BURIED FLEXIBLE STEEL STRUCTURES

MultiPlate MP200

MULTIPURPOSE TECHNOLOGY

ViaCon

MultiPlate MP200

MultiPlate MP200 structures are used for road, railways and industrial applications such as:

- culverts
- bridges
- overpasses
- tunnels
- underpasses
- ecological crossings
- hangars
- shelters
- warehouses
- conveyor belt protection
- protection of pipes and heat-pipes
- sewage and liquid tanks
- storage bins

Introduction

Galvanized steel components have been successfully used in civil engineering structures for over 100 years. The first applications such of constructions took place in North America and Russia, where the idea of using them in road and rail construction was born. Today, buried corrugated steel structures are widely used in construction around the world. MultiPlate structures are often referred to as flexible structures.

Soil steel interaction allows flexible steel structures to act in conjunction with the surrounding soil fill to support the loads. The structures are economical, easy and quick to build. The average installation time with a small crew is only a few days.

MultiPlate MP200 structures have been used in Europe since 1986. These systems have been manufactured by ViaCon Sp. z o.o. since 2005.

MultiPlate MP200

Approvals and Certificates:

- MultiPlate MP200 has a CE Certificate of Factory Production Control No. 1023-CPR-0640F.
- Technical opinion of the Central Mining Institute (GIG):

BBA APPROVAL INSPECTION TESTING CERTIFICATION
CERTIFICATE 17/H270

VIACON SYSTEM FOR CORRUGATED STEEL BURIED STRUCTURES

Standard sequence of construction of MultiPlate MP200 structure consists of:

- construction of foundations
- delivery
- assembly
- backfilling
- finishing work

MultiPlate MP200 structures have many advantages, such as:

- simple design due to standard drawings and a calculations database for standard applications
- fast and easy assembly
- assembly possible in temperatures below zero
- assembly possible with no traffic interruptions
- assembly possible with total or partial prefabrication of the structures
- light weight, the corrugated steel plates can be delivered easily and economically to remote locations
- reduction in the total time and cost of construction

Production

MultiPlate MP200 production process involves the mechanical shaping of flat steel plates into corrugated curved plates which are later hot-dip galvanized. The finished corrugated plates can also be epoxy painted on request. All of the manufacturing takes place in a quality controlled factory process.

Steel used for production of MultiPlate MP200 conforms to PN-EN 10025 and PN-EN 10149
Steel grade: S235JR, S355J2 or S355MC
Yield strength for this steel is 235 MPa and 355 MPa.

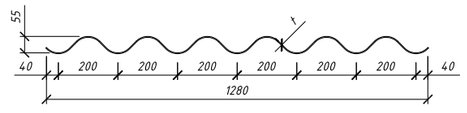


Fig.1. Cross section of a MultiPlate MP200 plate

Standard length of plate is n × s + 120, where s = 235 mm, and n = 4 ÷ 10. Standard width of plate is 1,2 m (m = 6). Other plate widths are available upon request (Fig. 2.).

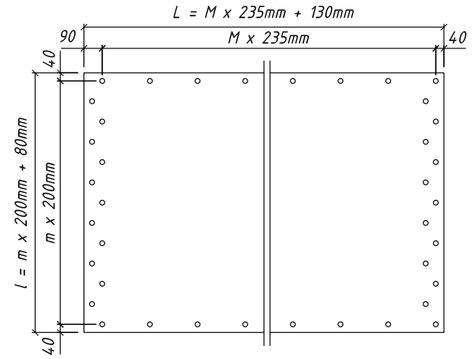
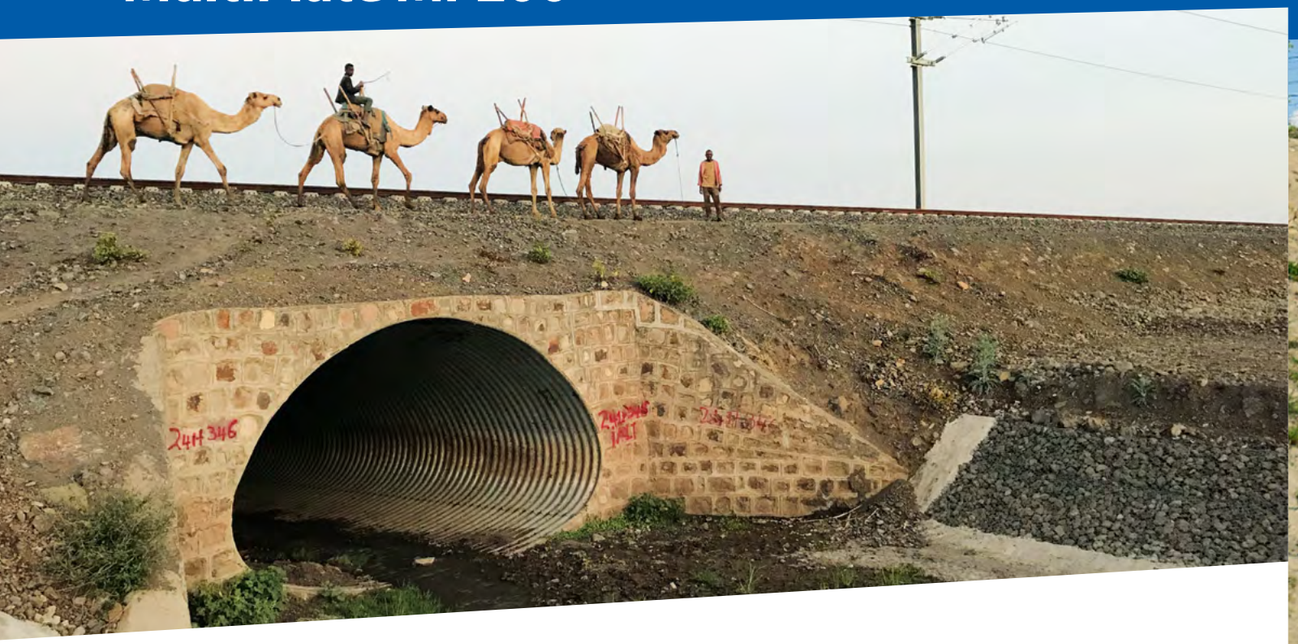


Fig. 2. Geometry of a MultiPlate MP200 plate

MultiPlate MP200



Tab. 1. Geometrical parameters of MultiPlate MP200 plate

Plate thickness [mm]	Yield strength [MPa]	Area [mm²/mm]	Moment of inertia [mm⁴/mm]	Section modulus [mm³/mm]
3,00	235 / 355	235 / 355	1 356,36	46,77
4,00	235 / 355	4,74	1 813,80	61,49
5,00	235 / 355	5,93	2 316,15	77,20
6,00	235 / 355	7,11	2 787,57	91,40
7,00	235 / 355	8,29	3 213,20	103,65
8,00	235	9,37	3 616,77	114,82

The selection of plate thickness depends on the structure's shape, span, depth of cover and live load. Please take the opportunity to consult your design with ViaCon's Technical Department for advice and assistance with your project.

Bolts, nuts, anchor bolts

Corrugated steel plates are joined with M20 bolts class 8.8. The lengths of the bolts are related to thickness of connected plates and type of connection. There are two types of bolt heads – oval-shaped and cone-shaped with dimensions: 32 mm, 37 mm, 45 mm, 50 mm, 70 mm. The bolt diameter of 20 mm and associated nuts correspond to the requirements norm of PN-EN ISO 898-1 and PN-EN 20898-2.

Anchor bolts casted into concrete with a diameter of 20 mm and length of 225 mm or 365 mm which are cast into concrete are made of steel conforming the requirements of PN-EN ISO 898-1 & PN-EN 20898-2.

All of the ancillary items mentioned above are delivered together with corrugated plates as a complete package for the structure.

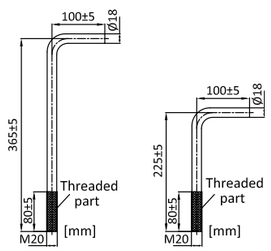
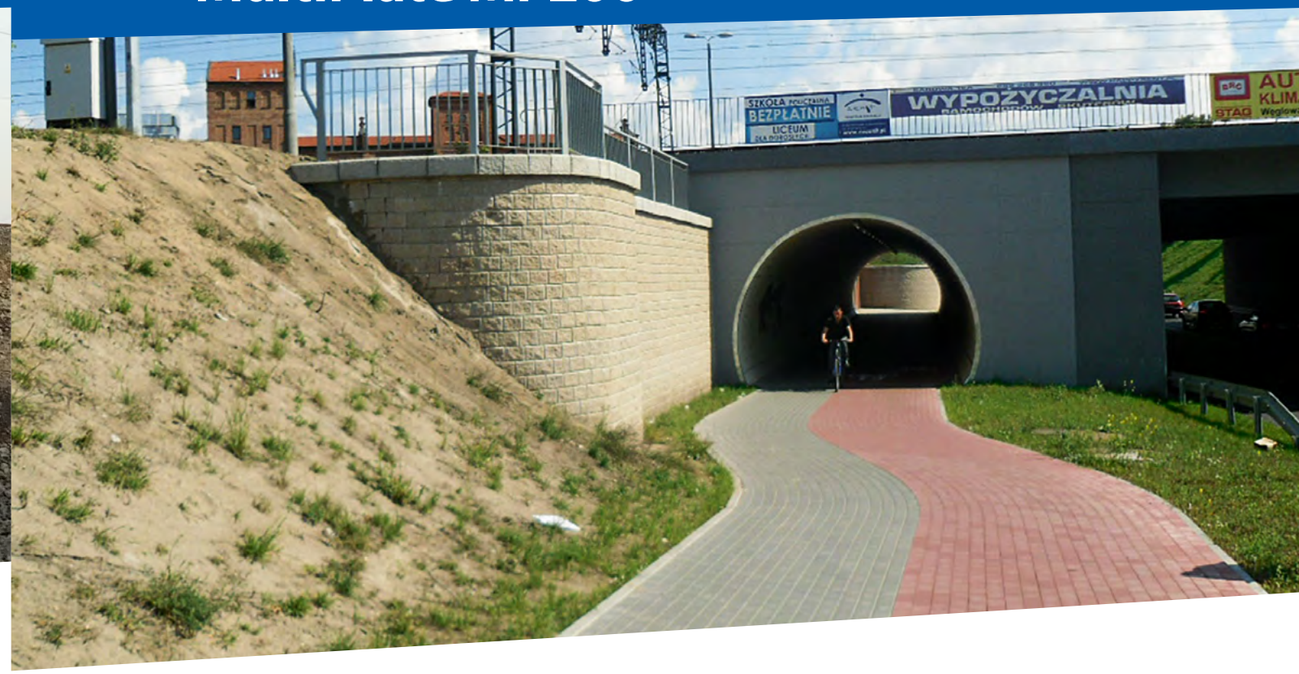


Fig. 3. Anchor bolts used to mount structure in foundation

MultiPlate MP200



Corrosion protection

Coatings applied by immersion including hot-dip galvanizing provide a durable method of corrosion protection to steel surfaces. The protection is particularly effective due to the intimate and lasting bond between the galvanizing coating and the steel surface, thereby providing extended service life. MultiPlate MP200 structures are protected by hot galvanizing as standard, with zinc coating layer according to PN-EN ISO 1461 (table 2).

Tab. 2. Zinc layer

Characteristics	Requirements acc. PN-EN ISO 1461	
	Minimal local zinc coating thickness [µm]	Minimal average zinc coating thickness [µm]
Steel plate:		
>6 mm	70	85
>3 mm to ≤6 mm	55	70
≥1,5 mm to ≤3mm	45	55
Bolts, nuts, anchor bolts	40	50

In order to extend the durability of MultiPlate MP200 structures, particularly in aggressive environments, additional corrosion protection can be provided by applying epoxy paint.

The protection of structures both by hot-dip galvanizing and epoxy paint creates the ViaCoat system conforming to PN-EN ISO 12944-5. Surfaces exposed to UV radiation have an additional coating of polyurethane paint layer in order to prevent discoloration.

Design

The design process of a MultiPlate MP200 structure consists of the following steps:

- design of MP200 structure (including assembly)
- design of engineered backfilling (including backfilling procedure)
- design of the foundations
- design of inlet, outlet and other associated fittings and elements

MultiPlate MP200 structures may be designed for all road and railway live load classes according to norm Eurocode EN 1991-2 or according to the relevant nationals standards for corrugated steel structures in the world.

Structural analysis

MultiPlate MP200 structures are designed with use of one of the following design methods:

- Swedish Design Mehtod, developed by Prof. Sundquist and Prof. Petterson,
- CHBDC - Canadian Highways Bridge Design Code,
- AASHTO LRFD Bridge Design Specifications,
- finite element method (FEM) in complex cases.
- Or other design methods as required for the region

Cover depth

Definition of the cover depth for road structures:
Vertical distance between top of the steel structure main barrel and top of the pavement including the pavement layer.

Definition of the cover depth for rail structures:
Vertical distance between the top of the steel structure barrel and bottom of the railway sleeper.

Tab. 3. Cover depth

Type of object	Minimum cover depth
Structures under roads	H_{min} = max { (Si/8) + 0,2 [m]; Si/6 [m]; 0,6 [m] }
Structures under railway	H_{min} = max { Si/4; 0,6 [m] }

Si – span of the structure [m]

In cases where construction traffic is assumed over a structure, the cover depth must be agreed with the Technical Department of ViaCon.

Lower cover depths may be accepted only after appropriate static calculations are made. The maximum depth of cover is designed individually for each structure. For high cover depths the load reduction techniques are available.

MultiPlate MP200

Geometry of structure in longitudinal direction

The base length of MultiPlate structures should conform to the following formula:

$$L_d = 40 + n \times 1200 + 40 \text{ [mm]}$$

where n = number of full rings along the length and each ring is 1200 mm long.

Top length of a structure is determined individually (considering inlets and outlets).

Ends of MultiPlate MP200 structures can be squared or beveled to match the embankment slope (Fig. 4). For structures curved in plane multiple linear increments are used to align to the designed curvature.

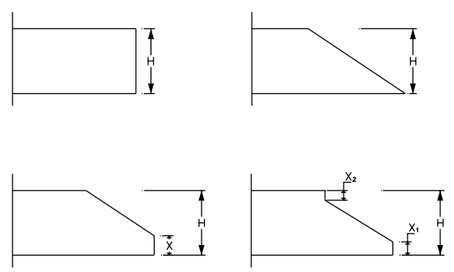


Fig. 4. End finishings for MultiPlate MP200 structures

Depending on whether the structure ends are required to be vertical or sloping the inlet and outlet, finishing details vary accordingly. If structure is vertically cut, a headwall continuously surrounding the structure's opening would be required. For beveled structures with a sloping end, the slope may be finished with grass, block-paving, gabions, reinforced earth or other end treatments.

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Skew angles

Special consideration is required for skew angles smaller than 55 degrees. Concrete collars and/or reinforced soil can be applied to the inlet and outlet zones.

Please contact ViaCon's Technical Department for advice.

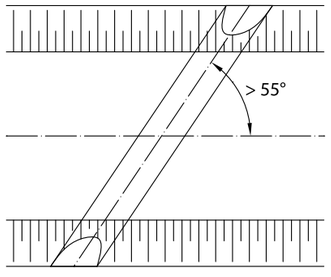

Fig. 5. Skewed structure

Concrete collar

Concrete collar is used:

- in order to stiffen inlet and outlet of the MultiPlate structure with beveled ends
- when the finishing element is used as support of the end treatment

A concrete collar is generally applied in the following cases:

- structures with skew angles to the road axis, when skew angle on outlet and inlet is ≤ 55° and span is > 3,5 m
- structures exceeding 6,0 m span
- excessive skews

For smaller objects which do not meet the above criteria, stiffened collar or other types of finishing may also be used, depending on the designers decision.

Concrete collar's steel face

The stiffening collar's geometry is based on lines smoothly curved in the three-dimensional space. This makes the construction of formworks complex and time-consuming.

In order to simplify the process of casting the concrete collars, ViaCon delivers steel structures with a steel collar that acts as a stay in place form, fitted to their smooth geometry. Ordering the structure with such elements makes the casting of the concrete collar easier and accelerates the construction process.

Multiple installation

For multiple structure installations, the minimum clear spacing between adjacent structures should be sufficient for the placement and compaction of soil (Fig. 6).

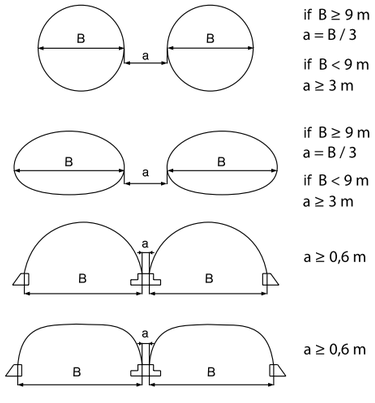

Fig. 6. Minimum clear spacing for multiple installations

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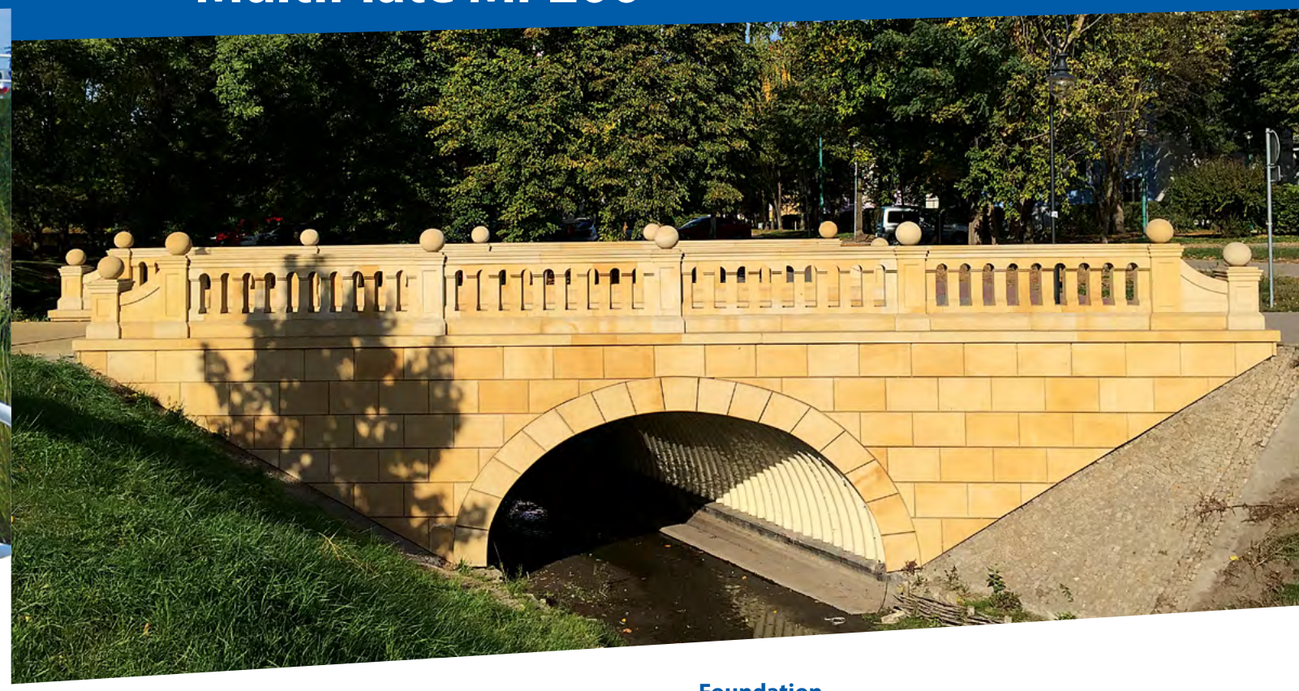

The minimum spacing requirement depends on the shape and size of structures. When the required distance cannot be achieved, the space between structures should be filled with C12/15 concrete or cement stabilized soil to the level where the distance between structures is not less than 10% of the structure span. Please contact ViaCon's Technical Department for advice.

Fot. 1. Flat steel attached to the structure with an open cross-section

Fot. 2. Connection of MultiPlate MP200 structure with concrete footing

Fot. 3. Connection of MultiPlate MP200 structure with flexible footing

Foundation

Closed shape MultiPlate structures (round, elliptical, pipe-arch) are placed on soil bedding as follows:

- minimum thickness of soil bedding should be 30 cm
- the top surface portion of the bedding should be shaped to fit to the bottom plates of a structure
- particular care should be exercised in compacting soil under the hauches
- top 5 - 15 cm of the bedding should be relatively loose material so that the corrugation can delve

MultiPlate MP200 structures with open shapes are placed on concrete (Fot. 2) or flexible (Fot. 3) footings.

The structures may be attached to rock foundation with use of a flat steel plate (Fot. 1).

Other solutions should be consulted with the Technical Department of our company.

Bedding and backfill

Material:

- gravel, sand-gravel mix, well graded aggregates and crushed stone can be used as bedding and backfill material
- aggregate grain size depends on size of corrugation profile; for 200x55 mm corrugations the max recommended aggregate particle size is 45 mm
- aggregate particle size should be 0-45 mm, uniformity coefficient $C_u \geq 4{,}0$, curvature coefficient $1 \leq C_c \leq 3$ and permeability k_{10}>6 m/24 hours
- the use of cohesive soil, organic soil and any frozen soils is not acceptable
- backfill material should be placed arround the structure in uncompacted layers not more than 30 cm thick and then compacted
- the backfill should be placed on both sides of the structure at the same time or alternating from one side of the structure to the other side to keep close to the same elevation on both sides of the structure at all times. No more than one layer (30 cm) difference in elevation is permitted for one side to the other. Each layer must be compacted to the specified compaction index before adding the next layer
- backfill material adjacent (up to 20 cm) to the structure should be compacted to minimum 95% of normal Proctor density and to 98% of normal Proctor density - in the remaining area

Deviation from these principles requires consultation with the ViaCon's Technical Department.

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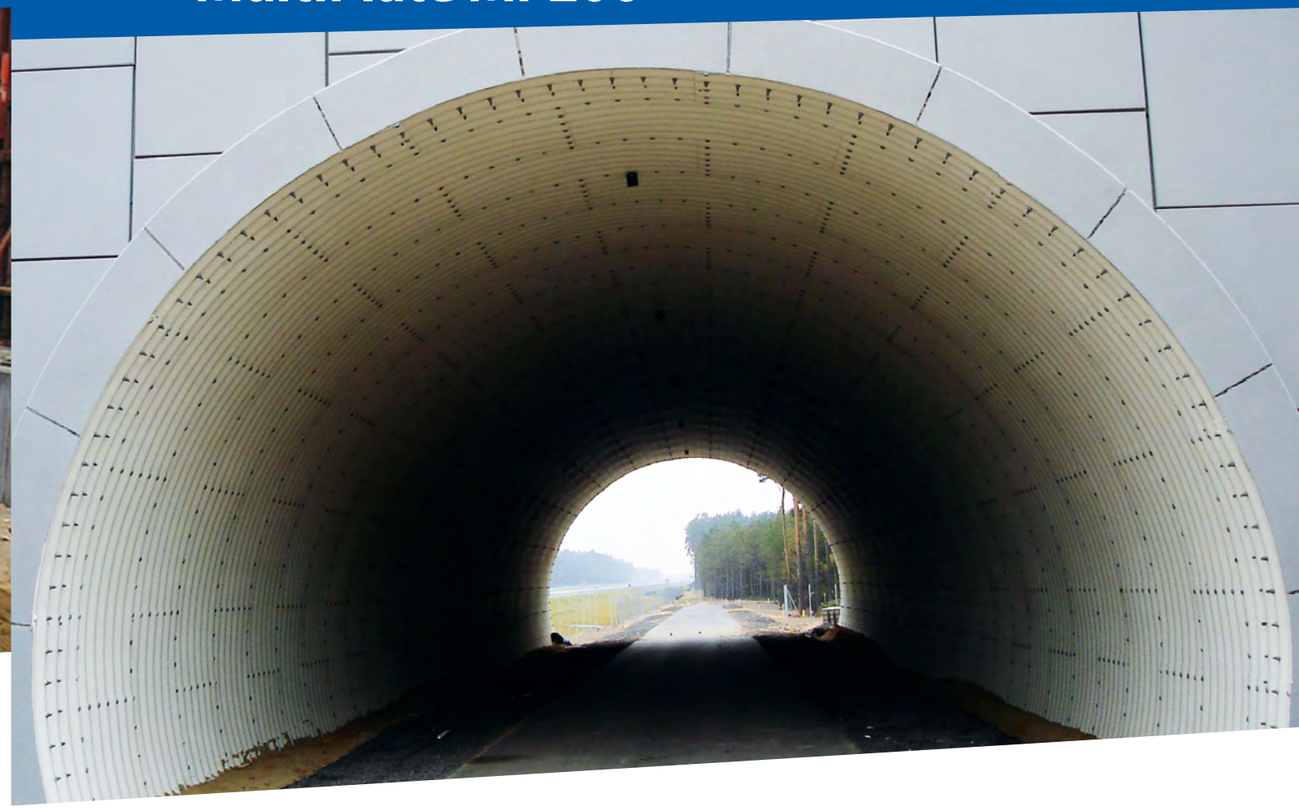

Protection against water ingress

In order to protect structures against water infiltrating through the backfill, protective measures may be applied. Typically a layer of 1.0 mm thick HDPE geomembrane enclosed by two layers of protective non-woven geotextile (nominally 500g/m^2) may be placed over the steel structures. For some overpasses this infiltration protection has been provided using two layers of bentonite mat (geosynthetic clay liner).

Exceptions to the above are possible after consultation with ViaCon's Technical Department. Placing the membrane directly on the structures is allowed provided that protection layers are applied.

End treatment (inlet/outlet)

Slopes may be finished by paving with locally available stones, blocks, etc. If gabion mattresses are used, additional waterproofing should be considered. Please contact ViaCon's Technical Department for advice.

For vertically cut structures, as an alternative to reinforced concrete headwalls, MSE (reinforced soil) walls may be applied using either concrete blocks, panels or gabions. If required, the ground around the MultiPlate MP200 construction can easily be reinforced during the backfilling process with geosynthetics.

Durability

Following factors have influence on structure's durability:

- aggressiveness of the environment
- abrasion
- level of corrosion protection
- plate thickness
- quality and frequency of maintenance

Procedures to verify the durability of MultiPlate structures:

- define the function of the structure
- define the required durability/design life of the structure
- define the aggressiveness of the environment (water, backfill, air)
- select the type of profile (shape of cross section)
- specify the plate thickness based on static calculations (acc. to Sundquist-Petterson method)
- specify the corrosion protection (thickness of zinc coating, paint coating, extent of the of painting, procedure)
- define annual loss of the protection layers in the upper and lower part of a structure
- calculate the structure durability by considering the corrosion progress over service lifetime
- compare calculated durability with the required

In cases, when the durability of MultiPlate MP200 structure is not sufficient, the following measures can be adopted:

- change the corrosion protection (thickness of zinc layer, paint coat)
- increase the plate thickness
- change profile (cross section shape) to reduce internal forces and increase sacrificial steel for corrosion.

Synergetic effects mean that the durability of a ViaCoat system is higher than the sum of durability of the individual protection layers and can be calculated as:

$$S_D = \alpha (S_C + S_Z)$$

where:
S_D – total durability of the protection layer
S_C – durability of zinc coat
S_Z – durability of the epoxy coat
α – synergy factor (from 1.5 to 2.0) (for 200 µm thick paint layer α = 1.5, for 400µm thick paint layer – α = 1.75)

Relining

MultiPlate MP200 structures are also commonly used to repair old culverts and bridges where it is not possible or desirable to construct a replacement. This method is termed relining. A corrugated steel structure is placed inside old an existing old structure (bridge/culvert/underpass) and the space between the old structure and a new structural plate is filled with concrete of class minimum C16/20.

This relining method allows the strengthening of the structures without traffic interruption and eliminates the need to remove/demolish the old structure. This may have the added benefit of retaining the character and aesthetics of the old structure.

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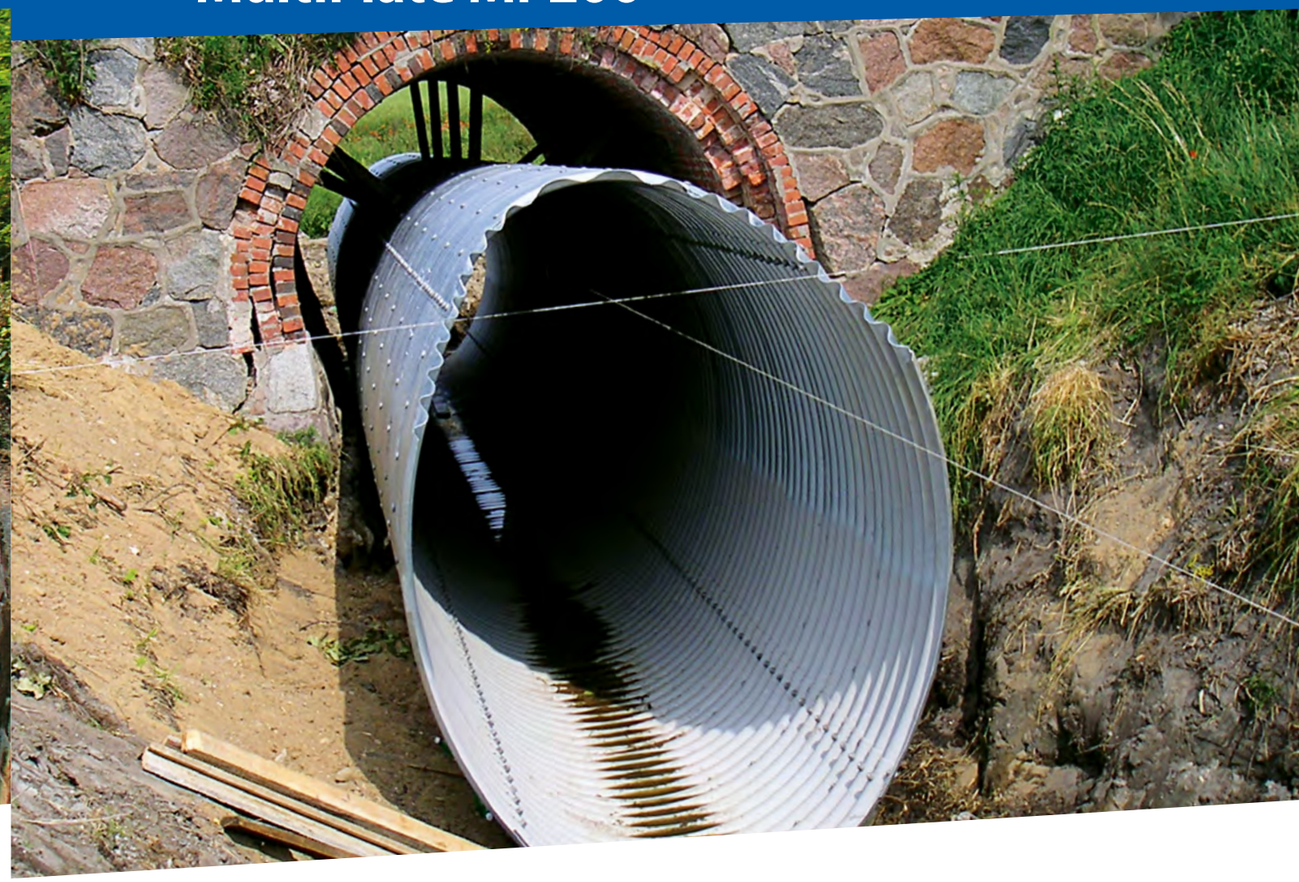

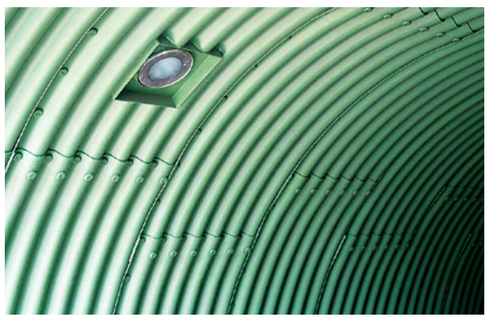

Fittings

MultiPlate MP200 structures can be equipped with additional elements depending on function of the structure e.g.:

- lighting boxes
- ventilation
- niche
- skylight
- connector pipes
- shelves for animals
- technical holes
- others

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