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APPLICATION OF STEEL CULVERTS IN SECTION OF OSIJEK – ĐAKOVO MOTORWAY

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Abstract

Application of steel culverts in road construction in the world is not a recent development. Their application in Croatia is sporadic and almost negligible. Construction of concrete tube culverts is a usual practice, for a number of reasons: developed construction technology, trained labor for the construction of such culverts, satisfactory design life, simple maintenance, etc. Despite all this, at a section of the Osijek – Đakovo motorway, in a number of locations, steel culverts have been constructed as a more cost-effective solution. The paper describes experience with the application of steel culverts at a section of the Osijek – Đakovo motorway. The procedure of the construction of steel culverts from spiral tubes and corrugated structural plate and the applied construction technology are presented. Advantages of the application of steel culverts have been pointed out, except for construction of new roads and in reconstruction of existing roads.

Keywords: steel culverts, road construction, road reconstruction, motorway

1 Introduction

In the last several years intensive motorway construction has been recorded in Croatia with a view to upgrade the existing road network and its fitting into European traffic routes. Those are state-of-the-art roads which separate natural units and urban areas. For this purpose it is necessary to construct a larger number of culverts that serve for passing the water through or passage of animals, pedestrians, and small vehicles below the roads. Culverts have to be constructed before other works on the road bed are carried out, so the selection of the type of culvert and the construction technology significantly impact the schedule of works on the road in general, as well as meeting the completion deadlines. This is also important in case of the need for reconstruction of culverts for purpose of reducing the time of the closure of the road for traffic.
In the practice of road design and construction in Croatia so far concrete tube culverts have been traditionally applied as a reliable and simple solution. In the face of that tradition, at the Beli Manastir – Osijek – Svilaj section of the Osijek – Đakovo motorway, which is described in this paper, tube culverts were constructed of steel spiral tubes and corrugated structural plate. The section of the motorway mentioned above is a part of the international European road corridor Vc running from Budapest via Sarajevo to Ploče, connecting the north of Europe with the Adriatic, which represents the backbone of the road infrastructure of eastern Croatia. Steel culverts are frequently constructed in countries with developed steel industry and expensive labor [1]. A comparison of steel pipe culverts that span up to 10m and conventional concrete culverts, for the equal static bearing capacity, shows that steel culverts demonstrate

numerous advantages [2] that could result in their increasingly intensive application in road design and construction in Croatia as well.

2 General characteristics of steel culverts

The selection of the type of culverts is affected by the height of the embankment above the culverts and the quantity of water that needs to be passed through. If a culvert has another application, then the selection is dependent on traffic requirements. In the selection of the type of the culverts the tradition of building (with a known and run-in technology) has a great role, and this is one of the biggest reasons for a frequent use of concrete culvert pipes in Croatia.
The basic characteristic of today's civil engineering is increasingly shorter deadlines set before the contractors. In that respect it is necessary to significantly accelerate construction of structures in road base, among others culverts, which significantly define the terms of construction of roads in general, and this, in the long run, can diminish the quality of performed works. One of the solutions may be the use of steel culverts whose construction is quick and simple and they represent a flexible solution because they can quickly and simply adapt to the requirements on the site [2]. They can also be built during the winter period, when it is not possible to carry out most of the works in the construction site. Savings in time and money is also possible in case of existing roads in the event of reconstruction (road expansion, a small correction of the routing) or maintenance works (which requires closure of the road for traffic) because those culverts may be extended or simply dismantled and re-fitted into another place without much difficulty.
Steel culverts are composite construction structures in which a joint operation of the arch of made up material and supporting wall of the steel culverts is enabled. Due to filling and moveable traffic load forces are created which act in the area of the spiral tube top. The tube is expanded laterally, and the lateral sides move toward the soil. Passive resistance of soil is activated and due to the flexibility of steel culverts balance is established. In this mechanism soil bears a part of the load, by which a cost-effective and stable construction is achieved [5]. According to the type of tubes, culverts are divided into steel spiral tubes and tubes made of corrugated sheet.

2.1 Spiral tubes

The first spiral tube was produced and used in the road drainage as early as in 1896 [3]. Positive experiences with this prefabricated, thin-wall and light elements were followed by a sudden increase in their usage for various applications.
Nowadays spiral tubes are produced in specialized plants in which a steel strip hot galvanized on both sides is rolled on a profiling machine and then wound on rings of corresponding diameter. The required length of spiral tubes is obtained by cutting the produced tubes with a saw that operates in parallel with the production process, thus enabling an uninterrupted winding procedure [4]. Steel spiral tubes of circular and jaw cross-section are used for culverts (Fig. 1.).

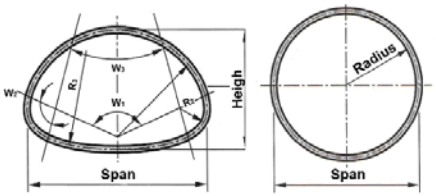

Figure 1 Cross-sections of Spiral Pipe Culverts: Jaw-shaped and Circular

To ensure simplicity of transportation and installation, the biggest length of an individual piece of circular tubes is 13.5m [4], whereas the diameter is between 30cm and 360cm [3]. Jaw-shaped profiles are available in various combinations of heights and spans (spans up to 3m). The biggest length of an individual piece of jaw-shaped profiles is up to 6m because of the possibility of connecting the tubes with special connectors (Fig. 2), whereas the total length of culverts is, actually, unlimited.

Figure 2 Connectors for Joining Spiral Tubes [4]

There are four types of connectors (Fig. 3.): partially corrugated, corrugated, flat, and universal. When joining spiral tubes, to secure the connection, first one of the three types of gaskets is placed: O-ring gasket, sleeve gasket, and strip gasket (Fig. 3.), and then the connector is tightened (Fig. 4) and fixed to the tube.

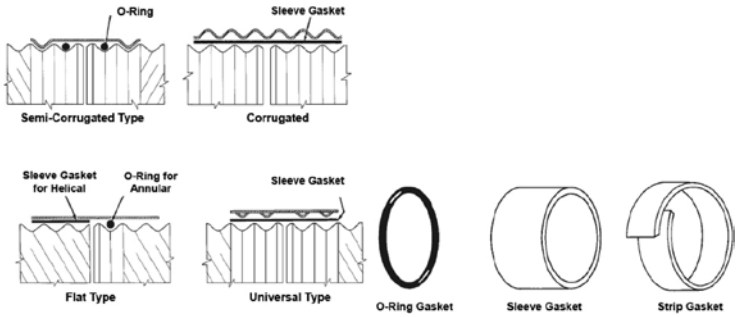

Figure 3 Types of Connectors and Gaskets [3]

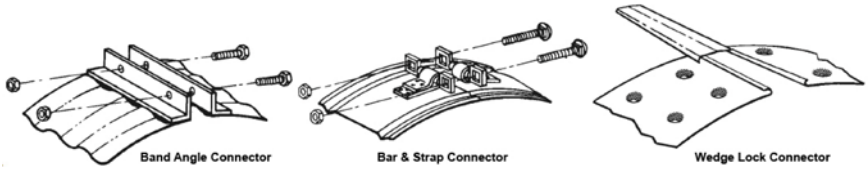

Figure 4 Types of Tightening of a Connector [3]

2.2 Corrugated structural plate

Application of corrugated structural plate in road drainage has been known for more than 100 years. When it was observed that the corrugated state of steel plate increases its stiffness and strength, a mass production of plates of corrugated metal sheet began. The first such plates were produced in 1784, whereas their mass production began only in 1890 [3]. In order to deal with increasingly large spans and enable larger flows, in 1931 for the first time tubes of corrugated sheet metal started to be used which were connected at the place of installation, whereas the first application in Croatia was recorded in 2003 at the Zagreb – Rijeka motorway (Vukova Gorica).

Construction of culverts by using tubes of corrugated sheet metal is somewhat more complicated in comparison with culverts with spiral tubes. The material is delivered to the construction site in the form of corrugated, perforated, and bent steel plates which are fitted with bolts at the place of installation and the desired shape is formed (Fig. 5). Profiles used the most are circular, arch-shaped, elliptic, and jaw-shaped ones. Spans of those culverts are larger than those of spiral tubes, so today spans larger than 20m are used as well (Super Cor culverts).

Figure 5 Construction of a Passage on the Vodnjan – Pula-Istria Y Road

To enable a long-term protection from corrosion, all elements were hot galvanized, while use of a protective coating based on bitumen or epoxide resin is recommended as additional protection from the impact of aggressive water or exhaust gases. A combination of zinc plating and coating renders twice the protection effect [4]. Since those structures are mounted from a number of pieces of corrugated sheet metal at the place of installation, as the protection from seeping the elements are connected by lapping, and the connections may be additionally protected from seepage water by fitting of sealing strip at the places of lapping of connections.

3 Possibilities of application of spiral tubes and corrugated structural plate

Culverts made of steel spiral pipes and corrugated structural plate may be of different profiles, and their application depends on it as well. Most frequently used ones are those with circular profiles, and such ones were applied on the Osijek-Đakovo motorway as well. Such profiles are used most frequently for placement into streams with small and high water flow, and the diameter of the tubes depend on it. Circular shape is ideal for large loads, if the height of surcharge of the material is large, as well as when the foundation is prone to uneven settlement. In addition, they are favorable in relation to occurrence of corrosion. Corrosion appears most frequently in the lower part of round-shaped tubes, where tensions are the lowest so those cross-sections are not only the most cost-efficient ones in terms of the quantity of water that they can pass through, but they also provide an additional safety reserve in terms of the duration of the structure.

In addition to the possibility of use for new objects, thanks to the mechanism of composite operation of the tubes and the surrounding soil, steel pipe culverts may be used in reconstruction of decrepit facilities. For this purpose the steel tube is placed below an existing facility, and the space between two facilities (at least 10-15cm) is filled with concrete (aerated concrete, lightweight concrete) or earth (a mixture of sand and binder which remains elastic) (Fig. 7) [6]. The binding material is set in layers, symmetrically, without leaving gaps. An advantage of this method of rehabilitation is savings in terms of time and money. The decrepit structure is improved without a stoppage of traffic because there is no need for dismantling the existing structure.

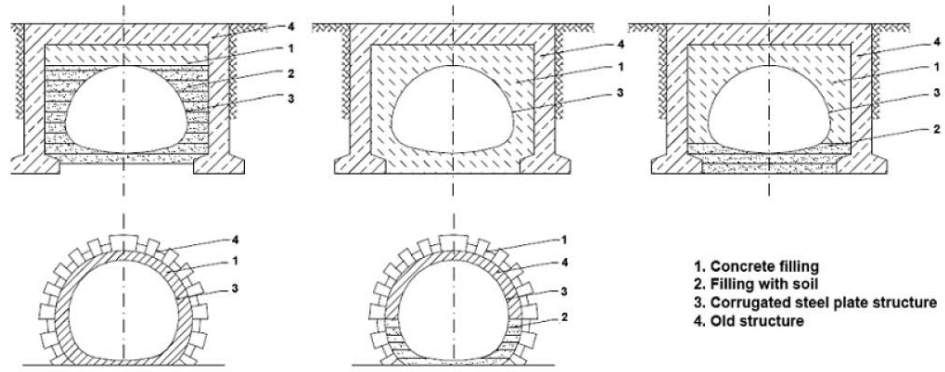

Figure 6 Rehabilitation of Facilities

4 An example of construction of steel culverts at a section of the Osijek–Đakovo motorway

At a section of the Osijek – Đakovo motorway a total of 39 steel pipe culverts were constructed. Of that number, 7 were constructed on the main route, whereas the remaining 32 were constructed on field roads by the motorway. On the main route of the motorway 2 culverts were constructed by using the corrugated structural plates produced in and transported from a plant in Austria, with span of 4.04 and 3.07 m, length 60.10 m and 42.10 m, respectively. The remaining 5 were constructed by using spiral tubes of the same producer. Their diameters are 1.40 (3 facilities), and two facilities with diameter of 1.80 and 2.00 m, respectively. The shortest span of the in-built spiral tubes is 18 m, whereas the longest one is 74.68 m. On field roads only spiral tubes with diameter 1.60 and 2.00 m were used, and their lengths are from 5.00 to 22.00 m. At four places on field roads it was necessary to secure flow of larger quantities of water, the difference between vertical alignment of the road and the waterway was small and did not allow use of larger openings; consequently, at those places two parallel tubes were constructed with equal diameters the size of which was 1.60 and 2.00 m, respectively (Fig. 7).

Figure 7 Steel Culvert with Two Spiral Tubes

Proper functioning of a joint operation of the soil and steel tubes is attained by good compaction of the surrounding material. At the section of the motorway mentioned above (plane terrain) steel tube culverts were constructed in a low embankment. The requirement for the module of compressibility of the material for the foundation of the tubes was at least 30 MN/m^2, and for the internal friction angle at least 30° [7], [8]. A layer of gravely sand thick 30 cm was placed on the formation soil for purpose of a better digging in of tubes. Immediately after fitting backfilling with earth, material is commenced (Fig 8). Gravel fill is set at the same time on both sides of the tubes in layers thick 20-30 cm along the whole width of the construction

pit. In doing so in the area 1m laterally and 0.5m above the top of the tubes only lightweight machines for compaction are used, with maximum operation up to 0.35m, and are driven in parallel with the tubes [7], [8]. In places where it was necessary to fit two tubes one next to the other, in order to avoid mutual adverse effect of the two tubes and ensure proper backfilling, tubes are placed at a distance 0.65-1.0m, and backfilling is carried out simultaneously for both tubes.

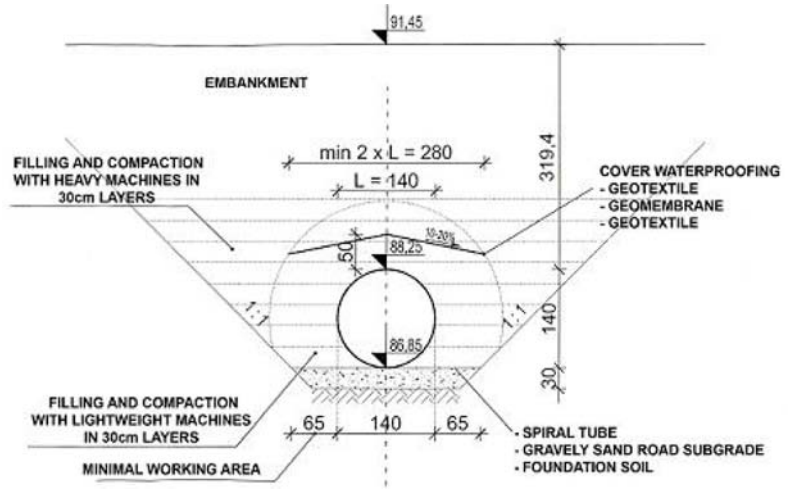

Figure 8 Cover Waterproofing of Steel Pipe Culverts

Proper operation and long life of those facilities requires protecting the steel culverts from adverse effects. Protection against corrosion is carried out in the plant in the production of steel tubes by hot galvanization, and may also be additionally protected by coatings on the basis of bitumen or epoxide resin. Protection by cover waterproofing is applied on culverts, placed in the road structures which are subject to effect of salt due to winter road maintenance when the surcharge of the material above the culverts is small. Geo-membrane situated between two layers of geo-textile (protecting it from damage) is fitted 0.5m above steel culverts in the shape of an umbrella with a drop of 10-20 % (Fig. 8). Width of waterproofing is 2xL (L-diameter of tubes).

Protection from erosion effect of water due to frequent change of the level of the waterway is carried out by lining inlet and outlet portal of the culverts (Fig. 9) which includes preparation of strip foundations and reinforced concrete wall and portal lining, and channel slope with trapezoidal blocks (d=8cm) on a concrete foundation (c 16/20, d=10cm) and gravel foundation thick 10cm.

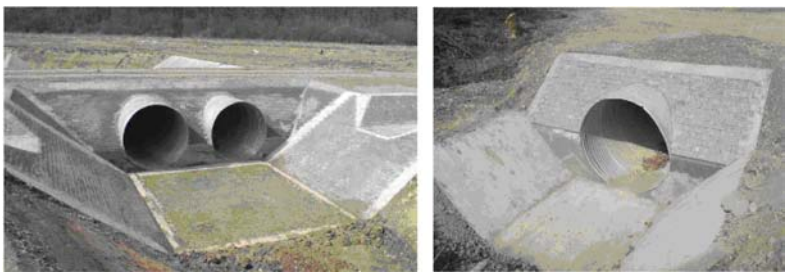

Figure 9 Protection of inlet and outlet portals

5 Conclusion

Experiences in the construction of steel culverts in Croatia are few. Usually, concrete culverts for which there is equipment for construction and previous good practice are applied, and the desire to acquire new knowledge and technologies is limited. In spite of that at the section of the Osijek – Đakovo motorway steel culverts have been constructed to a significant extent. Own experiences of application of steel culverts in the manner described in the paper have shown that the steel culverts with the diameter of up to 240cm irrespective of length are up to 20% cheaper than concrete. In comparison with concrete culverts the time of construction is shorter, transportation and handling is simple due to their small mass, and may be simply applied both in the construction of new roads (forest roads, in water supply works, in construction of sports facilities) and in reconstruction works. In case of larger-diameter steel culverts made of spiral tubes there are no savings, and they can be even more costly in comparison with concrete due to high costs of transportation to the construction site. Tubes of larger dimensions are transported as special freight with special accompaniment and marking and application of corrugated structural plate culverts imposes itself as a more favorable solution. The choice of design solutions and type of culverts based on comparative analysis, due to prominent advantages of application and own lessons learned, might result in a greater application of steel culverts in Croatian civil engineering practice.

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