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STRUCTURE IN BIG SKEW – GLADSAXE CASE DENMARK[1]

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This paper presents how to solve the end treatment for buried steel structure designed initially in an incorrect way. Structure VR9 with span of 4.77m and rise of 3.83m was designed with skew of 28 degree with beveled end cut 1:1.5. Due to heavy loads LM1 LL vehicle the cut end would be subjected to huge deformations. The solution of the problem required the designing of: geogrids to reduce the horizontal active pressure and the 3D concrete frame to carry the vertical loads (soil and traffic). Fem 3D analysis and final solution of cut end reinforcement will be presented in this paper.

Key words: Buried steel structures, underpass, big skew

1. INTRODUCTION

The background for this project was that the capital city in Denmark, Copenhagen wanted to promote the interest in cycling. They decided to make it safe for the cyclists so they created a programme as part of which municipalities could apply for funding of projects that would promote the use of bicycles as transportation.

Gladsaxe Kommune and Nordvand A/S organised a competition of designing a cycle route that went through Gladsaxe city. The route should have passed some large roads with heavy traffic and also have an access ramp to one of the main streets.

ViaCon A/S made a proposal together with the consultant engineering company, Grontmij with a MultiPlate structure. The design also involved a framed sheet pilling wall at one side of the MultiPlate underpass because the route should curve a lot.

The design should include the connection from the MultiPlate structure to the sheet pilling wall. The result was a traditional concrete headwall around the tunnel. On the other side of the underpass the idea was to make a bevel end with

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a declanation of 1:3. Because of a skew angle of more than 28° the cut end reach a lenth of approx. 15 meter.

To stabilize this long bevel end the engineers of ViaCon in Poland made a combination of a concrete collar and a soil reinforcement using 7 layers of geogrids. The geogrid had a strength of 20 kN/m and was fastened to the side of the MultiPlate with steel angles iron bars. The grid was supplied in 1 meter width and the design consisted of 7 layers with a distance of 190 mm to 460 mm. The length of the grid should not be less than 4 meter from the MP side plates.

The conctractor should install compacted sand on top of each geogrid layer. Each layer of geogrid should be stretched out before backfilling with sand.

The concrete collar was designed to be minimum 400 mm width and cover the steel plates of 600 mm. The concrete collar should be made of reinforced steel (Ø8-Ø16 mm) and weigh approx. 1.1 tons in total. Framework was made by the contractor who also had to build 4 support collars of concrete (wood) that should help stabilize the structure during backfilling. The distance between these blocks was 3000 mm.

2. REPAIR PROGRAMME

2.1. Numerical analysis

PipeArch structure VR9 (Fig.1) with span of 4.77m and rise of 3.83m (Fig.2) was initially designed with a skew of 28 decimal degree which is out of the permissible range of 125≥□≥55. Structure was also beveled 1:1.5. Due to this fact structure outlet was susceptible to damages. To avoid any failurex during construction very detailed numerical model of steel structure was created.

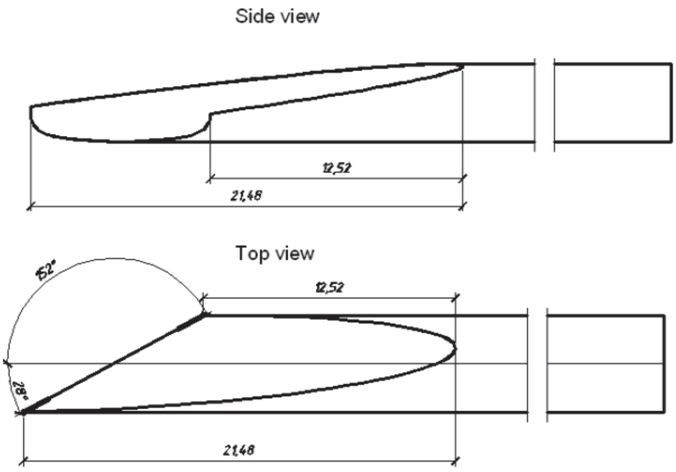

Figure 1. Geometry of skewed and beveled end of the structure

Main parameters of structure:
- Dimensions of cross section (SpanxRise): 4.77x3.83m;
- Length: 49.85m;
- Bottom Centreline Length:BL=2.49m;
- Top Centerline Length TL=2.49m;
- Skew 28°,
- Bevels 1:1.5.

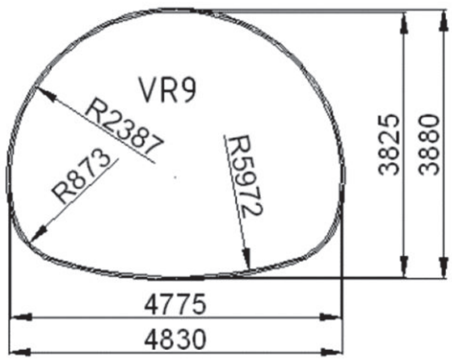

Figure 2. Cross section of the structure

Geometrical FEM (Fig.3) was created using an orthotropic shell elements with parameters corresponding to MP200 corrugation.

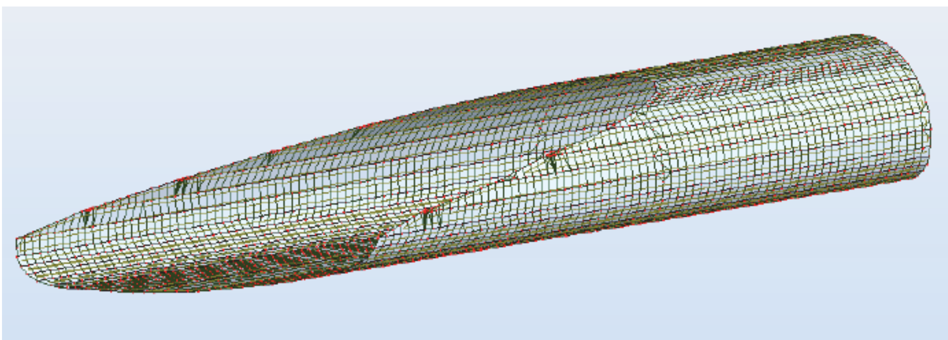

Figure 3. FEM Geometrical model of the structure

Three different analyses were conducted.

a. 1-st was the buried steel structure without any additional elements. Result of analysis showed a deformation (Fig. 4) of the free edge of the sheel equal to 14.1 cm.

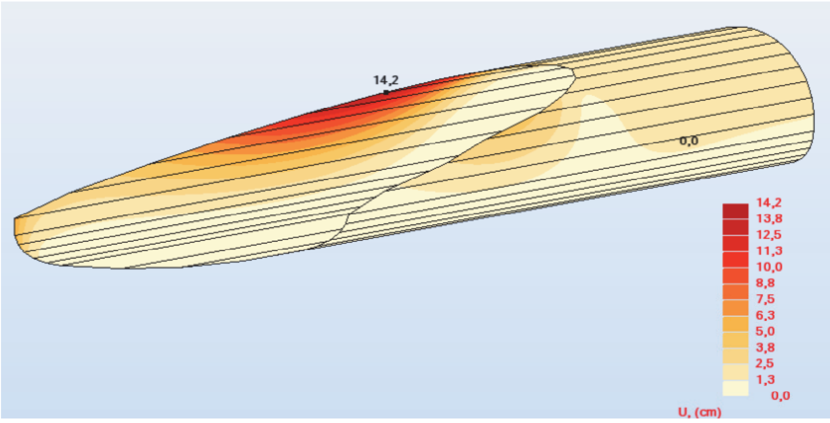

Figure 4. Total displacement of culvert without any support

Total deformation of the vertical element was 6.5cm which was not accepted by the local road authority.

b. The second one was the same structure but to reduce the lateral pressure the geogrids were used. The deformation of steel shell (Fig. 5) with reduced horizontal pressure was 4.1cm

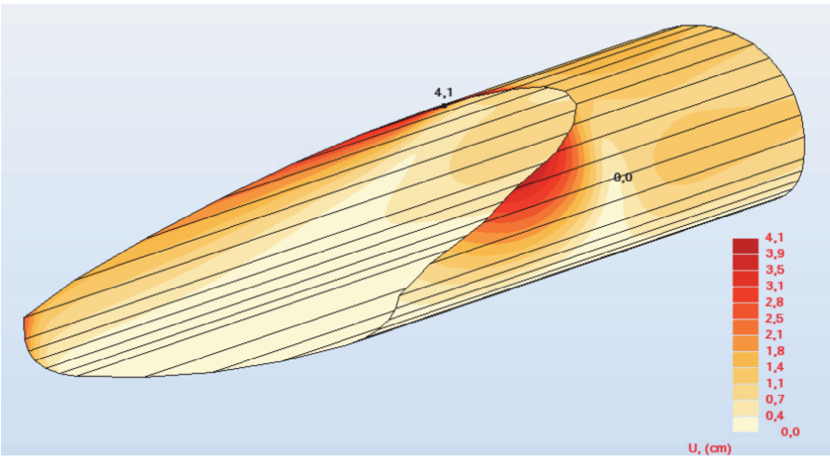

Figure 5. Total displacement of culvert with attached geogrids

c. The 3rd one was the steel structure with concrete 3D frame (Fig.6) and also with monooriented geogrids. This solution minimized deflections of free edges of the steel shell.

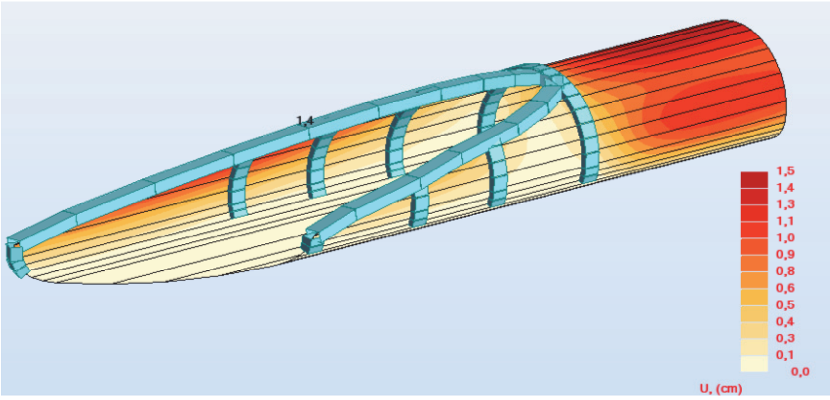

Figure 6. Total displacement of culvert with attached geogrids and concrete collar

Analyses shown above were presented to Customer and the 3rd option was chosen . So called Repair Programme was introduced with detailed location of geogrids and form of cast in place concrete frame to reinforce the free edges of the structure.

3. CONSTRUCTION OF THE UNDERPASS

The MultiPlate structure was built in the place (Fig. 7) where the underpass crosses the road.

Figure 7. Assembled structure – bottom section painted with bitumen. The ramp on the left

Because of the length and the weigth it was decided to lift the tunnel in two parts (Fig. 8).

The tunnel should be positioned between the steel sheet pilling walls – after that casted with concrete (Fig. 10).

A reinforced concrete collar (Fig. 11) was made around the long bevel end to ensure an accurate shape of the completed structure. By using a geogrid reinforcement system (Fig. 9) the job was done excellently.

Figure 8. MultiPlate structure has been split into two parts – ready for lifting

Figure 9. The 21.6 m long bevel end has been provided with geogrid (soil reinforcement)

Figure 10. MultiPlate structure is placed between the sheet pilling walls

Figure 11. The formwork was made with accuracy – not an easy job

4. SUMMARY

Proper finishing treatment plays a key role in maintaining buried steel structures. They are operating fine with recommended skew ranges but if we go out of range some problems related to major deformation can occur. To reduce this deformation we can use the geosynthetic materials i.e woven geotextile or geogrids, but by using these materials we will only reduce the horizontal deflections. Vertical deflections caused by the soil weight can not be carried by geosynthetic materials because they don't have any bending stiffness. Situation can be improved using concrete frames.

Figure 13. The MultiPlate structure is finished and the pedestrians use it every day

By using additional elements the system which is relatively easy and cost-effective is going to become more complicated and expensive.

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