STUDY REGARDING THE POSSIBILITY OF INCREASING THE CAPACITY FOR PERSON TRANSPORTATION AT UNIREA SHAFT, SLĂNIC PRAHOVA SALT MINE

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Abstract: *In this paper, we show aspects regarding: the possibility of increasing the transportation capacity for persons at Unirea Shaft, Slănic Prahova Salt Mine, through creating a two-storey cage and maintaining the maximum static load of the machine at the actual value, the analysis of the influence of the two-storey cage on the guidance system of the shaft and the study of the necessary modifications at the tower of the extraction machine and in the ramp of the underground pit in the case of the two-storey cage, according to the adopted transportation system (with or without manoeuvres at the surface ramp).*
Key words: *transportation flux, cage, embarking ramp.*

1. Introduction

Romania is a country with numerous highly attractive tourist destinations, due to the existing natural potential. In this category we can also include the salt mines, known especially for their therapeutic effect on people's health. The most well-known “salt palaces” are the ones at Slănic Prahova, Turda, Praid, Cacica, Târgu Ocna and Ocnele Mari.

The salt mine's aerosols (micro-particles which are in suspension in a gassy environment) treats different illnesses, especially respiratory ones. Among these, let’s mention: bronchial asthma, asthmatic bronchitis, sinusitis, disorders of the nervous system and even cardiac insufficiency, chronic rhinitis, tonsillitis, allergies, chronic exhaustion etc.

Slănic Prahova, one of the most important spas in Romania, is situated between the valleys of Prahova and Teleajen, at about 44 kilometres from Ploiești and an altitude of 400 meters. Slănic Prahova Salt Mine is one of the biggest salt mines in Europe and is visited by hundreds of tourists every day. The peak is reached on weekends, when the number of visitors exceeds 1,000.

Fig. 1. *The shape of a trapezoidal room and the interior setup at Unirea Mine*

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The mining works for opening Unirea Salt Mine began in 1938 and salt was exploited in this salt mine between 1943 – 1970. After 1970, the salt mine became a touristic attraction and inside it a treatment sanatorium was set up with beds, playgrounds for children, a sports hall, tables and a small shop. The mine is made up of 14 rooms with a trapezoidal profile, with 10 meters opening at the ceiling and 32 meters at the base.

The height is of 54 meters (figure 1). The elevation difference between the surface and the mine's base is of 208 meters and is traversed by the cage in approximately 90 – 120 seconds, with a speed of 2.3 metres/second.

2. The constructive solution of the two-storey cage

Starting from the construction of the tower and of the manner of building the second embarking ramp, on the eastern side of the rower, at a height of 3,650 mm from the actual ramp, we obtained the constructive solution of the cage, which is shown in figure 2. It is composed of: 1 –metal frame; 2 – superior panel; 3 – superior cabin; 4 – intermediary panel; 5 – inferior panel; 6 – inferior cabin [4].

In order to make the execution easier and to reduce the fabrication price of the cage, we kept the same cable bonding device DLC-1, the same draw bar with a section of 160 X 52 mm and the same laminated spring with 12 sheets, with a section of 60 X 6 mm. In order to keep the mass of the cage below 2,300 kg, the person transportation cabins were made of pressed wood with density of up to 0.5 kg/dm3. The cabins can be made as separate subassemblies and fitted inside the metallic frame. This solution allows the easy maintenance of the metallic frame by dismantling the cabins and bringing them out in the shaft's ramps. Also, in time, changes can be made to the cabin construction in order to improve the transportation conditions.

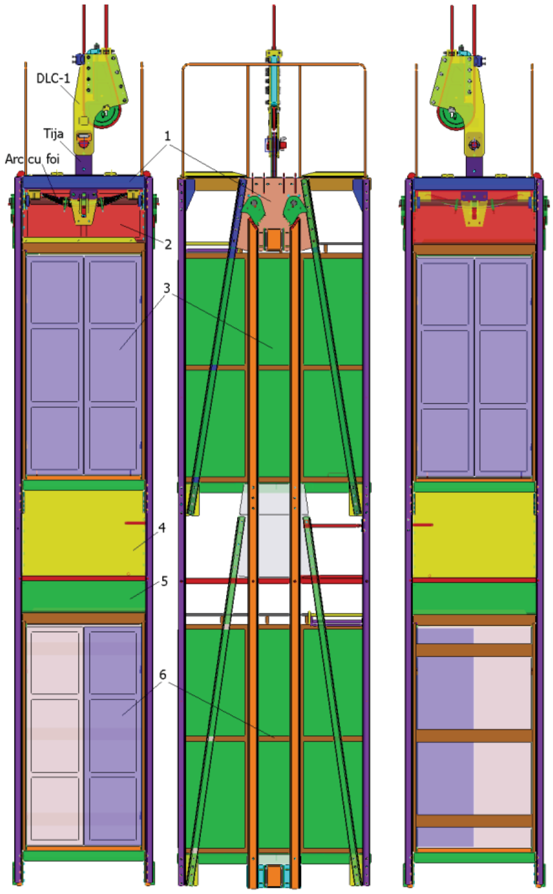

Fig. 2. *Constructing the two-storey cage*

In figure 3, we show the construction of the metallic frame of the two storeys cage, which is composed of: 1 –superior frame; 2 – central stringer; 3 – safety catch mechanism; 4 – exterior stringer; 5 – stiffening stringer 1; 6 – superior support frame; 7 – evacuation stair step; 8 – intermediary frame; 9 – stiffening stringer 2; 10 –inferior support frame; 11 – roof cap; 12 – handrail.

The metallic frame of the cage is a dismountable metallic construction and its elements are fitted with M16 X 40 screws, which allows for its assembling in the shaft ramp, by positioning the central stringers on the wooden guy and inserting between them the four frames. The transmission of the loads between the frames and the central stringers is done by fixed support elements and not by screws. The central stringers rest on the superior frame by four hanging corners and the support frames rest on the central stringers throughout two central sheets [3].

The elements of the metallic frame and the elements of the safety catch mechanism were verified dimensionally using a calculation abstract and we obtained safety coefficients with a value greater than 8.

In figure 4a we show the assembling position of the safety catch mechanism on the cage, when the spring with 12 sheets with the section 60 X 6 mm is deformed with an arrow of 75 mm, having conserved a potential energy which produces the driving of the safety catch mechanism when the drag force of the draw bar is lower than 0.55 from the weight of the shaft, which means the cable has broken. The transmission of the deformation force of the string is transmitted to the lever, mark 10, and through bolts and flanges to the arms mark 7, which produce the circling of the axis, mark 3, and the piercing of the claws' teeth in the wooden guy [4]

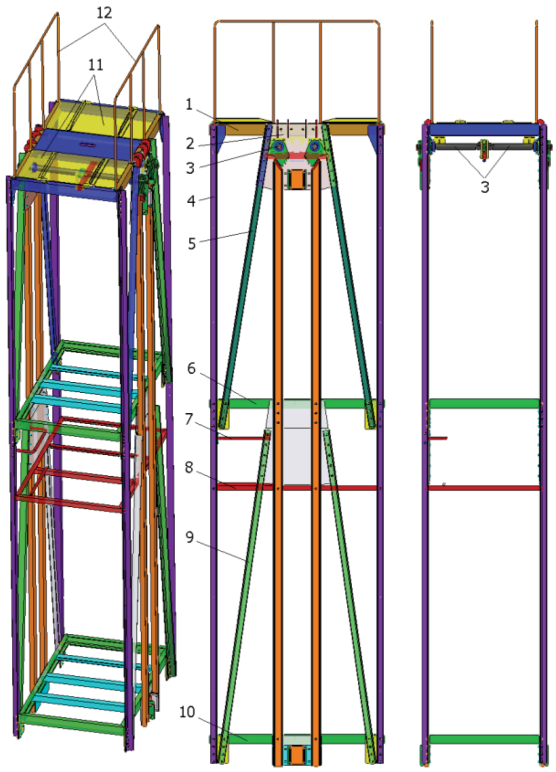

Fig. 3. *The construction of the metallic frame of the two-storey cage*

In figure 4b we show the position of the safety catch mechanism when the spring is totally relaxed, having a height / interior arrow of 150 mm. In this case, the teeth of the claw pierce throughout the wooden guy on a depth of 41 mm, blocking the cage on the wooden guy. The piercing depth of the teeth of the claw is limited by the circling stop of the claw on the central stringer by the form of the claw, which has a stopping spur. In this way we avoid the possibility of sectioning the wooden guy and the fall of the cage down the shaft.

In figure 5, we show the constructive solution of the superior cabin, which is composed of: 1 – lateral frame; 2 – lateral wall; 3 – floor; 4 – floor hatch; 5 – right door; 6 – left door; ceiling reinforcement; 8 – frame of the ceiling hatch; 9 – prolongation frame of the stair of the hatch; 10 – roof; 11 – roof plate.

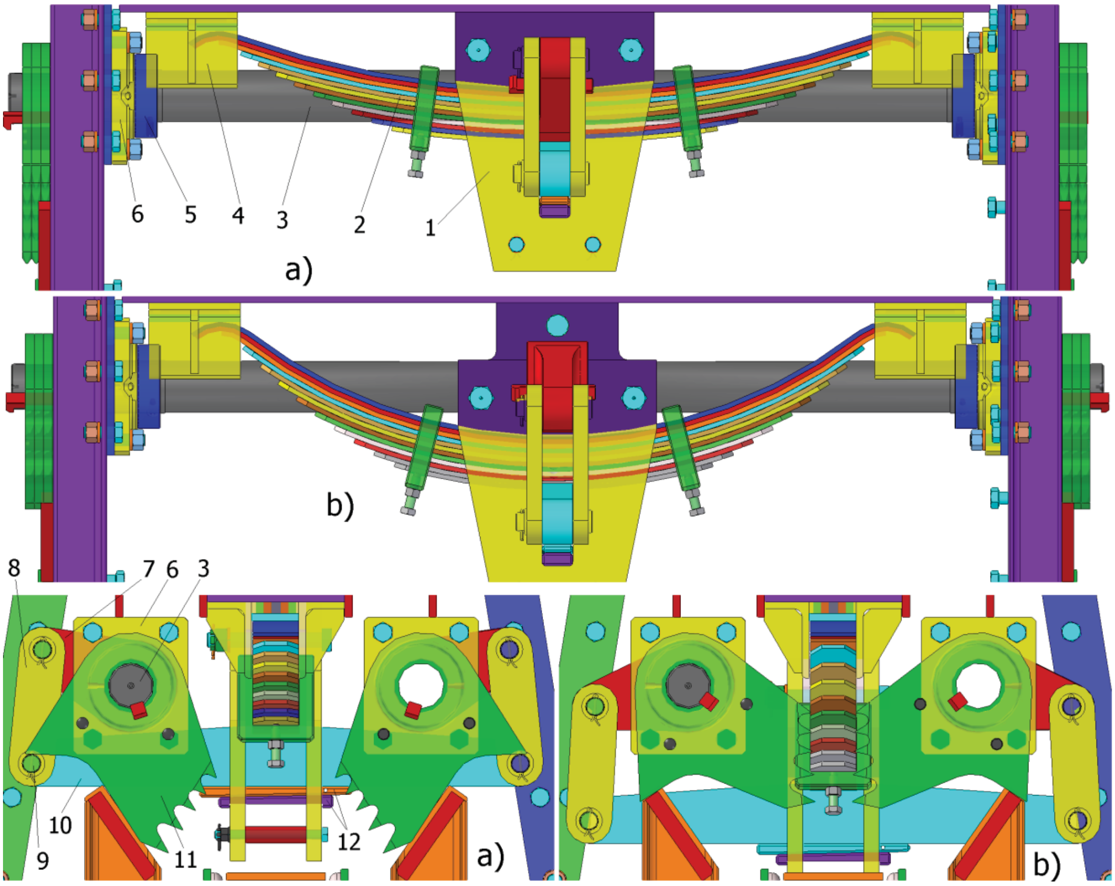

Fig. 4. *The construction of the safety catch mechanism*

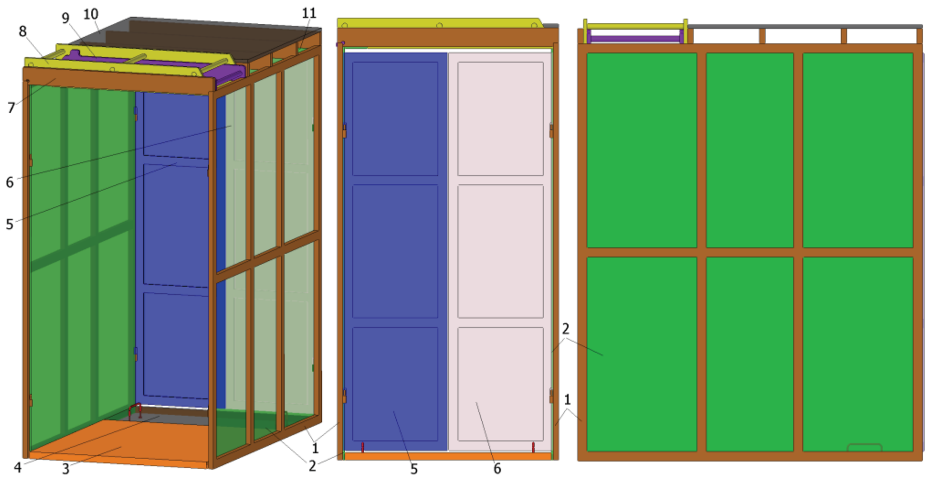

Fig. 5. *The construction of the superior cabin*

Fig. 6. *Cabin with opened hatches*

The superior cabin has doors at both ends, due to placing the surface ramp on the opposite side (eastern side) of the shaft from the underground ramp, which is on the western side. The cabin doors open on the interior, with a closing and blocking system at the exterior, being opened and closed by the human operator that oversees the shaft's ramp.

The lateral frame, the floor, the floor hatch, the door frame and the enforcing of the roof are made of pressed wood, and the lateral walls, the ceiling plate and the roof plate are made of white polycarbonate with a thickness of 10 mm. The doors will be provided with loops from transparent polycarbonate plates with a thickness of 6 mm.

The frame of the ceiling hatch and the prolongation frame of the stair of the hatch are made of pressed wood, which is blocked and unblocked from the exterior. The frame of the hatch is positioned with two hinges from the frame of the lateral wall and, by its constructive form; it allows a placement at 10 degrees in respect to the lateral wall, like in figure 6.

In the first phase, we open the hatch in the ceiling and we evacuate the persons in the superior cabin. After that, the rescuers descends in the superior cabin and lifts the floor hatch and opens the ceiling hatch of the inferior cabin and retreats into the superior cabin and oversees the evacuation of the persons in the inferior cabin.

The construction of the inferior cabin is shown in figure 7 and is composed of: 1 – lateral frame; 2 – lateral wall; 3 – floor; 4 – left door; 5 – right door; 6 – ceiling reinforcement; 7 – ceiling hatch frame; 8 – hatch staircase extension frame; 9 – roof; 10 – ceiling plate; 11 – backside reinforcement; 12 – back wall.

The construction of the inferior cabin is similar to that of the superior cabin, with the difference that one end of the cabin is closed by pressed wood reinforcements, and the back wall is made up of white polycarbonate plate with a thickness of 10 mm.

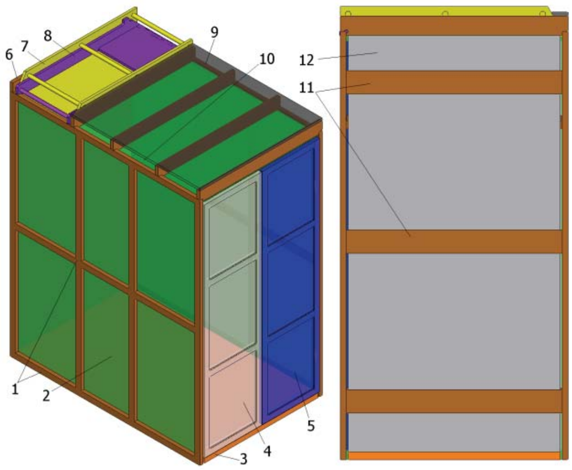

Fig. 7. *The construction of the inferior cabin*

3. The tower of the extraction installation of Unirea shaft, Slănic Prahova Salt Mine

In figure 8, we show the tower of the extraction installation at Unirea shaft, Slănic Prahova. It is a mechanical construction made of the tower proper and the abutment. From the evidence kept at Slănic salt mine, it is supposed that the year of construction is 1930, which means it's over 80 years old..

The construction materials from which the tower is made are laminated metallic profiles of the type L, U, I and thick plate, executed with the technical, mechanical and geometric characteristics corresponding to the year 1930. The joints of the composing elements are done with welding at the abutment and with rivets and screws at the tower. The tower's foundations are of monolith concrete and the pinning down of the tower and the abutment is done with metallic screws for the foundations.

Fig. 8. *The extraction installation tower at Unirea shaft*

3.1. The analysis of the shaft tower at Unirea, Slănic

In Figure 9, we show the sketch of the tower from the Unirea shaft at Slănic saline. The sketch was made based on existing documentation and by making measurements. This allowed us to determine the calculus model of the tower and of its solicitation loads [2], [5].

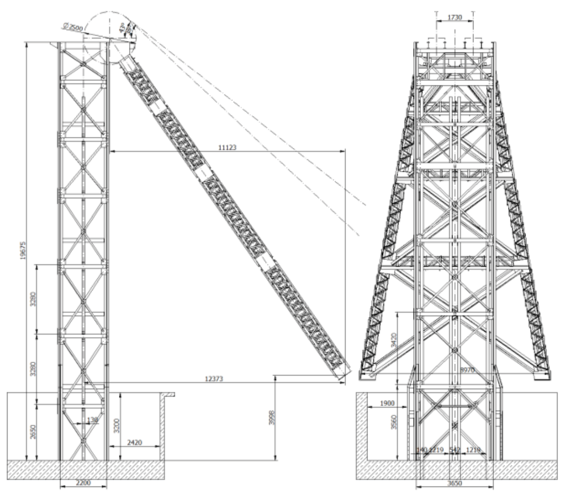

Fig. 9. *The tower's sketch with the dimensions necessary for the calculation model*

Also, this allowed the determination of the dimension of 3560 mm between the floors of the two cabins of the cage with two storeys, which will double the flux of person transportation on the shaft. In the case of the setting up of the second ramp for embarking at the level of the support platform of the abutment, by annulling the two stiffening braces of the tower and replacing them with another metallic construction that will be shown subsequently.

The calculation abstract was made for a dynamic coefficient of the extraction installation of 1,6 and, based on the constructive geometry of the tower and on the geometrical characteristics of the sections of the composing elements (tower, platform, abutment), we made a geometric calculus model of the tower. The static undetermined system of the tower was solved using the Mohr-Maxwell unitary loading method and the Vereschagyn procedure, and we obtained the bending moment and normal and cutting force diagrams, which are shown in figure 10 [1].

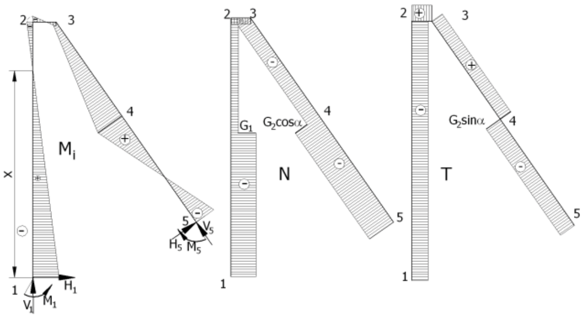

Fig. 10. *The bending moment and normal and cutting force diagrams*

After analysing the tower for the three solicitation cases: 1 – both cages are empty; 2 – a cage is loaded with persons and a cage is empty; 3 – both cages are loaded with persons, the following results were obtained:

- The maximum tension resulted from the calculation abstract in the area of the second section of the tower which is about to be modified was of 10,77 N/mm2;
- The maximum tension resulted from the tensometrical measurements on the braces of the second section of the tower is of 23.1 N/mm2, resulted at the safety braking on the cage with a mass of 2750 kg;
- In both cases, the safety coefficient for OL 37, with a flowing limit of 210 N/mm2 has a value greater than 9;
- We can observe that, as a result of dismantling the braces that will be replaced, in the same loading conditions, we obtain small modifications of the tensions in the 12 measurement points;
- After realizing the metallic construction for realizing the second surface ramp and replacing the two braces, new measurements will be made for the same loading conditions;
- In the first phase, we will realize the metallic construction for replacing the two braces, in order to make the measurements and to get to the next stage of realization of the cage.

3.2. The analysis of the influence of the two storeys cage on the guidance system of the shaft

In order to avoid transversal oscillations during movement inside the shaft, the transportation means (the cage) moves along the guidances that are fixed and supported by transversal dashes (binding pieces) encased in the shaft's walls on its entire depth (at equal distances). The transportation means (the cage) is guided laterally, because the loading and unloading is done frontally.

Fig. 11. *Gibs*

As a result of introducing the two-storey cage for the transportation of staff in the shaft, it is necessary that the gibs at elevation + 7110 (figure 11) under the bridge where the cables are stored and oiled with vaseline from elevation + 10660 (figure 12) are moved at its level.

Fig. 12. *Bridge for storage and oiling*

The stopping devices (tappets), the gibs for thickening the guidance fitted alongside the tappets, under the resistance dashes (dashes avoiding the pulley) stay at initial elevations and their positions do not require modification.

Replacing the one storey cage with the two storeys cage, due to the increase of the cage's height, has influence on the longitudinal rocking (the rotation angle), according to figure 13, for the maximum margin allowed at fitting (new guidance) between the wooden guidance and the gliders of the evacuation vessel of 10 mm, whether the evacuation is done frontally or laterally, or the wearing allowed during functioning, of maximum 15 cm on the frontal surface decreases from α_1=0,209107755^0 (12$'$,54646536) to α_2=0,093773696^0 (5$'$,62642177) for j = 10 mm, and for j = 15 mm, it decreases from α_1=0,313659893^0 (18$'$,81959359) to α_2=0,140660387^0 (8$'$,439623235).

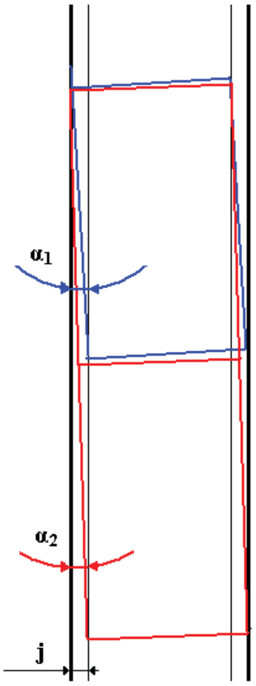

Fig. 13. *Longitudinal rocking angle*

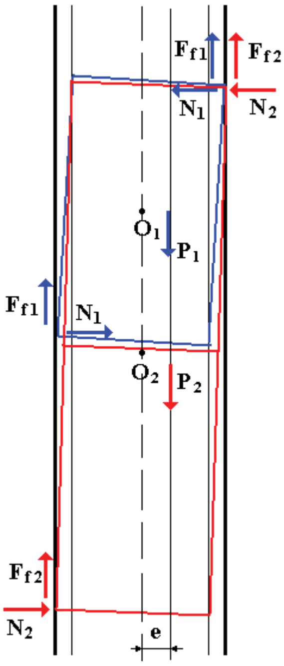

Fig. 14. *The forces system at transportation*

Also, by replacing the cage with one storey with the one with two storeys, the friction force between guidance and the revetment of the gliders also decreases. According to figure 14, considering that the forces that act during a transportation cycle are P1 for a one storey cage andP2 for a two storey cage, in the conditions in which they are situated at the same e distance from the symmetry centre and the transportation is realised with the same acceleration a. The other forces indicated in the figure are friction forces F_{f1} and F_{f2} and normal reactions N_1 and N_2.

For the one storey cage we have:

P_1 = (2300kg+800kg) a = 3100 a, l = 2740mm

For the two storey cage we have:

P_2 = (2300kg+1600kg) a = 3900 a, L=6110mm

Writing the equations for vertical projections and the moment equations according to O_1 and O_2, for each cage, for the same friction coefficient μ,we get two equation systems.

By solving the two equation systems, and calculating the rapport between $F_{f\,1}$ and $F_{f\,2}$, the results are that F_{f2} is≈1,77smaller than F_{f1}.

4. Studying the necessary modifications at the shaft's ramps

4.1. The ramp from the surface of the shaft

Starting from the construction of the two storeys cage, which will double the transportation capacity on the shaft of Unirea Salt Mine, we determined the height between the two embarking / debarking ramps from the cage of 3560 mm.

In figure 15, we show the 3D model of the new ramp from the surface of the shaft of Unirea Saline from Slănic, which was realized based on the tower's documentation and for the tensometric measurements that were done, figures 16 and 17.

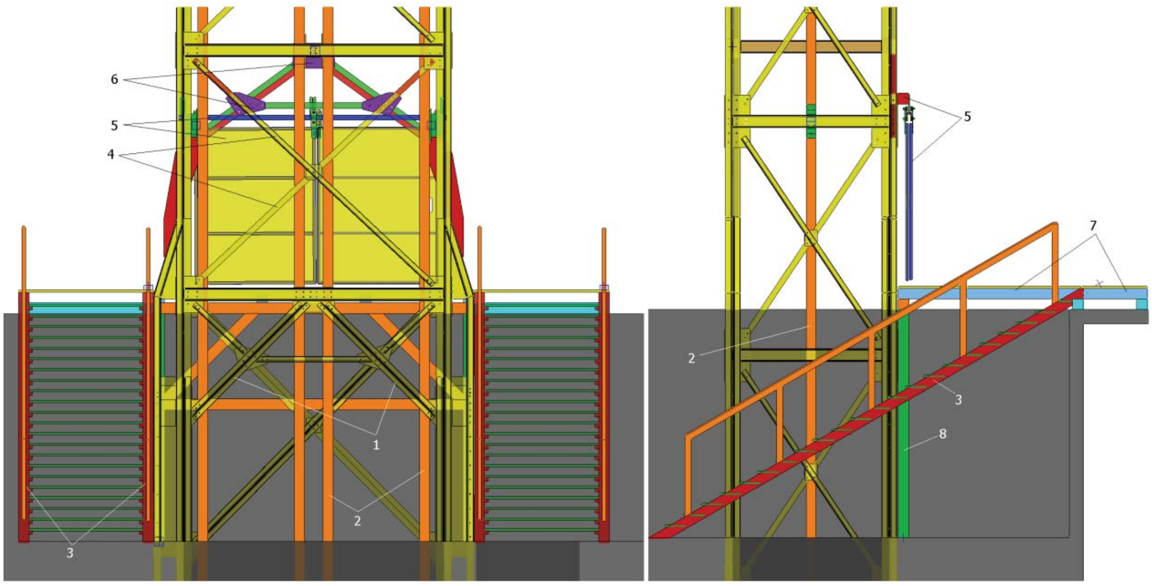

Fig. 15. *The 3D model of the new ramp at the surface of the shaft at Unirea salt mine, Slănic*

Fig. 16. *The location of the strain gauge stamps on the diagonals of the faces' panels*

Fig. 17. *Measuring points*

This is composed of: 1 – the existing ramp; 2 – the cage's guys; 3 – access stairs to the new ramp; 4 – braces that will be replaced; 5 – the closing doors of the new ramp; 6 – the new solution to replace the braces; 7 – the ramp's platform; 8 – support foot of the ramp.

The new ramp was designed to have a single access entry for persons at the two embarking ramps, one stair being used for access at the superior ramp, and the other for evacuating persons that come out from the saline using the superior ramp. For this, we used the parapet and the support platform of the tower's abutment.

In order to set up the new ramp, we must dismantle the two braces, marker 4, on the eastern side of the tower and replaced with the metallic construction, marker 6. Also, we must modify the metallic stair that provides access at the pulleys platform, by annulling the inferior section and realizing a new access section at the stair's platform on the southern wall of the tower. This new access section at the metallic stair of the tower must be separated from the superior embarking ramp with an access door.

The superior ramp is provided with safety doors for closing the shaft's compartments during the movement of the cages on the shaft.

The sustaining system of the doors is tied to the new metallic construction of the tower.

The platform, marker 7, set up at the superior ramp, is resting on a foot, marker 8, which is resting on the concreted platform of the lower ramp and on the eastern wall of the tower.

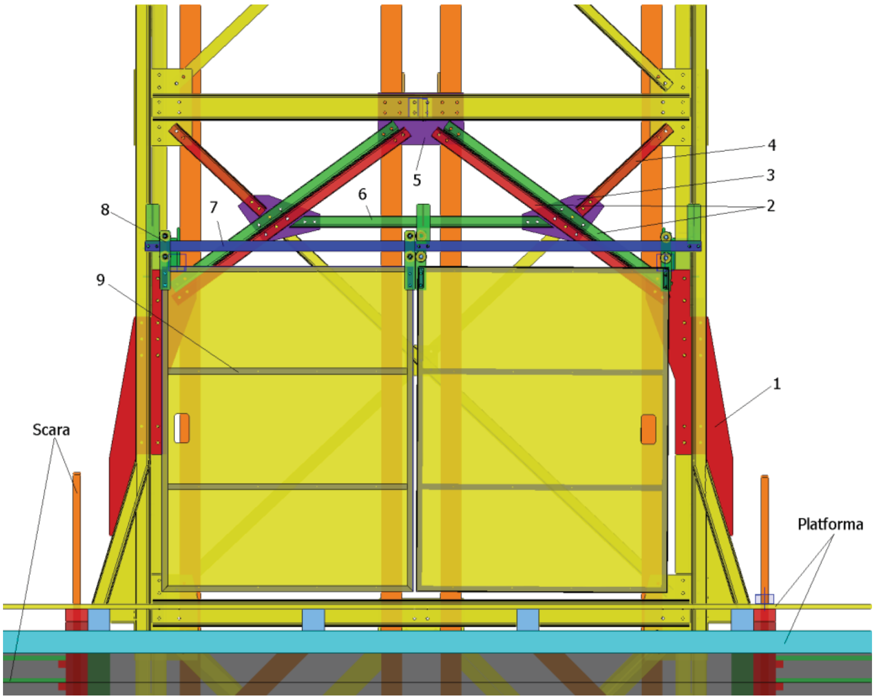

Fig. 18. *The metallic construction for the superior ramp*

The metallic construction of replacing the braces from the second section of the eastern wall of the tower is shown in figure 18, where the following were noted: 1 – stiffening and support gusset; 2 – closing braces; 3 – linking gusset; 4 – support braces; 5 – dash gusset; 6 – stiffening stringer; 7 – spar for door support; 8 – pulley support for the door; 9 – sliding doors. The fitting of the new metallic construction of stiffening the tower's section is realized by assembling with screws of M16 X 45, using the gussets of the replaced braces.

4.2. The ramp of the underground of the shaft

In figure 19a we show the actual solution of timbering the pit, solution which must be modified by the new transport system according to the model in figure 8b, where the following were noted: 1 – foot; 2 – longitudinal base dash; 3 –transversal dash; 4 – supplementary longitudinal dash; 5 – longitudinal dash 1; 6 longitudinal dash 2; 7 – cage guy; 8 – central foot; 9 – left inferior foot; 10 – right inferior foot; 11 – superior foot.

The modification of the ramp of the underground shaft is done by cutting the longitudinal dash 1, marker 5, in order to create the access space to the superior cabin of the two storeys cage. The ends of the dash that was cut are sustained by the inferior and superior feet, and the central transversal dash will be supported by the central foot, marker 8, composed of two wooden profiles of 200 X 200 mm.

The left inferior foot rests on the longitudinal dash of the ramp which will be fitted over the inferior ramp.

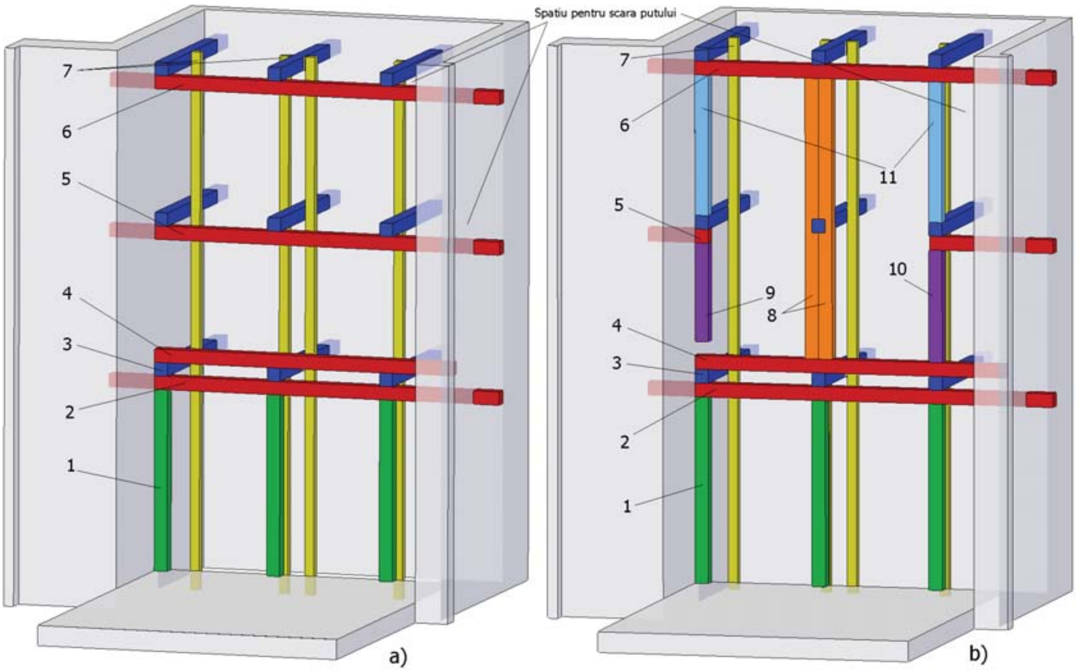

Fig. 19. *The modification method of the shaft's binding in order to realize the underground ramp*

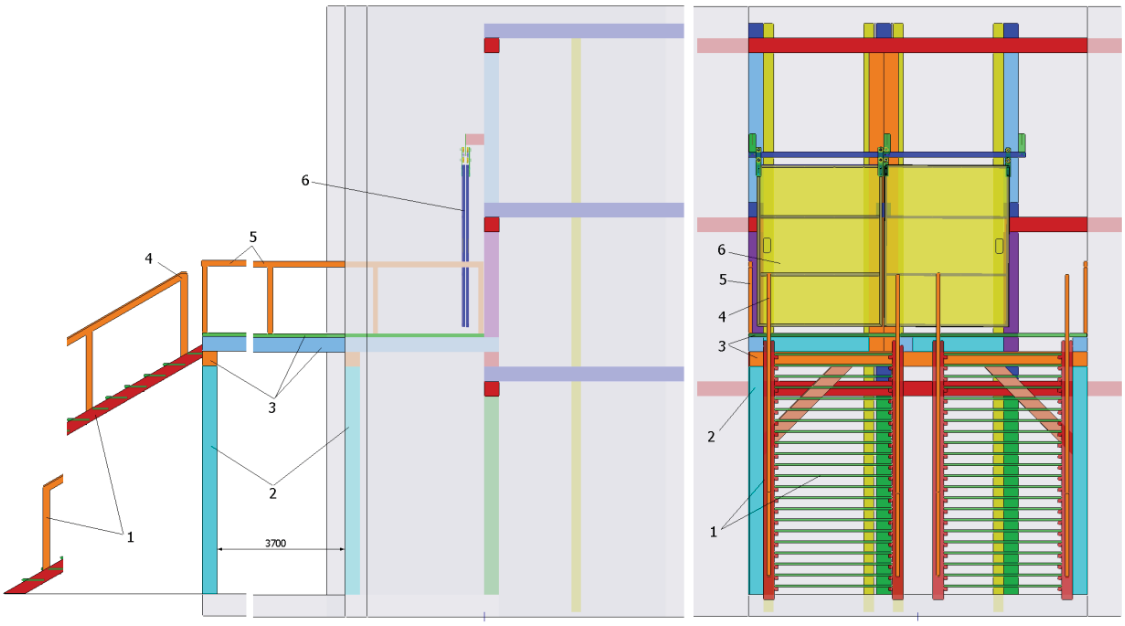

Fig. 20. *The construction of the superior ramp of the underground pit*

A solution of setting up the superior ramp of the pit in the underground is shown in figure 9, which is composed of: 1 – access stair to the superior ramp; 2 - the feet that support the platform of the ramp; 3 – the structure of the platform; 4 – stair handrail; 5 – platform handrail; 6 – safety doors of the superior ramp.

The solution proposed for the platform of the superior ramp of the underground shaft took into consideration the set up mode of the current ramp, which has a waiting space for the persons that will be transported at the surface, a space that is separated from the access aisle to the saline by a wall. Also, according to work protection and safety regulations, the space in front of the safety doors of the ramp must be free for a distance of 5 meters.

The two access stairs to the platform of the superior ramp will be allocated thus: one for the waiting space (the one on the right), and the other to the access aisle to the saline.

The construction of the stairs is similar to the ones at the surface, with an inclination of 30 degrees and a transversal space of 1.6 mm, which is enough for the moving of two persons in parallel.

5. Conclusions

Based on the constructive solution of the hatch with two storeys shown in figure 3, on the calculation abstract and on the general sketch of the cage, we can make the following determinations:

- The dimensions of the cage were imposed by the construction of the tower, more exactly by the distance between the existent ramp and the first section of the tower, which is 3650 mm.
- In order to fit into the actual mass of the cage, which is of 2.300 kg, the cage had to be made of a metallic frame, which offers the cage its resistance structure, and two cabins of pressed wood and polycarbonate plates for the transportation of people.
- We kept the cable bonding device DLC-1, the rod of 160 X 52 mm and the spring with 12 sheets from the actual cage, which allows the fast and economical construction of the new cage with two storeys.
- The construction of the metallic frame is easy to do, to fit in the ramp of the shaft and to maintain during the exploitation, due to the possibility of assembling/disassembling of the cabins that transport persons and to pull these on the ramps of the shaft.
- The cage was provided with an intermediary frame which would allow the fitting of the supplying battery of the illumination system and the installation of a station that allows the staff to talk to the exterior.
- The superior cabin is provided with double doors on both sides, due to the emplacement of the surface ramps on the eastern side pf the tower and of the underground ramp on the western side of the shaft.
- The cage doors open on the interior and block on the exterior and can be opened only by the human overseer from the ramp of the shaft.
- The cage is provided with an evacuation system of persons through the superior side of the cage in the case of its blocking on the shaft.
- The safety catch mechanism was improved by limiting the rotation of the claws so that we can avoid the sectioning of the wooden guy.

In order to realize the superior ramp in the tower of the extraction installation at Unirea mine, Slănic, we must make the following modifications:

- We will dismantle the braces in the second section of the eastern wall of the tower;
- We will fit in a new metallic structure for stiffening the second section of the eastern wall of the tower;
- From the calculation abstract regarding the comparison of the resistance modules of the sections by way of the new construction of the tower's section with the ones of the old construction there are no differences, which is favourable to the new construction;
- We must discard the metallic stair from the eastern wall, in the area of the first section of the tower;
- We will realize a new part of the access stair to the platform of the pulleys in the superior ramp – the platform must be separated from the ramp by a door;
- In order to set up the platform of the superior ramp we used the construction of the parapet of the inferior ramp and the concreted platform under the abutment, and the access to this is done by two stairs, one for ascending and one for descending;

In order to realize the superior ramp in the underground in the shaft of Unirea Mine, Slănic, the following modifications must be made:

- The reinforcing structure of the shaft is modified, by cutting the longitudinal dash that is second to the last dash and by rebuilding the reinforcing structure of the shaft with support feet of the transversal dashes;
- We must set up a superior ramp with a big platform of 4.59 X 5,80 min order to keep the space from the inferior ramp and to embark from the waiting area and the disembarking into the access aisle existing in the saline;
- The platform of the superior ramp has one end fixed on the reinforcing structure of the shaft and is enclosed by the shaft's walls, having the same width as the inferior ramp of the shaft.

All these modifications were imposed by the dimensions of the cage with two storeys, respectively by the distance between the floors of the two cabins of 3560 mm.

In accordance to the research carried out and to the data displayed above, it is possible to double the flux of person transportation at Unirea shaft belonging to Slănic Prahova salt mine.

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