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# GOOD PRACTICE IN CONSTRUCTION OF FLEXIBLE SOIL-STEEL STRUCTURES WELL DONE INSTALLATIONS OF BURIED BRIDGES[1]

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The following article raises questions on good practices that should accompany both the design and installation process of corrugated soil-steel bridges. Solutions for crucial elements of soil-steel structures developed over the years of experience and observations are put forward. The authors put special emphasis on issues related to the flexible soil-steel structures protection against water and point to new developments in the waterproof design area. The paper presents examples of properly executed civil engineering facilities, which indicated further development directions. The authors wish to draw attention to the fact that with the popularization of corrugated steel plate bridges the necessity of dissemination of correct and reliable solutions among designers and contractors increases. They provide a guarantee for long and seamless bridge utilization.

Key words: Buried structure, water protect, support, drainage, animal overpass.

## 1. INTRODUCTION

The emergence of flexible soil - steel structures goes back to the last years of the nineteenth century. The first research into buried structures were carried out simultaneously in the United States and Russia. In the beginning, there were only steel corrugated pipes. Along with the technology development engineers started to divide sections into single elements joined with screws. This enabled the construction of larger structures, providing a wide range of applications in nearly all areas of civil engineering.

The dynamic development of structures made of galvanized corrugated steel plates occurred after World War II to meet the demands of the economy of the time for the reconstruction of the destroyed communication infrastructure. The unquestionable benefits of technology were appreciated:

– the relatively low cost of the facility construction,

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- solution simplicity,
- reduction in total time of building a bridge,
- small financial expenditures associated with subsequent maintenance facility.

Mentioned benefits arise from the specific construction of corrugated soil-steel bridges. The most crucial and demanding elements of later maintenance were eliminated. In flexible steel structures, dilatation elements are not applicable, a continuity of road embankment above the structure allows for the elimination of approach slab in the bridge access area, apart from that proper moulding of the steel structure, eliminates the occurrence of rapid subgrade`s stiffness change. Structures with closed and pipe-arch shapes are devoid of external supports, on the other hand, the foundation of open shaped structures could be much lower and less stocky than counterparts occurring in classical bridges. In addition, in soil - steel structures there are no lines of bearings constituting an additional element subjected to periodic maintenance treatments.

Prevalence of the technology, increased designers' baggage of experience and far-reaching technical progress made it possible to better understand the composite action of steel sheets and surrounding soil. Thanks to intense researches conducted on the fully scaled models, as well as the development of computer science based on FEM (finite element method), it was possible to develop new shapes of flexible structures, and also new types of corrugation. All these enabled to build soil – steel composite bridges with spans exceeding 20m, in the 90s of the twentieth century.

The simplicity of this kind of structures, both in terms of design solutions, as well as the process of investment realization, led to too trivial treatment by designers and contractors. It resulted in some omissions which caused errors both on construction site and during the design process, which affected the further utilization of this structure type. Observations of carried out investments showed the necessity for standardization of repetitive elements solutions. Lifetime experience has resulted in *Details catalogue for buried flexible steel structures*. The most important elements of the catalogue, examples of implementation and new development priority will be discussed further.

## 2. DETAILS CATALOGUE FOR BURIED FLEXIBLE STEEL STRUCTURES

Details catalogue is divided into five parts, the descriptive section provides a brief overview of the whole document and clarifies the requirements for bedding and engineered backfill. Subsequent parts concern the soil - steel structures divided by the types of corrugation:

- profile type 381mm x 140mm;
- profile type 200mm x 55mm;

– profile type 68mm x 13mm and 125mm x 26mm.

The last part presents details of amphibian shelves in culverts made of corrugated steel plates.Structures of profile type 381x140 and 200x55 consist of a single corrugated plate bolted peripherally and longitudinally. Helically corrugated steel pipes have two types of corrugation: 68x13 and 125x26. The paper features solutions for structures of first two types of corrugation.

Elements that require the most attention are related to the corrosion protection against rainwater. In the following parts of the paper the authors expound a problem of different ways to protect composite steel bridges, which result from many years of experience.

### 2.1. Soil-steel structures protection against rain water

General assumptions related to the rainwater preserve do not differ for the steel structures of profile 381x140 and 200x55. The protection is performed by a geocomposite layer consisting of the 1,0mm thin polypropylene (PP) or high-density polyethylene (HDPE) geomembrane layer enclosed by two layers of non-woven geotextile with CBR> 5,0kN and weight min. 500g/mm$^2$. Geocomposite should be laid with bilateral decrease of no less than 5.0% and ended with drainage. What is more, the “umbrella” must go beyond the steel structure more than its height (the minimum is 2m), as an example see the Fig. 2.

The drainage system should consist of a pipe with diameter of 160mm, 8 kPa nominal ring stiffness and perforation on upper 220 degree. It is surrounded with 8/16mm pebbles and wrapped in geotextile CBR> 5,0kN and weight min. 500g/mm$^2$, according to Fig. 1. Insulation performed this way is the first part of the structure protection against rainwater and to assure adequate barrier for further water migration is regardful execution on construction site.

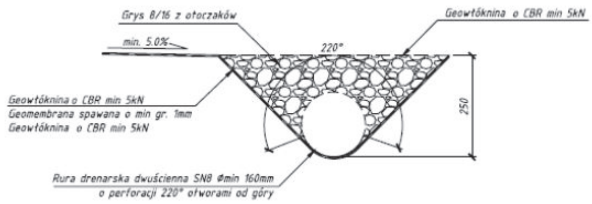


Fig. 1. Drainage detail at the end of a geocomposite layer

Another common method used to provide water tightness of composite soil-steel bridges is applying polyurethane adhesive sealant in structure slits and bolted connections. Caps made from polypropylene or polyethylene with size matched to the shape of bolt heads/nuts protect the sealing material from damage during backfilling. This solution often provides additional security for the most vulnerable places exposed on the water expansion despite the use of geocomposite.

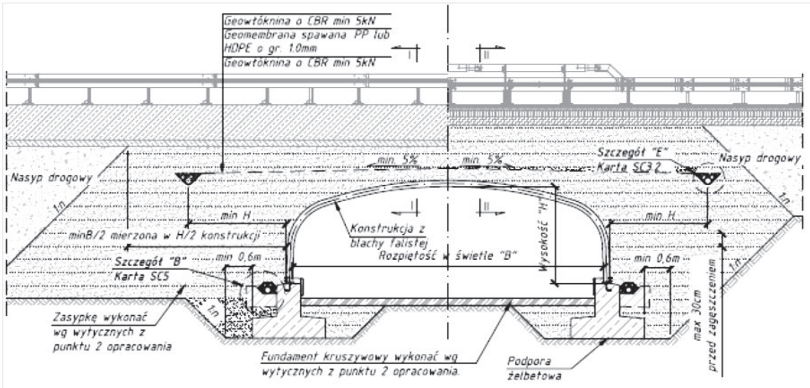


Fig. 2. Geocomposite hydroinsulation above the structure solution

Fig. 3. Filled of structure edge with sealant

Fig. 4. Filled of bolts connections with sealant

## 2.2. Connection of soil – steel corrugated structure with footing.

The performance quality of the connection of flexible steel structure with footings is also a very important factor affecting the proper serviceability. This is the place where water from backfill is most likely to penetrate the structure. In open shape profiles, we distinguish two types of bearing supports, external and intermediate supports. External support is the one on which one side of the structure is rested, while on the intermediate support two structures are based. Intermediate bearing support is more common in structures of high corrugation like 381x140. Some typical solutions are given below.

2.2.1. Connection of flexible steel structure of wave profile 381x140 with footing – external bearing support

In this case the connection is maintained by a steel base channel fixed with anchors in axial spacing 381mm to concrete foundation.

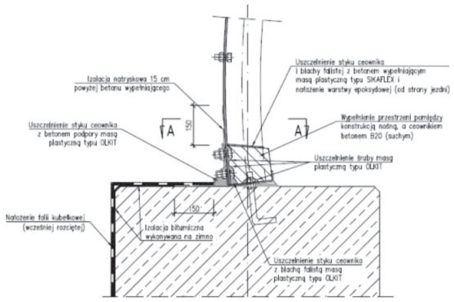


Fig. 5. The older solution of external bearing support for super-core structure

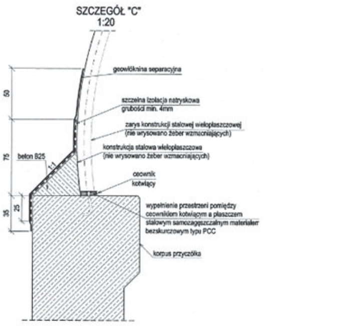


Fig. 6. external bearing support for super-core structure. Animal overpassWZ-61C over express road S-5 in Poland

Initially, extreme supports of facilities such as PZ6 over express road S-8 were sealed with permenently elastic material placed both on the connection between steel base channel and bearing support and connection between steel structure and concrete that fills the channel, as shown in the Fig. 5 and Fig. 9. Afterwards the permanent elastic material was replaced by a 4mm thin two-component, latex and bitumen-based, spray applied insulation, like in Animal overpass WZ-61C over express road S-5 in Poland (Fig. 6).

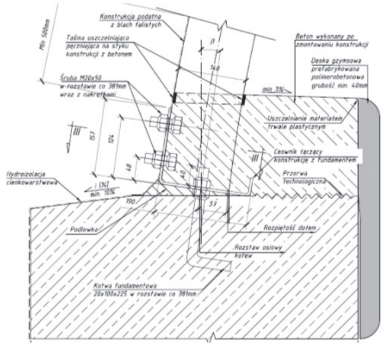


Fig. 7. Connection of supercor structure with concrete

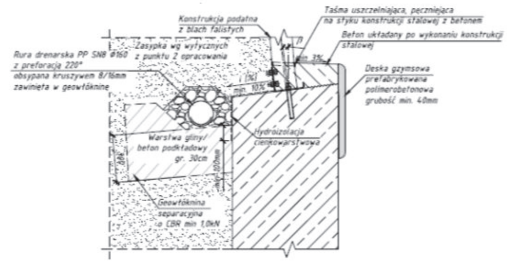


Fig. 8. External footing drainage

Currently, the conncection of steel structure with concrete footing presented on Fig. 7 is executed. The system is basen on a previous solutions, however it was supplemented by elements improving its aesthetics. The upper surface of the foundation must be formed to preserve the counter slope of min. 10% towards backfilling. The void between a base channel and ground should be filled with concrete, the steel plate and concrete contact must be protected using expanding sealing tape as well. From the air side on top of the foundation concrete overlay is carried out in accordance with Fig. 7, sealing tape is used for preventing contact with the concrete and steel plate. An additional element is prefabricated cornice board, which fulfills the aesthetic function and protects the foundation from water condensing on the metal surface. On such prepared foundation, 4 millimeters either two-component, latex and bitumen-based inuslation or two-component insulation based on methyl methacrylate resins at 0.5m length from the edge of the base channel can be applied.

Another crucial element for the correct protection is the drainage arranged along the external support. It allows the ground to receive water in the vicinity of the foundation. Drainage is composed of the same elements as that used at the ends of the geocomposite, but in this case, it is placed on the layer of concrete or impermeable soil. Fig. 8 shows the drainage details.

Fig. 9. Performed hydro insulation of external bearing support.
Animal overpass PZ-6 over express road S-8 in Poland

2.2.2. Connection of flexible steel structure of wave profile 381x140 with footing – intermediate bearing support.

Design of the intermediate support consists of the same elements as the external one (Fig. 7). However, the location of drainage pipe is changed, which in this case is placed in the middle of the support between the two steel structures. Initially, the entire space between the steel plates was filled with concrete with the top surface declined towards the support axis. Elastic mass was used for contact seal between concrete and soil-steel structure. The following step was to spray-tight two-component, latex and bitumen-based insulation with a minimum thickness equal to 4,0mm. On the prepared foundation, drainage pipe wrapped in grit and geotextile is placed, see Fig. 10 – Fig. 11.

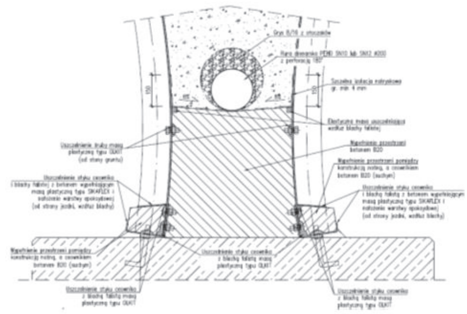

Fig. 10 Previous solution of intermediate footing drainage. Animal overpass PZ-6 over express road S-8 in Poland

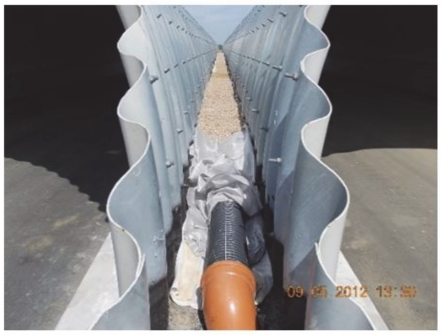

Fig. 11 Performed hydro insulation of intermediate bearing support. Animal overpass PZ-6 over express *road S-8 in*

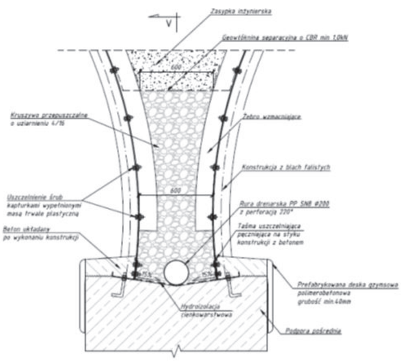


Fig. 12. Current 1detail of intermediate footing drainage

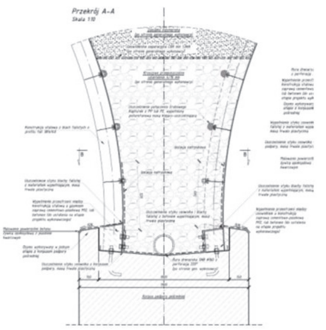

Fig. 13. Hydro insulation of intermediate bearing support. Animal overpass PZDg-9A over express road S-6 in Poland

In the current solution, the concrete between the structures has been abandoned and the drainage pipe has been moved down. As in the case of external support from the air side, the contractor should perform concrete overlay ending with cornice board, and the space between adjacent structures is filled with grit 8/16mm and covered with isolation, non-woven geotextile with CBR> 1,0kN and weight min. 80g/mm$^2$. In addition, steel structures slits and bolts are secured with adhesive sealant as shown in detail in Fig. 12.

Concrete and steel structures surfaces should be covered with waterproofing spray-applied material, either two-component, latex and bitumen-based inuslation or two-component insulation based on methyl methacrylate resins, at the height min. 0.5 m over the construction of support element.

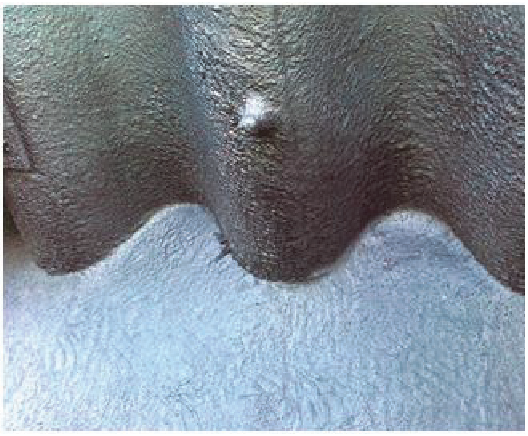

Fig. 14 Performed spray-applied hydro insulation of intermediate bearing support. Animal overpass WZ-61C over express road S-5 in Poland

Fig. 15 Drainage performed on intermediate footing. Animal overpass WZ-61C over express road S-5 in Poland

2.2.3. Connection of flexible steel structure of wave profile 200x55 with footing

In the case of a structure with corrugation profile 200x55 in the foundation, there has to be a specially prepared seat upon which the steel structures is based. After whole structure assembled the socket is filled with self-compacted non-shrinking Polymer Cement Concrete (PCC) mortar.

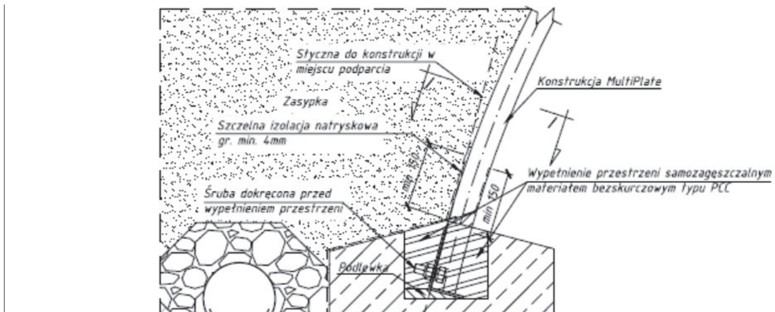


Fig. 16. Connection of multi-plate structure with concrete footing

As in the previous structures, the backfill side of the foundation and steel structure from backfill side should be covered with a watertight coating system and also drained in accordance with the previous guidelines.

## 3. NEW DIRECTIONS IN THE DEVELOPMENT OF ENGINEERING SOLUTIONS

Recently, in an increasing number of projects, designers are eager to utilize a new watertight solution – EPDM membrane. This is an elastomeric material used so far in hydraulic engineering (tanks and artificial water reservoirs).

Because of the properties, elasticity, tensile strength, shape memory, ease of installation, and repair EPDM has been proven to be an effective sealer for corrugated metal plate structures. In contrast to the currently employed geocomposites, the EPDM geomembrane is placed directly on the structure and conforms to the structure shape. In-situ testing confirms the effectiveness of this material.

By stacking a membrane directly on the steel structure, there is no need to drain the backfill at the end of the EPDM membrane, as there is in a classical solution. Another advantage is evident in structures with beveled ends, because EPDM Geomembrane can be easily adapted to this shape. Currently, it is the most widely used alternative to the above solutions.

Fig. 17. EPDM geomembrane placed on super-core structure

Fig. 18. EPDM geomembrane placed on multi-plate structure

Fig. 29 EPDM geomembrane placed on super-core structure. Railway tunnel in Algeria. Span of circular structure is over 12m

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