TUBOSIDER

ITEM SPECIFICATION

CULVERTS AND BEARING STRUCTURES

VERSIONE 2023

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INTRODUCTION

The underground culverts in corrugated sheet, otherwise known as *Corrugated Steel Culverts or Soil Steel Composite Bridges*, are flexible metallic structures, consist of more corrugated metal plates, appropriately curved and joined together by means of bolted joints, available in various shapes such as circular, elliptical, lowered and arch.

The load-bearing function of the culverts is based on the exploitation soil-structure interaction that is established between the metal structural profile and the detected technical surrounding, which plays a fundamental role in ensuring the structural stability.

The underground culverts are commonly employed in the civil engineering sector for road applications, hydraulic or railway, such as bridges, culverts crossing, vehicle or pedestrian underpasses, ducts.

The market for *Soil Composite Steel Bridges* grew rapidly, starting from the first applications of the ‘70s up to today's implementations they see the metal culvert in great light itself as a viable alternative to other more conventional types of construction of major engineering works such as bridges road, rail or concrete or structural steel concrete tunnels.

They are structures that provide great savings in terms of material, time and resources, thanks to the high resistance of the sheet, the reduced thickness used, the high level of prefabrication, the optimization of transportation time and implementation.

This structural methodology was implemented by Tubosider the late '70s.

The span currently covered by the types of standard ducts arrive to a maximum of 7 ÷ 8 m., up to reach 10 ÷ 12 m. of light in the case of culverts arch equipped with lateral thrust reinforced concrete beams.

1.0 WORKING PRINCIPLES

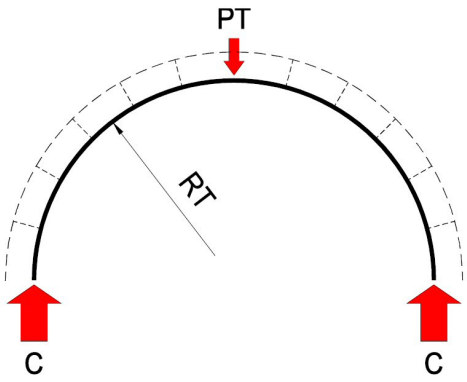
Culvert design is based on the compressed ring theory.

The loads transmitted by the soil are distributed evenly over the whole surface of the culvert.

The structure is therefore compressed and the stress induced, "**C**" (ring compression) is proportional to:

- the pressure exerted by the soil on the ring, "**PT**";
- the crown curvature of the structure, "**RT**" (in a circular structure RT corresponds to half the diameter);

according to the formula: **C** = **PT** · **RT**



The theory assumes that the soil transfers the loads evenly to the metal structure and that this reacts in a uniform manner, without any points of discontinuity.

If the principle of the loads being correctly distributed over the ring is missing, i.e. if the structure does not work perfectly under compression, then the culvert must be considered critical.

In pratical terms, great importance is therefore given to:

- the formation of the technical block, i.e. the composition and degree of compaction selected and laid for the materials that make up the sub-base and the covering for the culvert: materials which must ensure that, in order for the culvert to hold, the pressure of the soil PT is in fact translated totally into radial pressure C;
- the sizing of the joints for the plates that make up the culvert, because they must be able to ensure the structure continuity.

The vertical drop of the culvert, or rather its deformation under load, is not considered as a calculation criteria for determining the longitudinal section of the structure and therefore the thickness.

Experience has in fact shown that the presence of a technical block built to perfection is more than adequate to allow the culvert to bear working loads when the ring is compressed up to full resistance..

For a technical block built to perfection, deformations less than or equal to 2 % of the theoretical rise of the culvert are permitted.

Deformations greater than this can be attributed to defects in how the technical block has been made.

In any case the steel structure is able to behave flexibly also in the presence of deformations less than or equal to 5 % of the culvert rise.

2.0 MATERIAL CHARACTERISTICS

All the culverts are produced with materials of the following types:

2.1 Plates

According to standard EN 10025-2 April 2005, grade **S235JR** steel plates must have the following mechanical properties:

• ***tensile strength***		Rm	360 ÷ 510	N/mm²
• ***yield strength***		ReH	235	N/mm²
• ***resilience***	***Temperature***		20	°C
	Energy		27	J
• ***elongation percentage***	Th. > 1.0 ÷ ≤ 1.5 mm.	A	≥ 18	%
	Th. > 1.5 ÷ ≤ 2.0 mm.	A	≥ 19	%
	Th. > 2.0 ÷ ≤ 2.5 mm.	A	≥ 20	%
	Th. > 2.5 ÷ < 3.0 mm.	A	≥ 21	%
	Th. ≥ 3.0 ÷ ≤ 40.0 mm.	A	≥ 26	%

The thicknesses shown on the tables are the nominal ones and refer to raw material without galvanisation coating.
Tolerance on thicknesses according to EN 10051 standards.
The weights too area the theoretical ones so they may vary according to the same tolerances on the thicknesses.

According to standard EN 10149-2 May 1997, grade **S355MC** steel plates must have the following mechanical properties:

• ***tensile strength***		Rm	430 ÷ 550	N/mm²
• ***yield strength***		ReH	355	N/mm²
• ***resilience***	***Temperature***		20	°C
	Energy		40	J
• ***elongation percentage***	Th. < 3.0 mm	A	≥ 19	%
	Th. ≥ 3.0 mm	A	≥ 23	%

The thicknesses shown on the tables are the nominal ones and refer to raw material without galvanization coating.
Tolerance on thicknesses according to EN 10051 standards.
The weights too are the theoretical ones so they may vary according to the sane tolerances on the thicknesses.

2.2 Nuts and bolts

High resistance class 8.8 bolts are used, with the mechanical properties stated in standard EN ISO 898-1 (screws) and in standard EN ISO 898-2 (nuts).

Depending on the type of corrugation, the following types of bolts are used with the relative tightening torques [a]:

Type of corrugation	Bolt type	Tightening torques [a] Class 8.8	
		Min. [b] Nm	Max. [c] Nm
T70 T100	M12	45	90 [d]
T200	M20	220	439 [d]

a Tubosider SpA recommends to carry out the regular calibration of the tools (torque wrench, air impact wrench,etc..).

b The acceptability limit is anyway at the discretion of the Third Party Engineer.

c According NTC D.M. 17 January 2018 (NTC 2018) 4.2.8. Joints – Table 4.2…… Tightening torques for bolts 8.8, Factor K = 0.16.

d Higher values of the maximum tightening torque are admitted at the discretion of the Third Party Engineer provided that the tightening torque applied does not lead to breakage of the bolts and/or the deformation of the plates to be connected.

2.3 Surface protection

In order to protect against corrosion, a hot-dip galvanisation bath is prescribed for plates and nuts and bolts, with a quantity of zinc that varies according to the thickness of the plates and the type of nuts and bolts, complying with standard EN ISO 1461: 2009, in particular:

Plates

Steel thickness mm.	**Local coating thickness minimum** μm.	**Mean coating thickness minimum** μm.
> 6.0	70	85
> 3.0 ÷ ≤ 6.0	55	70
≥ 1.5 ÷ ≤ 3.0	45	55
< 1.5	35	45

Nuts and bolts

Diameter mm.	**Local coating thickness minimum** μm.	**Mean coating thickness minimum** μm.
> 6	40	50
≤ 6	20	25

or other regulating standards.

The protection is adequate for ensuring product durability under normal environment conditions.

Aggressive environmental conditions other than those identified above must be the subject of a special study, in order to decide the type of supplementary protection to be given (sacrificial thicknesses or epoxy treatments).

Environmental categories, risks of corrosion and corrosion levels

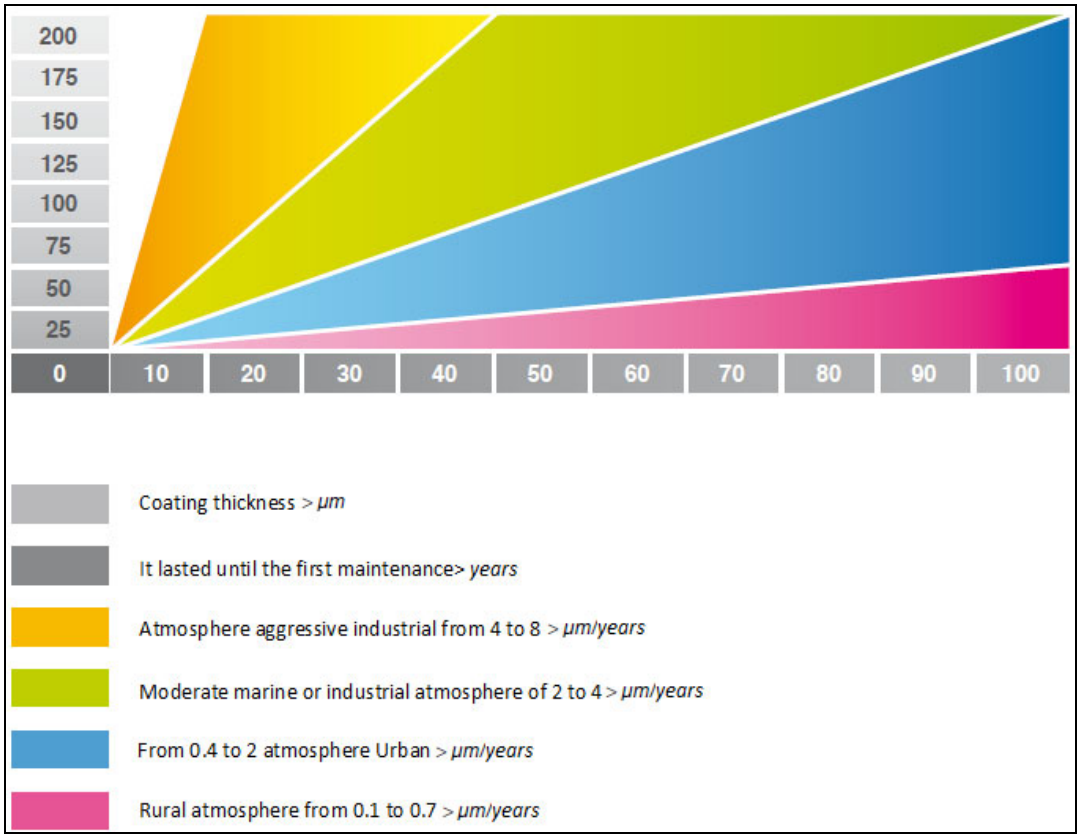
Code	Corrosion category	Risk of corrosion	Corrosion level average zinc thickness loss [e, f] µm/year
C1	Inside: dry	Very low	≤ 0.1
C2	Inside: occasional condensation Outside: rural environment	Low	From 0.1 to 0.7
C3	Inside: high humidity slight pollution Outside: urban or temperate coastal environment	Average	From 0.7 to 2
C4	Inside: swimming pools, chemical plants, etc. Outside: industrial environment or urban coastal	High	From 2 to 4
C5	Outside: industrial environment with high humidity or high coastal salinity	Very high	From 4 to 8
Lm2	Sea water in temperate regions	Very high	From 10 to 20 [g]

e The thickness loss values are identical to those in ISO 9223, except for the levels of 2 mm. (per year) or more, which have been rounded up to the nearest whole number.

f Changes in the air for the different environments through the years.
A substantial reduction in pollution, especially of sulphur dioxide, has taken place over the past 30 years world-wide.
This means that the current corrosion levels (the table is based on data for the period 1990 to 1995) for each environmental category are much lower that historical levels, even lower levels can be foreseen in the future if pollution continues to diminish.

g Sea water in temperate regions is less corrosive to zinc than tropical sea water, which is usually warmer.
This table can be used in marine environments in European temperate regions.
For tropical conditions the advice of a galvanising specialist should be sought.

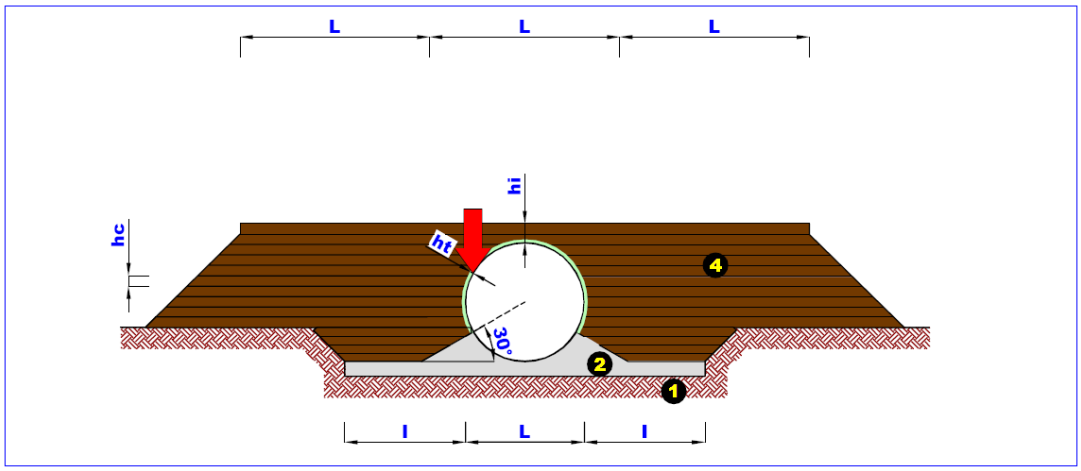
Typical duration of a zinc coating until first maintenance for different environmental categories and relative corrosion levels



2.4 Technical block

The static function of the culvert is guaranteed not only by the steel structure but also by the compacted soil around it that forms the technical block.

The correct sizing of the technical block and its perfect execution are illustrated in *Chapter 5.0*.
On the contrary, the use of materials with pieces lager than 10 cm. is extremely damaging for forming the "**ht**" layer.



1 general main embankment (level to be determined depending on the capacity of the ground on site, client's responsability)
2 artificial foundations and bedding
4 side holding backfill
I ≥ 1.00 m. on a good soil - L otherwise
L culvert span
ht 20 cm. sand max. 5 mm.
hc 20 30 cm. max. layer height
hi minimun backfill level, enough to allow site vehicles to circulate

The remaining part of the technical block will be made with backfill classified according to AASHTO M145-91 standards, i.e. according to CNR UNI 10006, of the group A1-A2-A3, free of any organic and non-organic impurities.

Soil classification according to AASHTO M145-91/CNR UNI 10006

General Classification	Granular Materials (35% or less passing 75µm) [No. 200]							Silt-Clay Materials (More than 35% passing 75µm) [No. 200]			
Group Classification	A-1		A-3*	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis:											
Percent passing:											
2mm (No. 10)	50 max.	---	---	---	---		---	---	---	---	---
425µm (No. 40)	30 max.	50 max.	51 min.	---	---	---	---	---	---	---	---
75µm (No. 200)	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 425µm (No. 40):											
Liquid Limit	---		---	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity Index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min**
Usual Types of Significant Constituent Materials	Stone Fragments Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Rating as Subgrade	Excellent to Good							Fair to Poor			

*The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate the superiority of A-3 over A-2.
**The plasticity index of A-7-5 is equal to or less than the liquid limit minus 30. The plasticity index of the A-7-6 subgroup is greater than the liquid limit minus 30.

For the final layer, before the road foundation, the use of a layer with a minimum height of 30 cm. is recommended, using materials from the group A1-A2-4-A2-5.

The granulometry of the pieces must satisfy the general requirements specified in standard EN 13242.

For durability, in order to prevent premature onset of steel corrosion and to ensure the perfomance stated in *chapter 2.3*, it is recommended the use of materials which offer electrical resistance of more than 8000 Ohm/cm and with a Ph close to the neutral value of 7 (values between 6 and 8).

In addition, water leakage into the technical block of ground around the structure should be avoided, as in time this could affect the mechanical and material compaction properties.

To ensure compaction of the technical block to no less than 85 % of the maximum density provided by the Proctor test modified according to standard EN 13286-2 the material used must be able to achieve a module of elasticity "**Es**" at least equal to 100 MPa (120 MPa for 90% compaction of the maximum density provided by the modified Proctor test).

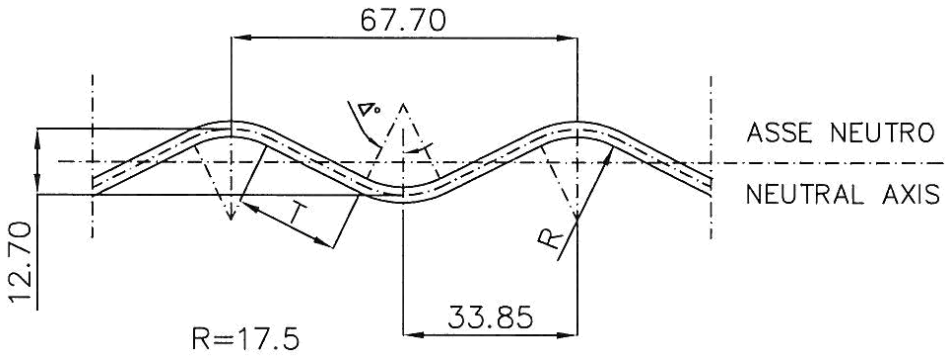
3.0 TECHNICAL FEATURES

Steel culverts are produced with four types of corrugated profiling of the the plates consdtituting the structures; the standard waves at the producing machine, based on different width and depth can be distinguished in:

Corrugation	Width mm.	Depth mm.
T70	67.7	12.7
T100	100	22
T200	200	55

The table below illustrates the geomatrical features of the wave for the four corrugation types, according to the commercial thicknesses of the used steel plates.

Corrugation **T70**



Thickness mm.	Tangent mm.	Angle Δ°	Moment of inertia cm.^{4} *	Section modulus cm.^{3} *	Radius of gyration cm.	Area cm.^{2} *
1.5	19.49	26.78	0.0307	0.0432	0.435	0.162
2.0	19.17	26.94	0.0414	0.0564	0.438	0.216
2.5	18.83	27.11	0.0526	0.0692	0.441	0.270
3.0	18.49	27.28	0.0642	0.0818	0.445	0.324
3.5	18.14	27.45	0.0764	0.0944	0.449	0.378

* per cm. of horizontal projection on the neutral axis

The holes on plates can be divided in:

- **circumferential holes**, on the plates sides along the culvert circumference; those holes are used to connect the different rings constituting the steel culvert;

- **longitudinal holes**, on the plates heads; those holes are used to connect together the plates constituting the culvert ring;

The bolts used for the longitudinal holes are sized so to guarantee the transmission of strains between the culvert plates; for this reason, the static calculation of the structure verifies the resistance of that bolted joint.

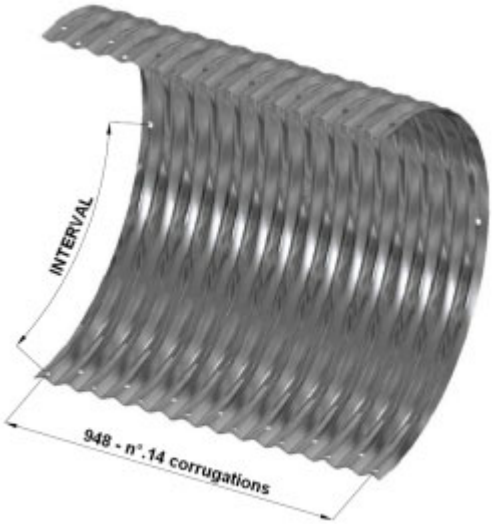
Depending on the number of bolts contributing to the bolted joint resistance and on the position and c/c distance between circumferential holes, it is possible to notice:

- the c/c distance of the circumferential holes, varying depending on the diameter;
- useful inter-axial distance of the rings of the structure 947.8 mm. (14 corrugations) → 0.95 m.;

- the bolted joint on the plates head (longitudinal holes), that may have:

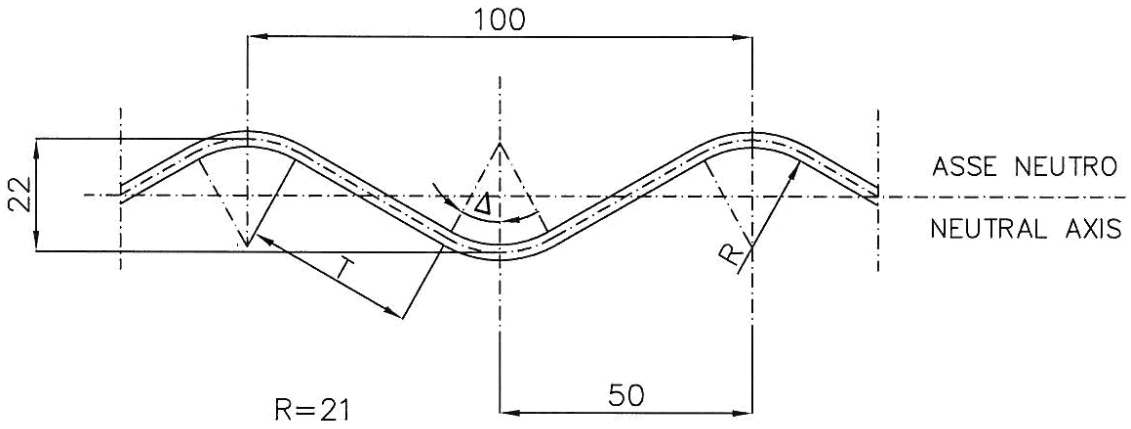
  a) 15 bolts each meter of the culvert length (standard bolting);

- bolts M12, class 8.8.



The mechanical tests on samples of the over-mentioned corrugation have been performed on 2006/2007, Politecnico di Torino – Structural Engineering and Geotechnical Department– Experimental Laboratory for Materials and Structures.

Corrugation **T100**



Thickness mm.	**Tangent** mm.	**Angle** Δ°	**Moment di inertia** cm.^{4} *	**Section modulus** cm.^{3} *	**Radius of gyration** cm.	**Area** cm.^{2} *
2.0	32.37	29.91	0.1218	0.1015	0.742	0.221
2.5	32.03	30.03	0.1534	0.1252	0.745	0.277
3.0	31.69	30.15	0.1856	0.1485	0.748	0.332
3.5	31.34	30.27	0.2185	0.1714	0.751	0.388

* per cm. of horizontal projection on the neutral axis

The holes on plates can be divided in:

- **circumferential holes**, on the plates sides along the culvert circumference; those holes are used to connect the different rings constituting the steel culvert;
- **longitudinal holes**, on the plates heads; those holes are used to connect together the plates constituting the culvert ring.

The bolts used for the longitudinal holes are sized so to guarantee the transmission of strains between the culvert plates; for this reason, the static calculation of the structure verifies the resistance of that bolted joint.

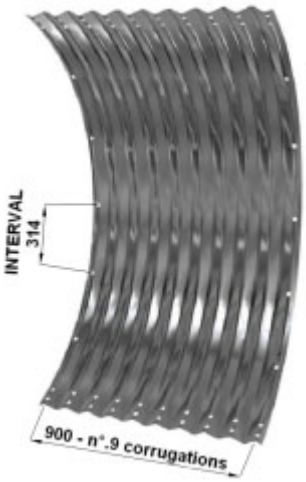
Depending on the number of bolts contributing to the bolted joint resistance and on the position and c/c distance between circumferential holes, it is possible to notice:

- c/c distance of the circumferential holes 314 mm.;
- useful inter-axial distance of the culvert rings 900 mm. (9 corrugations) → 0.90 m.;

- the bolted joint on the plates head (longitudinal holes), that may have:

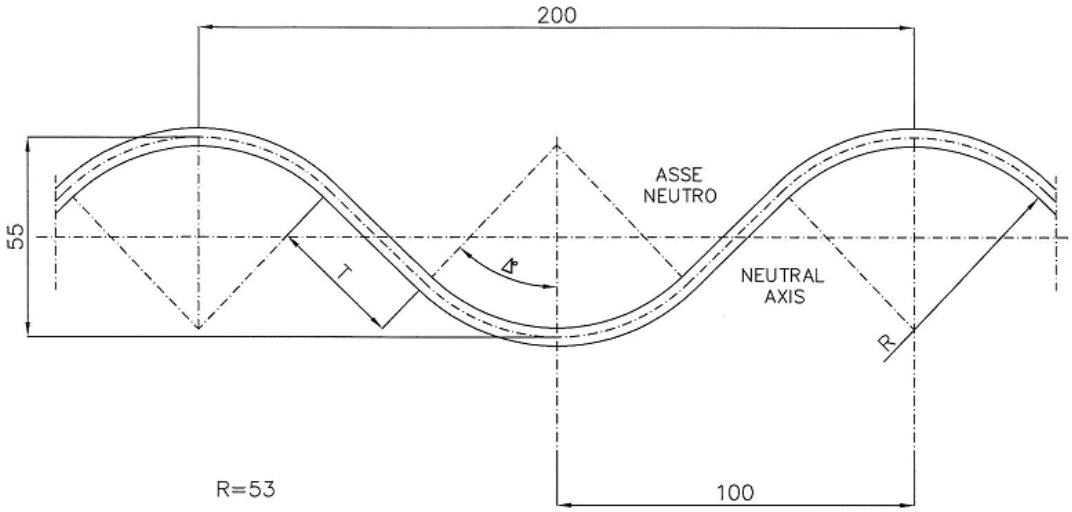
  a) 20 bolts each meter of the culvert length (double bolting);

- bolts M12, class 8.8.



The mechanical tests on samples of the over-mentioned corrugation have been performed on 2006/2007, Politecnico di Torino – Structural Engineering and Geotechnical Department– Experimental Laboratory for Materials and Structures.

Corrugation **T200**



Thickness mm.	Tangent mm.	Angle Δ°	Moment of inertia cm.^{4} *	Section modulus cm.^{3} *	Radius of gyration cm.	Area cm.^{2} *
2.5	33.02	44.93	1.1272	0.3921	1.954	0.295
3.0	32.17	45.19	1.3564	0.4677	1.956	0.354
4.0	30.41	45.73	1.8192	0.6167	1.961	0.473
5.0	28.55	46.33	2.2888	0.7629	1.967	0.591
6.0	26.55	46.98	2.7658	0.9068	1.973	0.710
7.0	24.39	47.71	3.2511	1.0488	1.980	0.829

* per cm. of horizontal projection on the neutral axis

The holes on plates can be divided in:

- **circumferential holes**, on the plates sides along the culvert circumference; those holes are used to connect the different rings constituting the steel culvert;
- **longitudinal holes**, on the plates heads; those holes are used to connect together the plates constituting the culvert ring.

The bolts used for the longitudinal holes are sized so to guarantee the transmission of strains between the culvert plates; as a matter of fact, the static calculation of the structure verifies the resistance of that bolted joint.
Depending on the number of bolts contributing to the bolted joint resistance and on the position and c/c distance between circumferential holes, it is possible to notice:

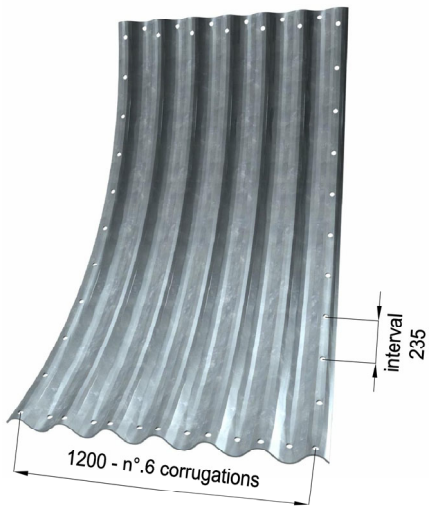
- c/c distance of the circumferential holes 235 mm.;

- useful inter-axial distance of the culvert rings 1200 mm. (6 corrugations) → 1.20 m.;
- the bolted joint on the plates head (longitudinal holes), that may have:

  a) 10 bolts for each meter of length of the culvert (standard bolting);

  b) 20 bolts for each meter of length of the culvert (double bolting);

- bolts M20, class 8.8.



The mechanical tests on samples of the over-mentioned corrugation have been performed on 2006/2007, Politecnico di Torino – Structural Engineering and Geotechnical Department– Experimental Laboratory for Materials and Structures.

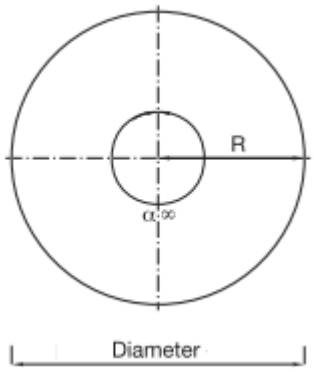
4.0 CATALOGUE RANGE

The following table summarizes the main geometrical features for each culvert type in the catalogue range, divided per corrugation type.

Type **C**

- water conduits
- drainage hydraulic collectors
- service galleries

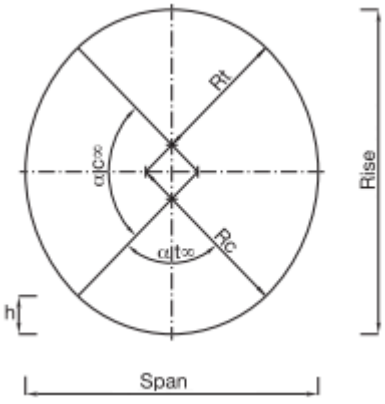
Corrugation **T70** – **T100** – **T200**



Type **E**

- water conduits
- drainage hydraulic collectors
- service galleries

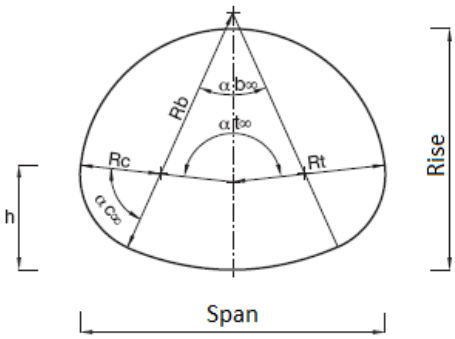
Corrugation **T100** – **T200**



Type **R** – **RA**

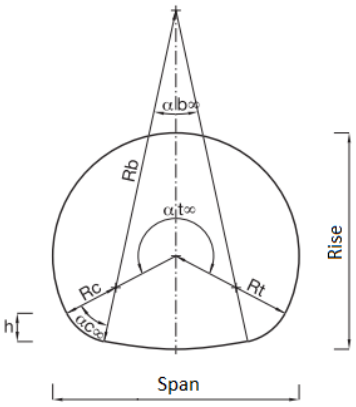
- water conduits
- drainage hydraulic collectors
- service galleries

Corrugation **T100** – **T200**



Type **TC – TR**

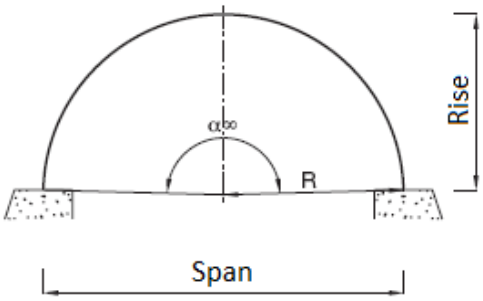
Corrugation **T200**



- galleries
- pedestrian underpasses
- road traffic
- formworks
- protection of mountain roads from avalanches or stones

Type **A**

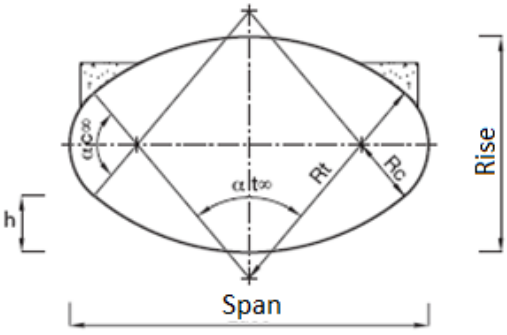
Corrugation **T200**



- covering of existing canals
- reinfrocemnet of deteriorated structures
- covering of small storehouses
- temporary shelters

Type **HPE**

Corrugation **T200**

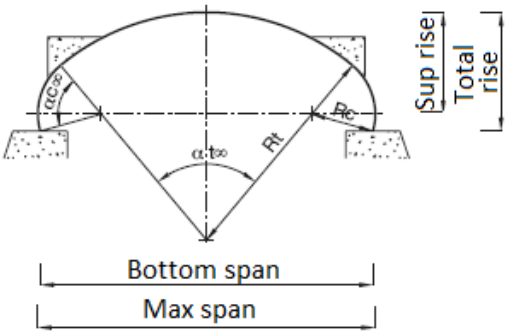


- water canalization
- bridges of I° and II° category

Type **LPA**

- water canalization
- bridges of I° and II° category

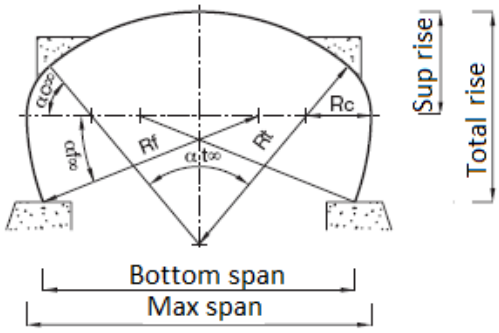
Corrugation **T200**



Type **HPA**

- water canalization
- bridges of I° and II° category

Corrugation **T200**



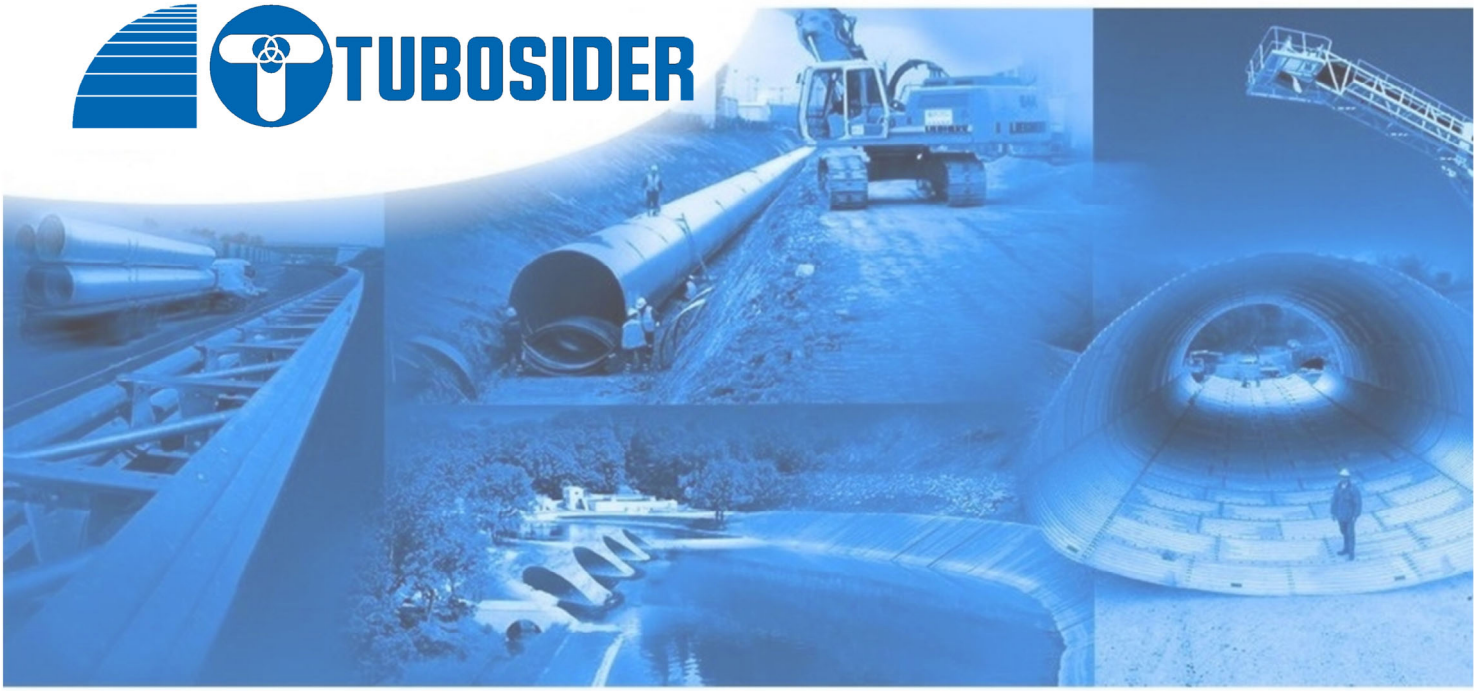
The different sections have been studied to better adapt the structures to the functional and spatial requirements:

- Round sections, type **C** and elliptical sections type **E**, optimal for hydraulic applications, can stand big loads;
- Pipe arches sections, type **R** and **RA**, particularly useful to guarantee a reduced rise (vertical dimension of the structure);
- Underpass sections, type **TC** and **TR**, are used for galleries, when it is necessary have a span sufficient to allow the vehicles and/or pedestrians passage;
- Big span arch sections, type **A**, **HPE**, **LPA** and **HPA**, used to cover canals or for applications requiring big dimensions.

Corrugation Type Span – Rise m.	T70		T100		T200	
	Min.	Max.	Min.	Max.	Min.	Max.
C	0.40	1.80	0.80	2.80	1.57	7.41
E			1.72 2.85	1.88 3.15	1.57 6.81	1.73 7.54
R			1.20 2.78	0.98 1.92	2.19 7.23	1.69 4.24
RA					1.86 7.30	1.55 5.23
TC					2.88 8.32	2.73 7.28
TR					2.89 8.48	2.55 6.70
A					1.75 7.55	0.85 3.66
HPE					5.75 12.14	3.46 8.70
LPA					5.75 12.14	2.02 4.99
HPA					5.75 11.85	3.17 6.85

The culvert effective dimensions may differ from the theoretical ones within a tolerance of ± 2%.

TUBOSIDER



"As the product is subject to continuous improvements, it is recommended that the user, before ordering, verifies with the Technical Department if the information contained in this document is updated".

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PREMIO
CIVILTÀ DEL LAVORO

Cod.Fisc. e P.IVA 03141780019
P.IVA Intracomunitaria IT 03141780019
Cap. Soc. Delib., Sott. e Versato € 10.000.000,00
Iscrizione Reg. Imprese Cuneo al n. di Cod. Fisc. 03141780019
Iscrizione R.E.A. della C.C.I.A.A. Cuneo al n. 218830
Tubosider S.p.A.
società soggetta alla direzione ed al coordinamento di Itinera S.p.a.

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