandwich structure with steel faces, figure 18, it can be seen that the variation between the equivalent stress and the load is directly proportional. The 50 mm core sandwich structure has the equivalent stress smaller than the 20 mm core sandwich structure. The PVC core sandwich structure - Foam_80 kg/m^3 with 20 mm thickness has the equivalent stress larger than the 20 mm thickness PVC core Foam_60 kg/m^3 foam sandwich structure. The sandwich structure with a 50 mm thickness PVC core -Foam_60 kg/m^3 has the equivalent stress larger than the 50 mm thickness PVC core – Foam_80 kg/m^3 sandwich structure.

From the chart of the equivalent stress to loading in the case of sandwich structure Epoxy-E-glass faces, figure 19, it can be seen that the variation between the equivalent stress and the load is directly proportional.

The 20 mm thickness sandwich structure has the equivalent stress larger than the 50 mm thickness sandwich structure. The sandwich structure with PVC core - Foam_60 kg/m^3 20 mm thickness has the equivalent stress larger than the PVC core sandwich structure - Foam_80 kg/m^3 with a thickness of 20 mm. The sandwich structure with a 50 mm thickness PVC core Foam_60 kg/m^3 has the equivalent stress larger than the 50 mm thickness PVC core Foam_80 kg/m^3 sandwich type structure.

Conclusions

Following the analysis of the arrows variation charts, it is noted that sandwich composite type structures having steel faces have a vertical displacement smaller than the sandwich composite type structures of the same type having Epoxy-E-glass faces, regardless of the loading of snow. However, it is noticed that the composite structure CO_PVC_60_50_G6 is less displaceable than the ST_PVC_60_20_G3 steel faces structure, on the same core material density, regardless of the load. Similarly, for the composite faces structure CO_PVC_80_50_G5, compared with the ST_PVC_80_20_G4 steel faces.

Following the analysis on variation of equivalent stresses charts, it is noted that sandwich composite type structures having Epoxy-E-glass faces have smaller equivalent stress than composite sandwich type structures having steel faces, regardless of the snow load (a low risk of collapse of the structure).

Therefore, it can be considered that sandwich panels with composite faces, with the thickness of the core (50 mm) can successfully replace panels with steel faces having a smaller thicknesses (20 mm), these being optimal alternatives solutions both from the light of the deformations, of the equivalent stresses, as well as of their weight.

Also, sandwich composite type structures with Epoxy-E-glass faces have the advantage of being much lighter than composite sandwich type structures with steel faces, regardless of the thickness of the core. They stand even better with the corrosive environment than those with the steel faces.

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