



Fortezza da Basso • FLORENCE (Italy)



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Recent developments of GRP solutions in the booming transportation market

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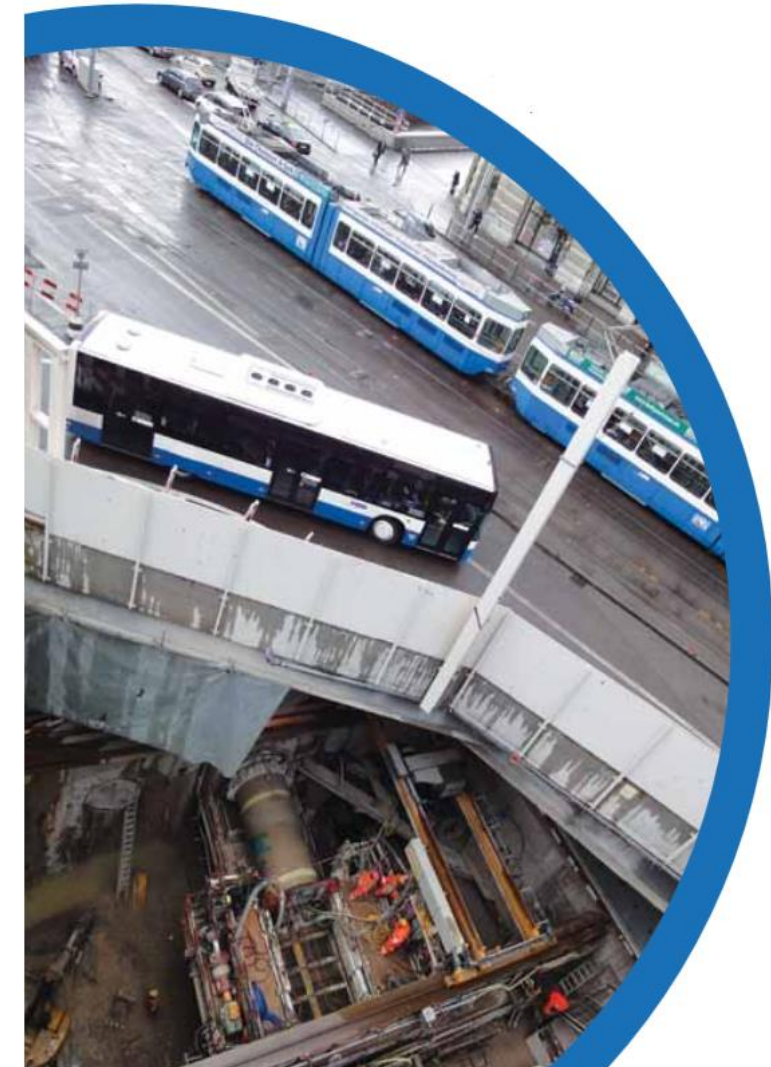
# Recent developments of GRP solutions in the booming transportation market

## TRANSPORT SECTOR

Recent significant development of GRP open cut and particularly trenchless pipe solutions has been notified in one of the world's largest industries, the transportation market :

- Roads to motorways,
- Airports,
- High speed and freight railways,
- Urban tramways,
- Multimodal platforms

Massive investments for new and existing infrastructures are made all over the world ensuring efficient, long lasting and environmentally friendly transport systems



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## GRP SOLUTION ADVANTAGES

Among the significant advantages of trenchless GRP solutions, we can mention :

- Tailor made solution (Pipe profile shape, Jacking Pipe Thickness),
- GRP Mechanical features and Design in line with severe service conditions,
- Installation simplicity (Bell and spigot coupling system, reduced weight...)
- Long life expectancy (long term strength, corrosion and abrasion resistance)



Bell & spigot joints



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## GRP SOLUTION – CASE STUDY

GRP Solution and associated method will be studied based on two examples :

- **JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (FRANCE),**
- **REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)**

# Recent developments of GRP solutions in the booming transportation market



## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Project Presentation

- Part of a larger project of the future T10 tramway implying urban reconfiguration work and update of the water network, especially in the sections located under the future tramway,
- The need to minimize the construction impact in a very dense urban area, the depth of work located on average at 12 m underground, the geotechnical parameters and the presence of numerous existing adjacent water networks imposed the choice of micro tunneling,
- Initially planed with two drives of about 500 meters in DN 2000
- Project includes connections to the existing network, as well as the installation of a dozen of lateral access to facilitate operations and maintenance of the collector.

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## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Project Presentation

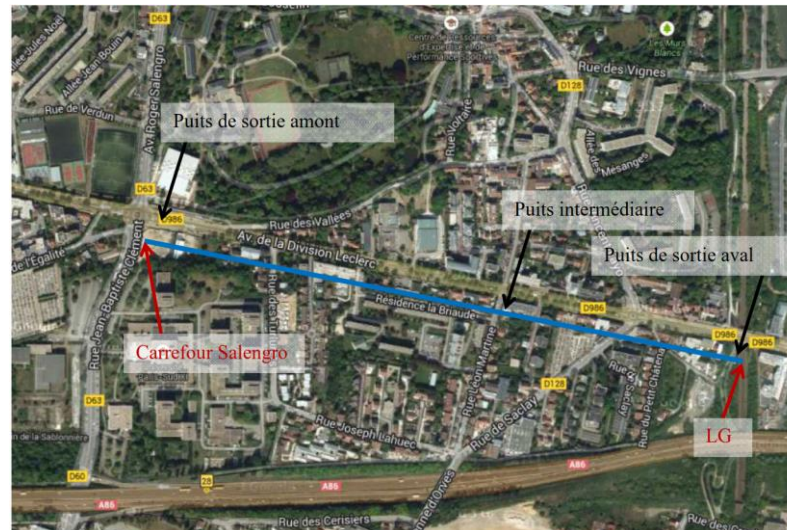
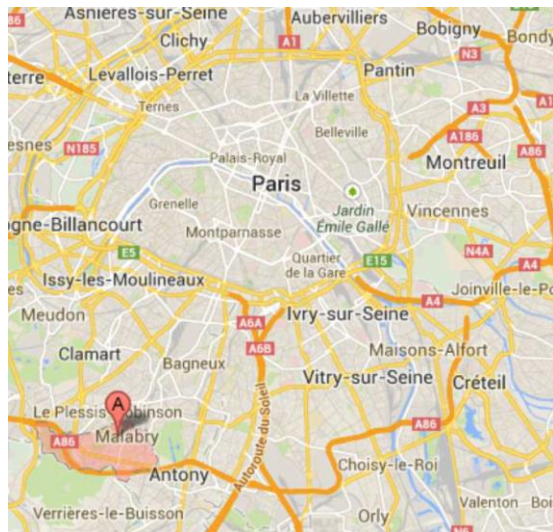


Figure 1 - Vue aérienne du site - source ARTELIA

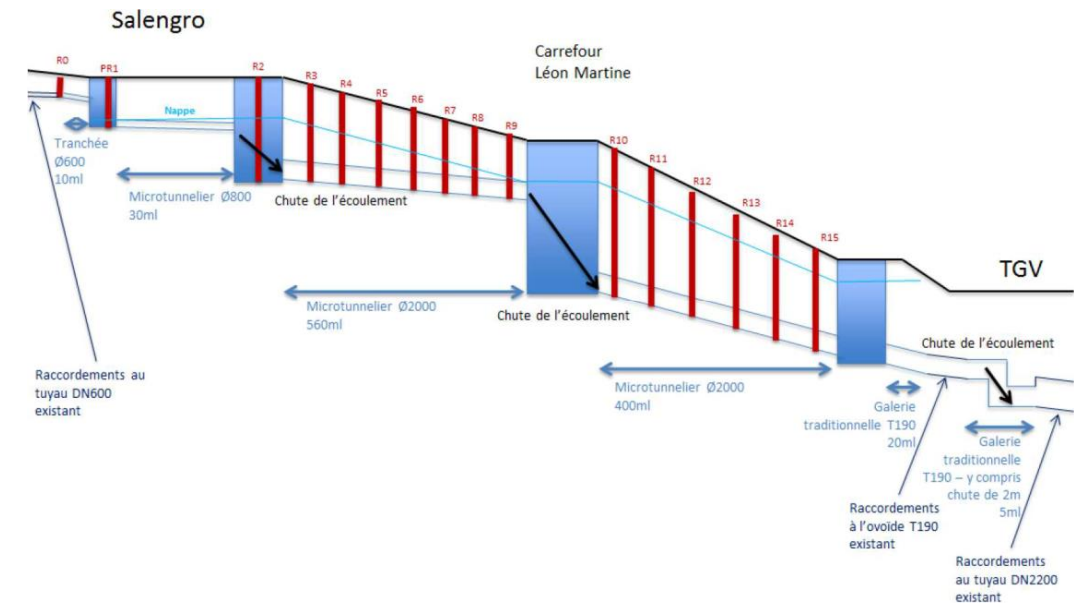


Figure 2 - Schéma de principe –source - ARTELIA Etude de projet

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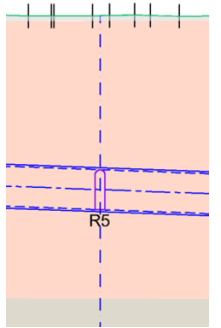


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## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Project Presentation / New Records

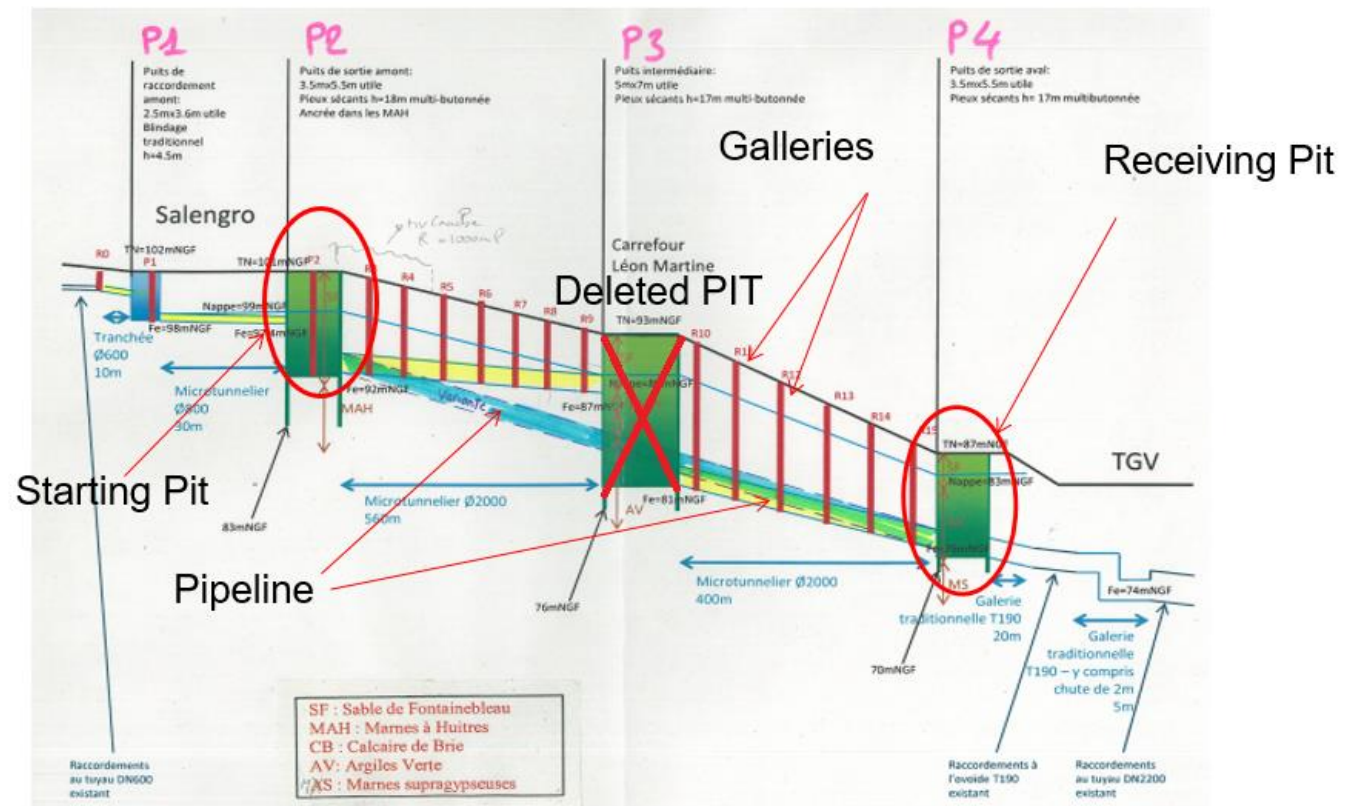
- The contractor formulated an interesting alternative by proposing a single drive, with only one starting pit and one receiving pit, reducing the impact of the construction site, its duration and the associated costs.
- French Record in length for a rectilinear jacking installation with GRP Jacking pipe DN 2160 mm : 928 m



# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Project Presentation / New Records

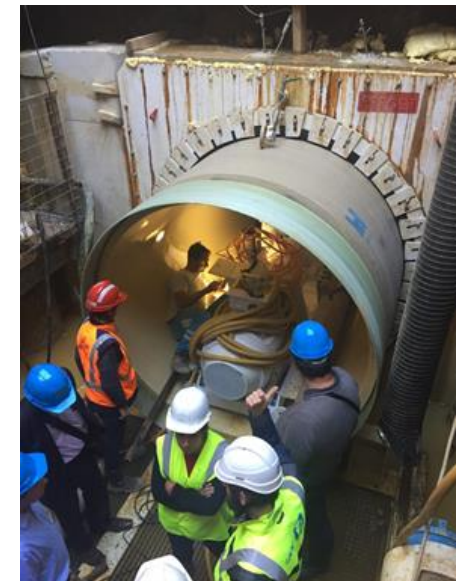


# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### GRP Product : Hobas GRP Jacking Pipe

- GRP Jacking Pipes - OD2160/ID2000 - Unit Length 3m - thickness 79mm
- Allowable jacking force 9020 KN (incl. 3,5 SF).
- High compression strength : 90 Mpa
- Weight 1134 kg/m
- Compatibility with AVN 1800 Herrenknecht



# Recent developments of GRP solutions in the booming transportation market



## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Product Standard

#### ISO 25780:2011

Plastics piping systems for pressure and non-pressure water supply, irrigation, drainage or sewerage -- Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin -- Pipes with flexible joints intended to be installed using jacking techniques

### Product Standard Providing Admissible Jacking Force Design

ISO 25780:2011(E)

C.3.2.1.2 Maximum eccentricity by a closed joint

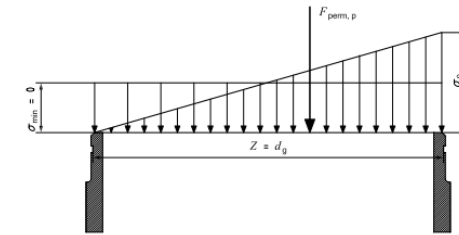
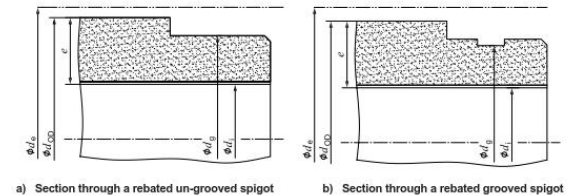


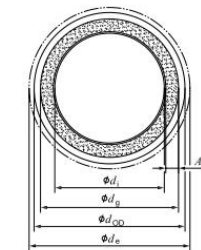
Figure C.4 — Closed joint — Maximum eccentricity

ISO 25780:2011(E)



a) Section through a rebated un-grooved spigot

b) Section through a rebated grooved spigot



c) Cross-section through spigot

# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### The Drive

- Total length of the drive 928 m
- 7 intermediate jacking stations installed. Only 3 IJS were used
- Maximum Jacking Force reached during the drive : 6000 kN
- Usual working pushing force : 3000 kN

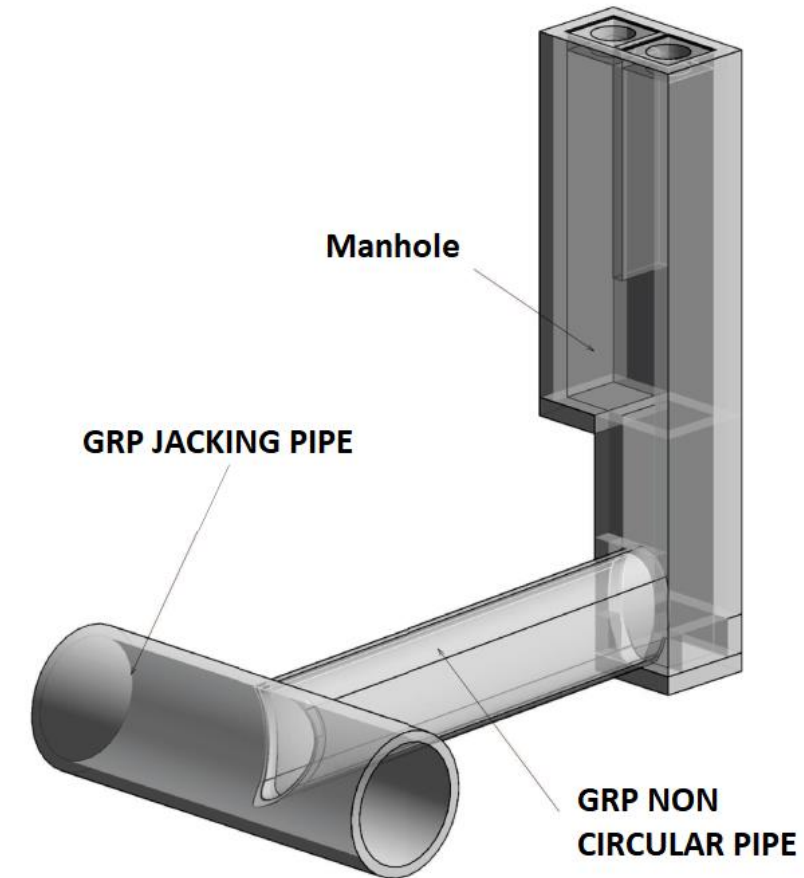


# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Lateral Connections

- 15 perpendicular 6-meter long galleries dug to create access to the network from the sidewalk
- Galleries were relined with non-circular (NC) ovoids made of GRP.
- A perfect continuity of the mechanical resistance and tightness between the collector and the galleries (4m of water table above the pipe crown)
- Ensuring the stability of the assembly in the very long term



# Recent developments of GRP solutions in the booming transportation market



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## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Design Method

- 3D Soil/Structure Interaction Model
- TSAI WU Failure Criterion (Composite Material)

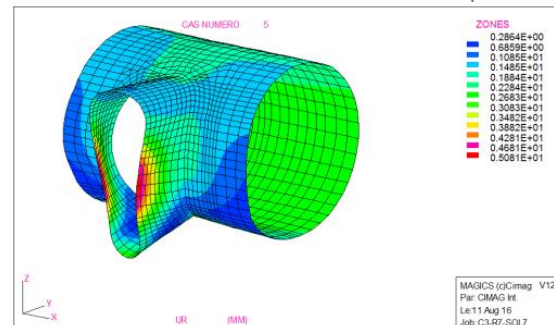
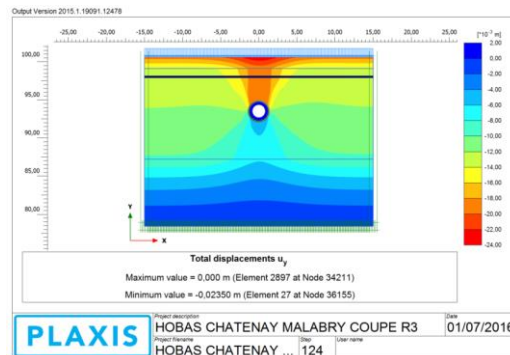
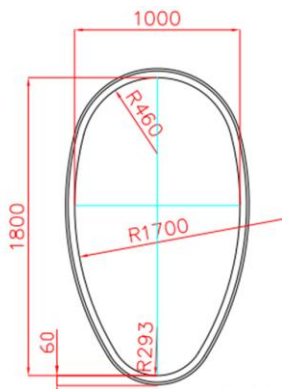
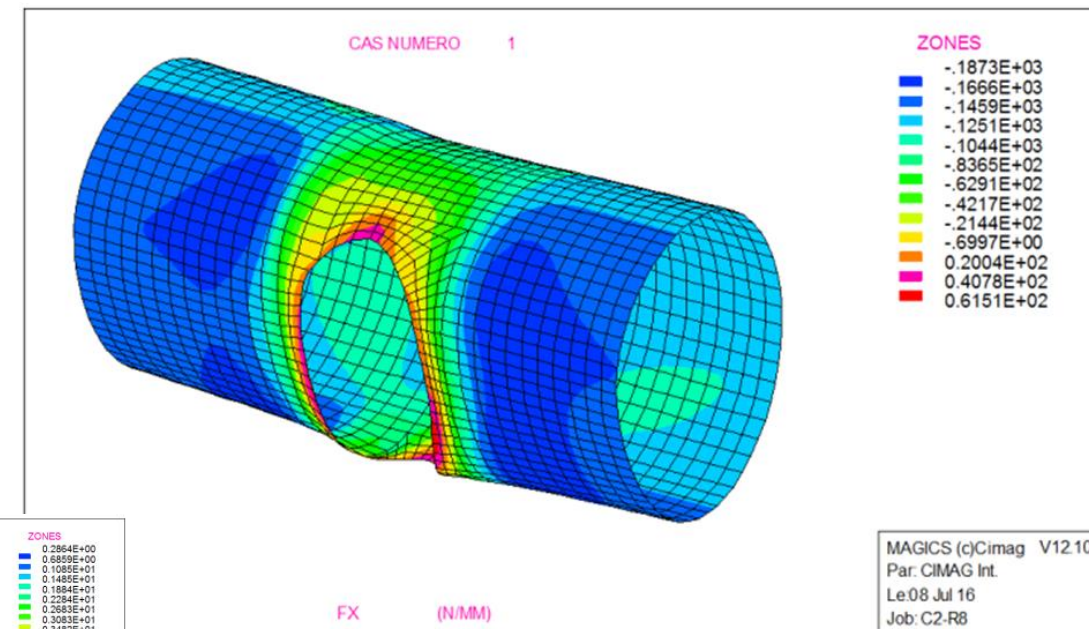


Figure 50 : Déplacements à la jonction avec l'ovoïde suivant : 5mm



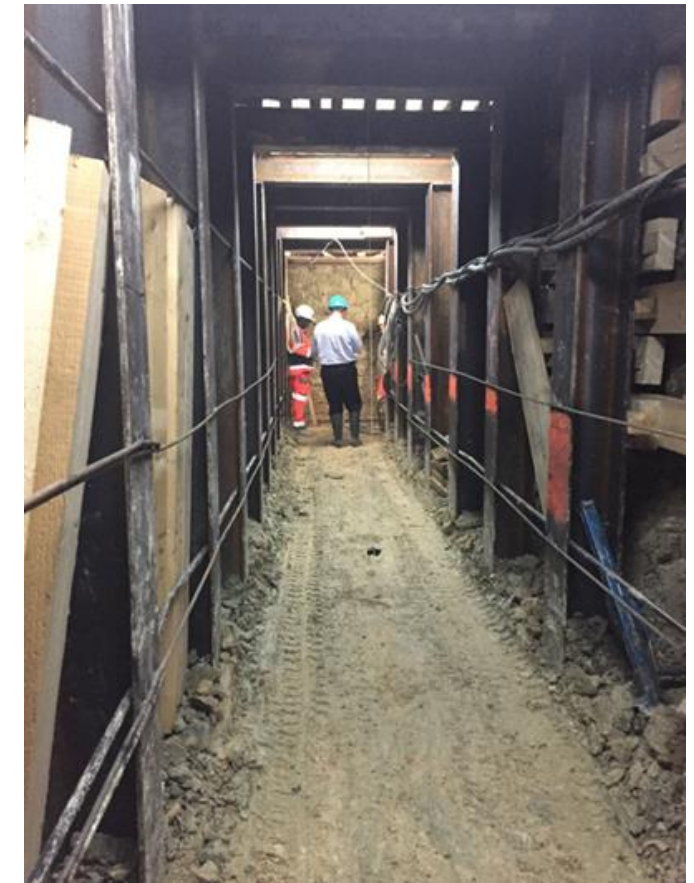
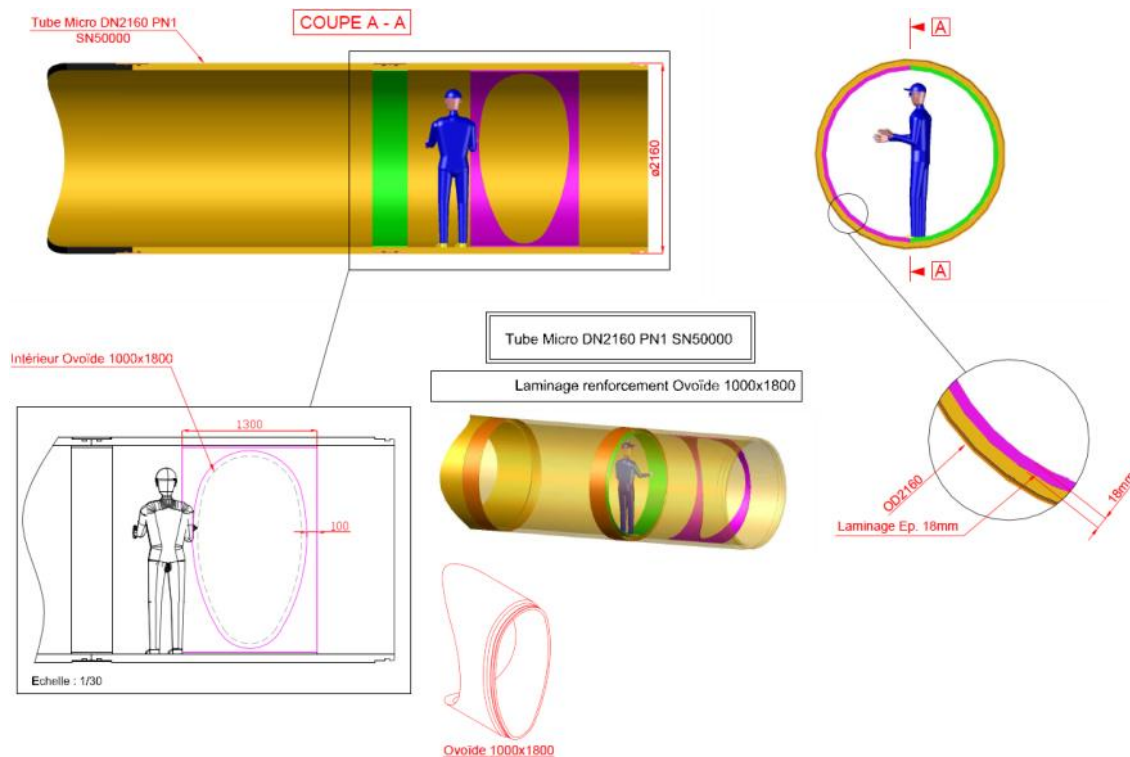
# Recent developments of GRP solutions in the booming transportation market



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## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Lateral Connections STEP N°1 : Pipe Reinforcement

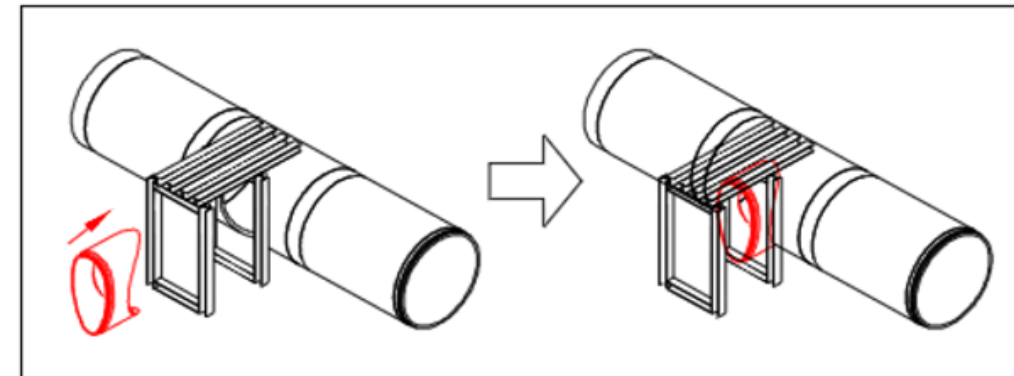
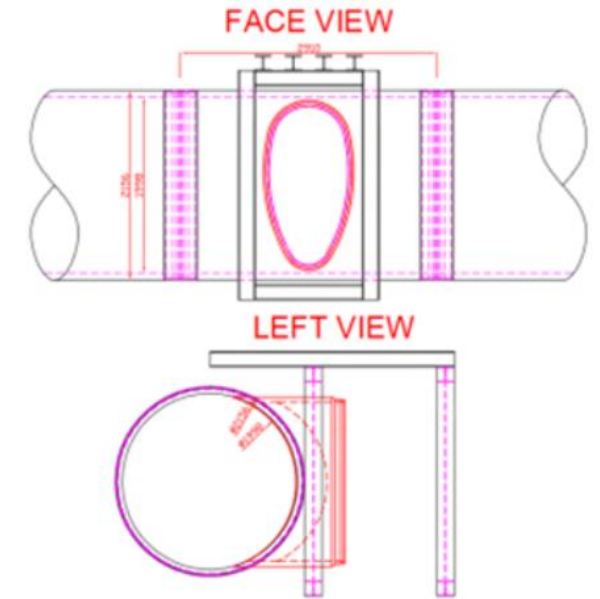


# Recent developments of GRP solutions in the booming transportation market



## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Lateral Connections STEP N°2 : Pipe Cutting and N.C. connection installation



# Recent developments of GRP solutions in the booming transportation market

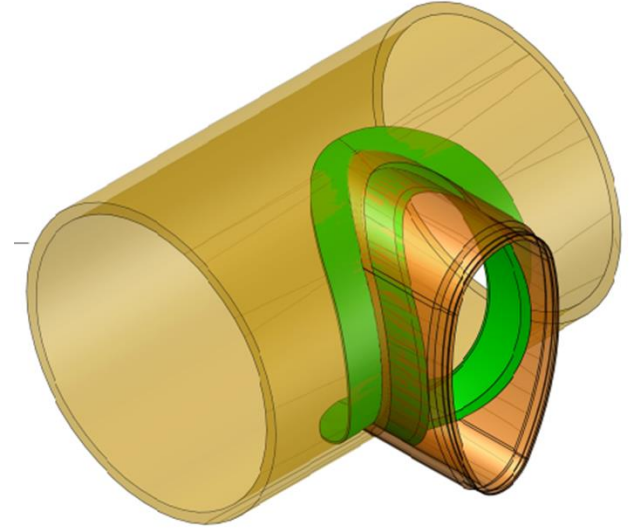


## GRP SOLUTION – JACKING PIPE PROJECT, “TAC CHATENAY MALABRY” – TRAMWAY (France)

### Lateral Connections STEP N°3 : To Laminate the “T” Connection

- Internal leak tight laminates reinforcement
- realized on site by Amiblu technical staff
- <https://www.youtube.com/watch?v=6ZUxk7opcN4>

### Lateral Connections STEP N°4 : Gallery/GRP pipe annular space Grouting



# Recent developments of GRP solutions in the booming transportation market

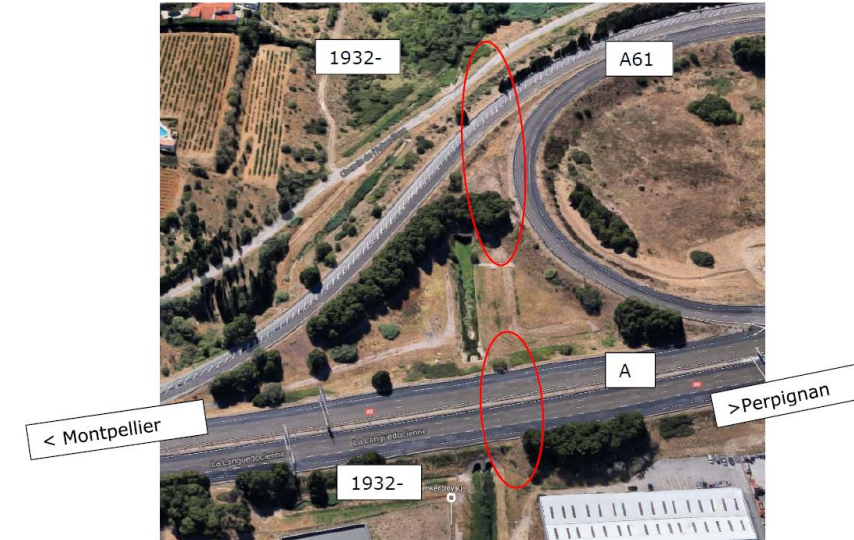
## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Project Presentation / Configuration

ARMCO / HAMCO Corrugated Metal Culverts arch profile 4040mm x 2840 mm

Length: 2x65m + 2x130m

Pipe diagnostic underlines that the corrugated metal culvert is locally deformed and significantly corroded, so it is classified as STATE III according French Recommendation 3R2014. Worst culvert deformations reduced the cross section to  $w = 3,75\text{m} \times h = 2,58\text{m}$



# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Project Presentation / Configuration



# Recent developments of GRP solutions in the booming transportation market

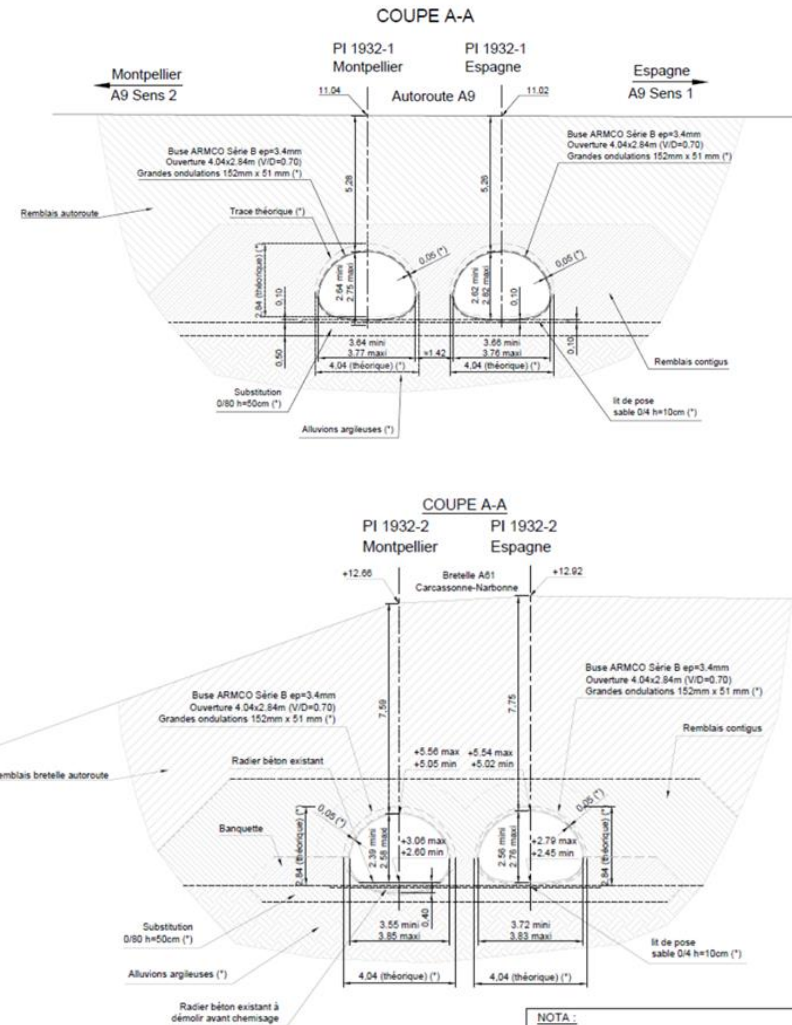
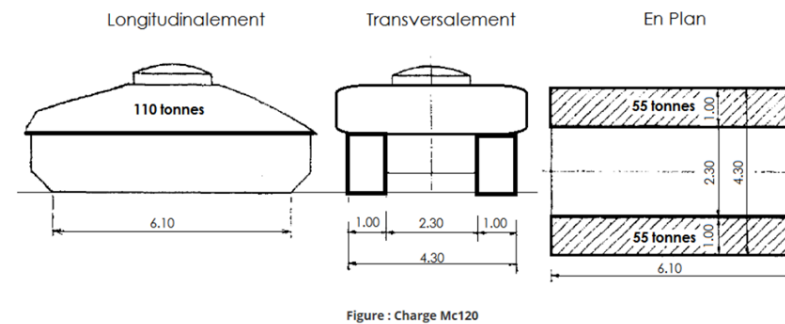


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## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Project Presentation / Loads

- Cover depths : 5,2 m to 7,8 m
- worst traffic model for the highest and lowest cover depths: Military System Mc 120 (110 t) - according to Fascicule N°61 (French National Document)
- Ground Water Hydrostatic Pressure : according 3R2014 Equal to the highest level reached by the water table, can not be lower than 0,5m above the lining top or 1,5m above the lining bottom (whatever is the greatest value).



# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Project Presentation / Geotechnical Context

In situ geotechnical investigations were made to define different soil layers properties to define the surrounding environment of the existing pipe (Nature, Specific weight, E-Modulus “Ménard pressuremeter test”, Poisson’s ratio, friction angle, cohesion, water table levels...).



# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Product Standard

#### ISO 16611:2017

Plastics piping systems for drainage and sewerage without pressure -- Non-circular pipes and joints made of glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resins (UP) -- Dimensions, requirements and tests

### Product Standard

ISO 16611:2017(E)

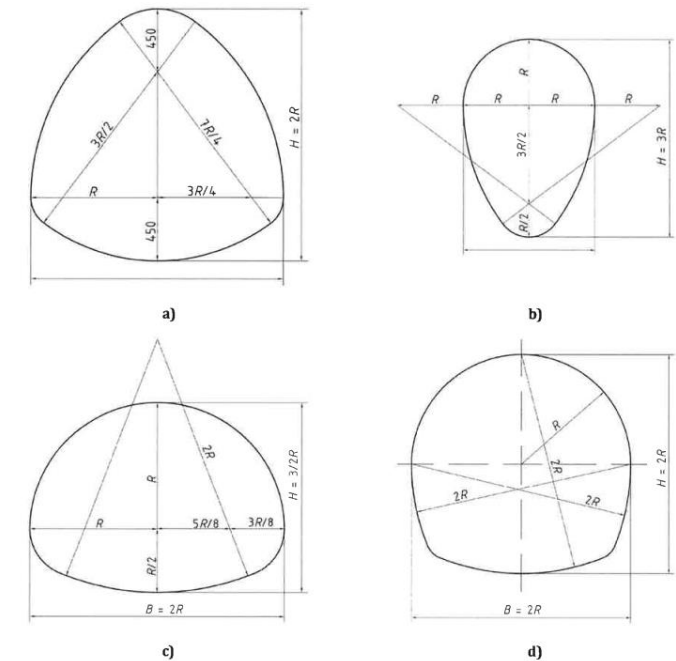


Figure 2 — Typical pipe profile shapes

# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Product : Amiblu GRP Non Circular Pipe Profile

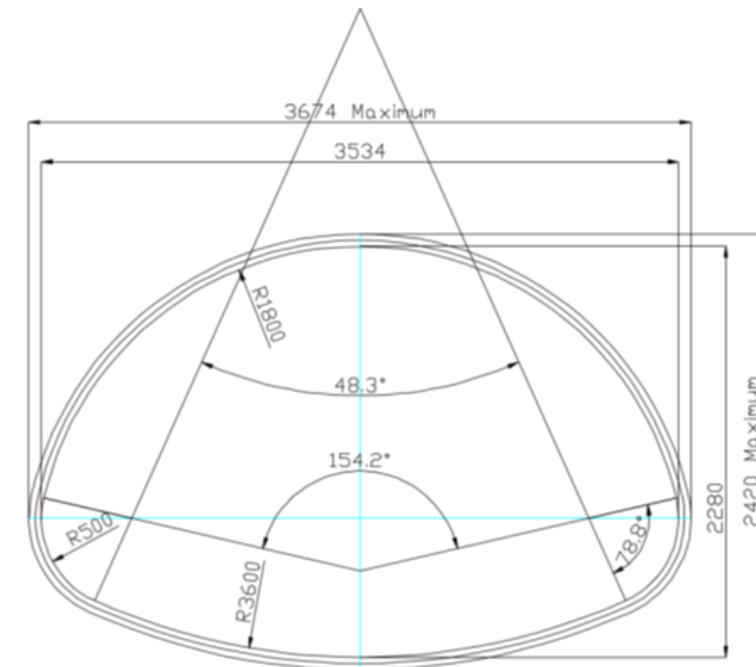
Non-Circular GRP Profiles is then geometrically designed and model according its mechanical Properties described in the Standard ISO 16611 “Plastics piping systems for drainage and sewerage without pressure -- Non-circular pipes and joints made of glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resins (UP) -- Dimensions, requirements and tests”.

Arch Shape Pipe Profile : 3534mm x 2280mm – Thickness : 40mm

Non-circular, glass fiber reinforced plastics profiles (NC Line)

No	Material Property (Mechanical properties refer to structural laminate without liner)	Standard	Unit	Value
1	Short-term bending modulus	ISO 178	MPa	~9500
2	Long-term bending modulus	ISO 10468	MPa	6000
3	Short-term bending strength	ISO 178	MPa	200
4	Long-term bending strength		MPa	80
6	Long-term bending strain (strain corrosion)	ISO 10952	%	0.8
7	Short-term longitudinal tensile strength	ISO 8513	MPa	18
8	Longitudinal tensile force (unit tensile strength)	ISO 8513	N/mm	---
9	Short-term hoop tensile strength	ISO 8521	MPa	~90
10	Abrasion test	CEN/TR 15729 <sup>®</sup>	mm	0.3

Non-circular GRP profiles (NC Line)



# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### New Method

« Nouvelles Recommandations pour le Dimensionnement de la Réhabilitation par Chemisage et Tubage des Réseau d'Assainissement », ASTEE 2014

### Product Standard

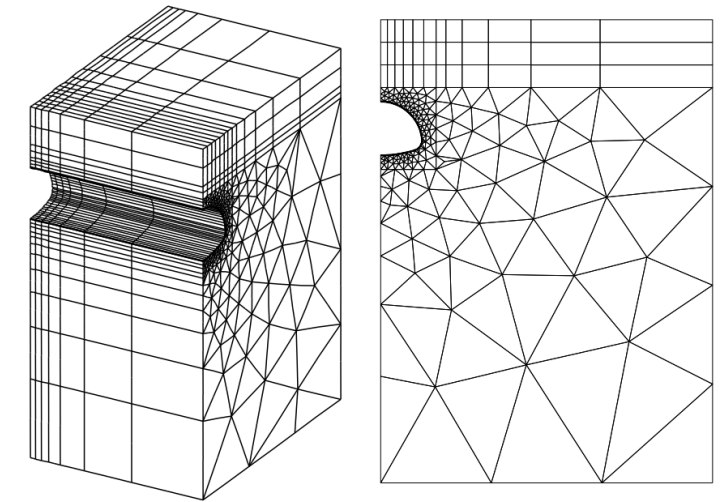


Figure 33. Exemple d'un maillage 3D (modélisation des charges de trafic) et 2D (modélisation des actions permanentes)

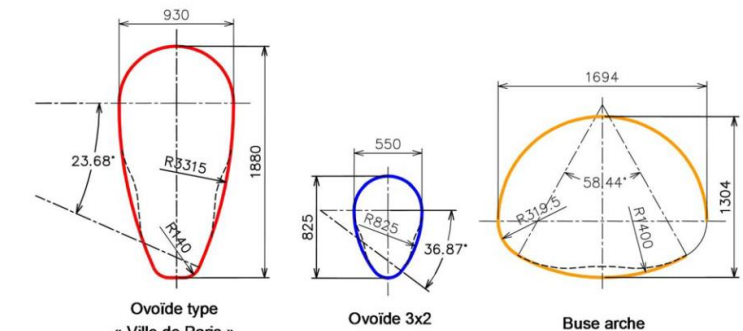


Figure 26 : Profils calculables

# Recent developments of GRP solutions in the booming transportation market



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## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Design Method

Finite Element calculation has been then realized according to the French Recommendations 3R2014.

Tubage (avec coulis) non circulaire

MENU MODULES MODE LIBRE

PROJET  
Société : Hobas France  
Nom de l'étude : Exemple  
Date : 22 / 06 / 2017

Etat conduit existant  
Etat I  
Etat II  
Etat III

Caractéristiques du tubage  
Désignation commerciale  
No Line HRD  
ED k (MPa) : 9500  
Epaisseur structurante (mm) : 80.0  
Flèche admissible à long terme  
d (mm) : 0.0

Charges d'exploitation  
Nappe ☒  
Nappe au niveau TN ☒

Géométrie du tubage  
Profil  
NC sans partie rectiligne  
NC avec partie rectiligne  
Géométrie : buse arche

Dimensions (mm)  
Périmètre : 3250.0  
H : 2280.0  
L : 3534.0  
R : 3600.0  
R2 : 0.0  
R1 : 0.0  
I : 0.0

Résultats  
Le produit convient  
Voir détails du calcul



NOTE DE CALCUL	
DIMENSIONNEMENT MECANIQUE DES CANALISATIONS D'ASSAINISSEMENT	
TUBAGE NON CIRCULAIRE	
<b>Référence du projet</b>	
- Société :	Hobas France
- Nom de l'étude :	Exemple
- Référence de l'étude :	Exemple
- Date :	22/06/2017 13:27:33
<b>Conduite existante</b>	
- Etat d'écroui :	Etat I
- Profil :	NC sans partie rectiligne
- Géométrie :	buse arche
- Périmètre (mm) :	9250
- Hauteur (mm) :	2280
- Largeur (mm) :	3534
- Rayon de courbure des pignons (mm) :	3600
- Rayon du raccord radius/pignon (mm) :	sans objet
- Rayon de la voûte (mm) :	sans objet
- Longueur du pignon (mm) :	sans objet
<b>Caractéristiques du tubage</b>	
- Désignation commerciale :	No Line HRD
- Matériau :	PRV
- Coefficient de Poisson :	0.3
- Module de flexion à CT (MPa) :	9500
- Module de flexion à LT (MPa) :	6000
- Contrainte de flexion à CT (MPa) :	200
- Contrainte de flexion à LT (MPa) :	80
- Allongement de flexion à CT (%) :	1.6
- Allongement limite à LT (%) :	0.80
- Flèche admissible à LT (mm) :	sans objet
- Epaisseur structurante (mm) :	40.0
<b>Caractéristiques du sol</b>	
- Hauteur de remblai :	0.50
<b>Charges d'exploitation</b>	
- Hauteur de nappe (m) :	2.78
- Pression hydrostatique (kN/m²) :	27.8
<b>Coefficients de sécurité</b>	
- yM : 1.2	- ySE : 1.5
- yG : 1.35	- yG,we : 1.35
- yQ : 1.35	
<b>Vérifications de la sécurité d'emploi (Etats Limites)</b>	
justification : sous l'action de la nappe	
ELL : Résistance à long terme :	0.17
Stabilité à long terme :	0.54
ELS : Allongement à long terme (composée verre uniquement) :	0.13
<b>Conclusion :</b> Le produit convient	

# Recent developments of GRP solutions in the booming transportation market

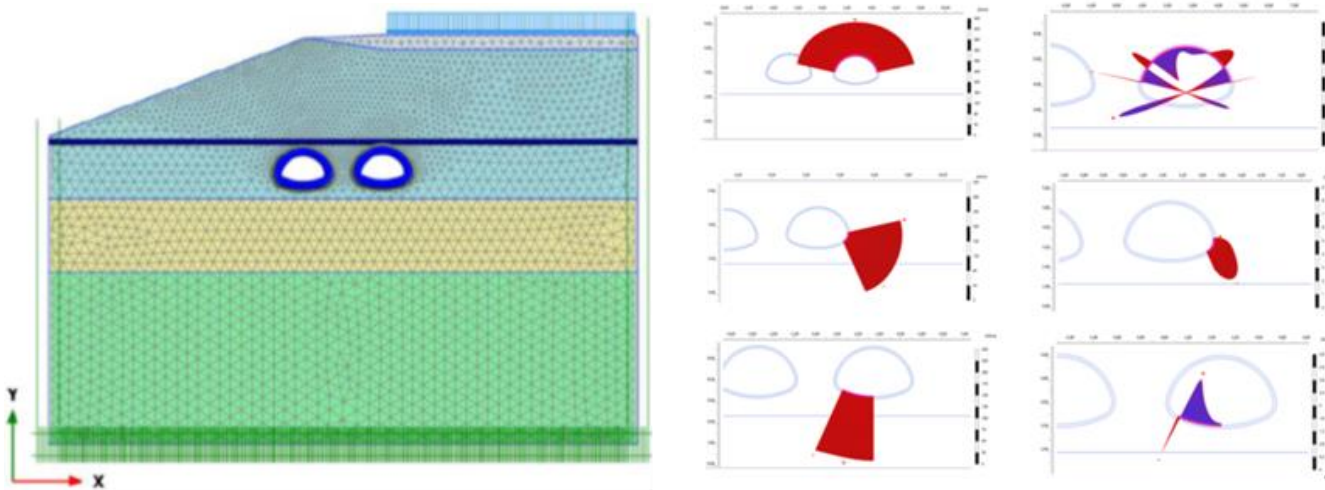


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## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Design Method

Finite Element calculation has been then realized according to the French Recommendations 3R2014.



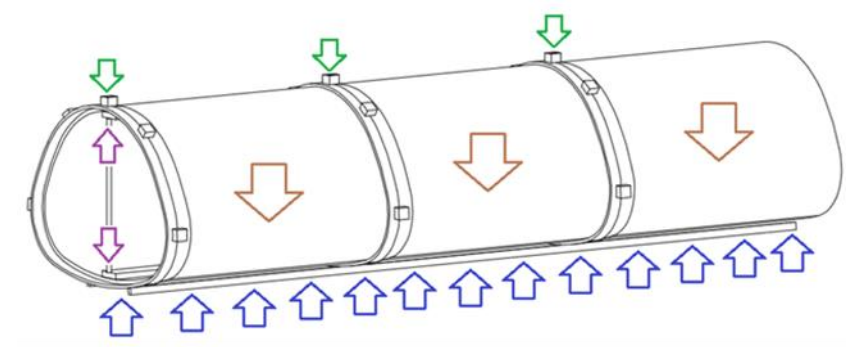
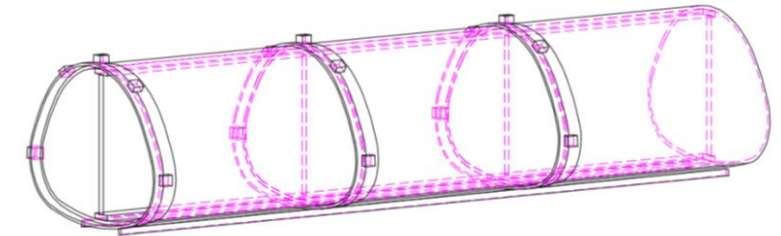
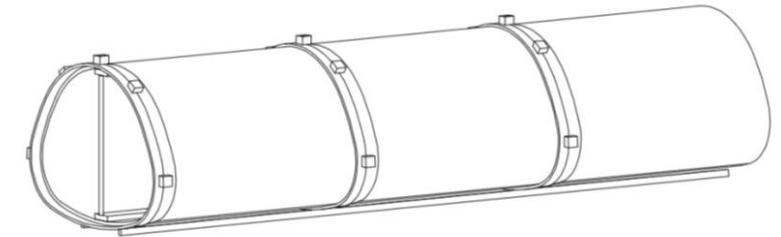
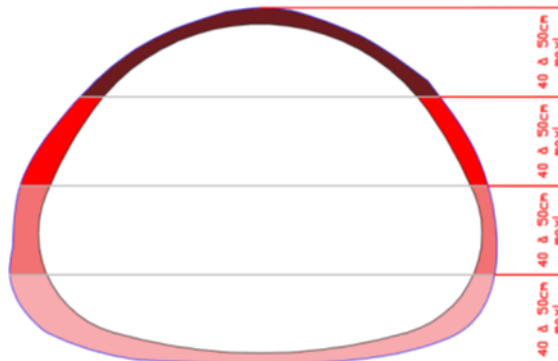
# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Installation Recommendations

Installation. Avoid GRP panel significant deformation due to buoyancy resulting force during grout injection (liquid grout)

#### PHASE INJECTION



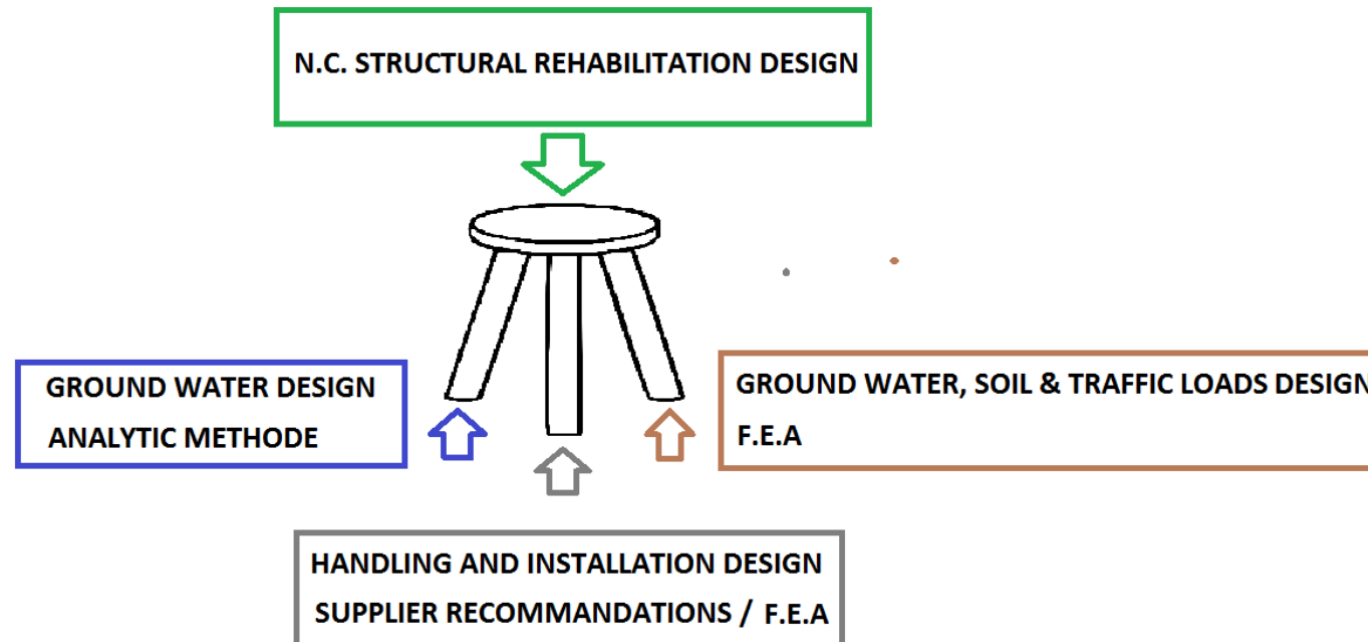
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## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

GRP thickness definition is based on short term installation and long term design



# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Installation



# Recent developments of GRP solutions in the booming transportation market



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## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

Operation Complete



# Recent developments of GRP solutions in the booming transportation market

## GRP SOLUTION – REHABILITATION OF NON-CIRCULAR CORRUGATED METAL CULVERTS UNDER A9/A61 HIGHWAY (FRANCE)

### Operation Complete



# Recent developments of GRP solutions in the booming transportation market



## CONCLUSION

**Digging up and/or replacing old underground pipeline systems is often an expensive choice, with aggravating conditions in urban areas (i.e. disruptions to traffic and to the landscape). Trenchless methods usually provide a more cost and time effective solution.**

**Glass fiber reinforced plastics is particularly suitable for to suit trenchless technology and provides a long-lasting high corrosion resistant pipeline solution.**

**Finally,**

- The recent Standards associated to N.C. GRP pipe (ISO 16611 – 2017 ) and to GRP Jacking pipe (ISO 25780 – 2011)**
- The recent published national methods for trenchless GRP design as the French 3R2014 recommendations (ASTEE 2014)**
- and the increasing use of Finite Element Modeling**

**enables to provide optimized tailor-made GRP solution in the context of the present booming transportation market.**