UNCONFORMABLE DEFORMATIONS AT A REINFORCED EARTH STRUCTURE

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A B S T R A C T
In the year 2012 the works at the detour road for Caransebes were finalized. Short time after, the passing structure from the position km 7+375, realized in a “reinforced earth” solution, presented deformations and degradations of some structural elements, which questioned the viability of the bridge. The paper presents some of these defects and tries to explain the phenomenon which leads to them. The remedy solutions will be established after the geotechnical investigations and the analyzing of the evolution of the deformations are done.

Keywords: settling, crack, vault, Freyssisol panel, parapet girder

INTRODUCTION
The bridge in discussion is realized in a “reinforced earth” solution and was finalized in 2012, being in exploitation the period of time from 21.12.2011 to 30.05.2012 and from the 31.07.2012 (Fig.1.). The passing structure over the Valley is situated on the national road No.6, on the detour road of Caransebes, at own km 7+735. DN6 (National Road) represents one of the main traffic routes on the East-West direction situated in the south and south-west area of Romania, which connects Bucharest with the cut-off point Cenad in the Timis county, passing the city of Timisoara.

In horizontal plane, the bridge is emplaced on a left turning curve with a radius of 950 m. The bridge passes the Valley perpendicularly. In longitudinal profile it finds itself in a slight ramp of 0,3% (Fig.2.).

MATERIALS AND METHODS
1. The structure
The structure was designed and executed based on the Freyssisol technology.

The passing of the valley is achieved through a vault bridge with a precast concrete vault, with sections, combined with earthwork in reinforced earth solution (3 substructures):

- the Orșova end – earthwork in reinforced earth solution as a Freyssisol system, 15 m;
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- the reinforced concrete vault with 1 span of 12.51 m and a height of 6 m; the vault consists of 6 adjacent arches, each one composed of 3 precasted elements; the vault is founded on 2 foundation frames out of reinforced concrete, each of them bearing on 2x5 columns; the total length is 17.20 m (Fig.3.);
- the Lugoj end - earthwork in reinforced earth solution as a Freyssisol system, 37 m;

*Fig.3. Vault of the main structure*

The total length of the structure is 69.30 m, with a maximum height of 12.30 m and an average height of 10.18 m. For the execution of the work 484 reinforced concrete panels with a thickness of 0.14 m were used, having the standard dimension 2.14 x 1.61 m, adapted to the kind of panel: basic, standard, superior or special.

The width of the bridge of 13.50 m contains the carriage way of 7.00 m and the parapet girders, 1.00 m wide on the right side and 1.10 m on the left side, respectively the carriageable drain of 0.80 m on the left side and the corresponding width of the road shoulder on current section. The bridge gauge is realized without footway, the structure being situated outside the locality.

2. **Determined degradations and possible causes**

   The reinforced earth block is realized continuously, the joint between the above mentioned substructures being visible only at the level of the reinforced concrete slabs.

   The vault structure is founded indirectly, with a settling possibility of the foundations practically zero, while the adjacent structures are bewared on surface foundations executed on natural terrain, having therefore possible settleings in time.

   The parapet girder is realized as a continuous beam over all the three substructures.

   Chronologically speaking, the first determined degradations were the horizontal cracks, which appeared at the superior panels, right under the monolith parapet girder out of reinforced concrete (Fig.4. and Fig.5.).

   There are cracked elements also in the proximity of the vault, at panels, which bear directly on the vault, phenomenon owned to the rigid concrete on concrete bearing (Fig.6.).

   The appearence of the crack in a slab, which had the movements blocked on the sides parallel with the crack, can be justified by the fact that a torsion phenomenon occured upon the superior margin by bearing the parapet girder on a settled earthwork, which simultaneously also lead to the loosening of the tension in the anchorage elements of the slab (Fig.7.).
The cracking of other slabs on the reinforced earth wall can be similarly justified, through increasing pressure on the slab, which has a loosened anchorage in a terrain with a destructively modified compaction value. In fact, under normal execution and exploitation conditions, the loading from the anchorages transmits the slab a counter effort to that produced by the earth pressure (Fig.8. and Fig.9).

Also the existence of cross cracks was ascertained at the upper side of the parapet girder, on both sides of the bridge (Fig.10-13.). The cracks on the upper surface of the parapet girder, situated not far away from the vertical joint between the substructures, can be explained through the bending
of the girder, due to its bearing on the wall out of precast elements and an earthwork which moved vertically, due to settlements.

![Fig.10. Left parapet girder - extrados](image1)

![Fig.11. Parapet girder – lateral surface](image2)

![Fig.12. Right parapet girder - extrados](image3)

![Fig.13. Parapet girder at extrados and lateral surface](image4)

The phenomenon recorded about 3 months earlier, consists of relatively large deformations of the walls, especially at the superior side (over the height of the last 3 panels), in the direction of their convex bending. The global plane unevenness is around 10 cm on each wall. The phenomenon is more ample on the EAST wall – ramp Orsova, covering the entire length of the wall (Fig.14). On the WEST wall the local plane unevennesses at the joint level between the panels reach approximately 7 cm (Fig.15). The phenomenon can be explained only by the lengthening of the reinforcement in the polyester. This can occur due to the geometry alteration of the reinforcement in a ground, which has a diminished compaction value. Under the load effect due to earth pressure out of dead load and from traffic, part of the 3% accepted lengthening for the polyester material can take place. Thus the movement of the panels becomes possible in horizontal direction and also the “swelling” of the walls. The diminishing of the compaction value was a consequence of water infiltration from the carriage way through the joint between the asphalt layer and the concrete carriageable drain, during the rainy period from May, when, by reason of the lack of the thin surfacing, the rain water was not draining from the margin of the carriage way, where the asphalt (binder) level was approximately 5 cm lower than the upper level of the drain.
By enlarging the distance between the walls with about 20 cm, a volume was created, which was filled with the migration of the filling material, with a thus diminished superior level. The parapet girder, which was bearing on this earthwork has followed its movement, and while lowering, it has rotated around the panel walls, amplifying the fissures and the existing cracks, respectively leading to other new ones.

RESULTS AND DISCUSSIONS

1. Viability state

Analyzing the presented facts referring to the viability state of the bridge on the detour road of Caransebes at km 7+375 over the Valley, situated near the locality Caransebes in the Caras-Severin county, the following can be asserted:

- fissures and cracks at the Freyssisol panels;
- cracks at the parapet girder;
- rotation of the parapet girder;
- deformation (plane unevenness) of the walls realized out of Freyssisol panels.

The nuisance value of these degradations for the stability of the structure can be determined only after the investigations regarding the state of the filling material are finalized.

2. Bearing capacity

The bridge was designed for a uniformly distributed load of 20 kPa, which represents 85% from the load provided by the STAS 3221-86 (Carriage way bridges. Standard convoys and loading classes) at chapter 4 – Equivalent in earth layer of the convoys. The mentioned standard makes the assignation, that for the loading class E (which all the passing structures on the detour road for Caransebes are designed for) an equivalent earth layer with a thickness of 1,30 m is considered, which means 23,4 kPa. The determined degradations are not due to the mentioned difference. The calculation did not consider the presence of water, while in the present situation the accidental presence of water in the filling material lead to the altering of its characteristics.

3. Quality of materials

Analyzing by comparison the documentation provided by the contractor, the technical design and the documents regarding the quality of materials put in place, it can be stated that these are in accordance with the design regulations, as follows (designed/executed):
CONCLUSIONS

For the maintenance of the structure in an adequate viability state, the completion of the investigations is mandatory:

• the determination of the compaction value for the filling as reinforced earth, in different sections in horizontal plane and at different levels in vertical plane, based on a judiciously established plan, in order to avoid the accidental degradation of the anchorage system with polymer reinforcement of the Freyssisol panels;

• the surveying with topographical precision measurements of the evolution of the recorded deformations:
  – especially at the upper side of the walls realized out of Freyssisol panels;
  – at the parapet girder (left and right), which shows rotation towards the carriage way, but also an extreme bending, which has lead to cracks in the joint area between the substructures.

Considering the large recorded deformations at the above mentioned walls, if the analyse of the investigation results, which are to be done, shows that a consolidation of the structure is needed, it is recommended to use a connection system of the two walls left and right by the means of tie rods introduced horizontally through the layer between two anchorage levels. The expansion force distribution in the tie rod, respectively the compression force on the panels affected by the deformation, can be achieved through a steel or reinforced concrete girder network, at which the aesthetical aspect will be treated carefully, in order to preserve the slenderness of the structure. Preliminarily the fissures will be sealed by injecting epoxy rasins and the cracks will be repaired with special mortars. The surface thus mended, will receive a colour evenness by dying it with concrete adherent paints, which also have the characteristic of anticorrosive protection due to sealing of the microfissures. This consolidation solution can be applied under traffic conditions, by restraining the velocity, on one traffic lane using a traffic light system. Should the accentuation of the parapet girder rotation be determined, extended investigations will be needed, which should clarify the causes leading to the mentioned phenomenon. In accordance to the investigation results, the measures for the maintenance of the structure in an adequate viability state will be established.

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