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Innovative facing for a 24 meter high Terre Armée wall near Pont de Normandie

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ABSTRACT: This article describes some of the interesting features of massive Terre Armée walls along the A29 freeway, just north of Pont de Normandie in France. Other recent developments in Terre Armée facing technology are also presented.

1. INTRODUCTION

Safety and reliability required extensive tests to be performed on the components of the Terre Armée system. This was the key to industrialisation of the technology in a field, geotechnical engineering, where each project is usually unique. The benefits are cost efficiency and consistency in the product. This also led to an homogeneity of appearance.

The need to better adapt the appearance of the facings to the environment while keeping the reliability of the structures led the Terre Armée company to develop several new types of facings. This article presents a group of related projects where the size of the structures justified the specific design of new types of facings required to comply with the stringent architectural constraints.

2. A29 : A CHALLENGING PROJECT

Opened in 1995 the Pont de Normandy, with a central span over 850 meter long, is the longest cable stayed bridge in the world. It crosses the Seine river near Honfleur south-east of Le Havre. 1.5 million vehicles are expected to transit on the bridge each year.

This is part of the global infrastructure planning for the north-western part of France : A16 will link the Channel tunnel to Paris while A29 will provide access to the Pont de Normandie and further down to the Atlantic coast (fig. 1)

The ramp on A29 from the river to the plateau north of the Seine, some 130 meter above the estuary level required important cuts through the chalk cliffs as well as very high fills.

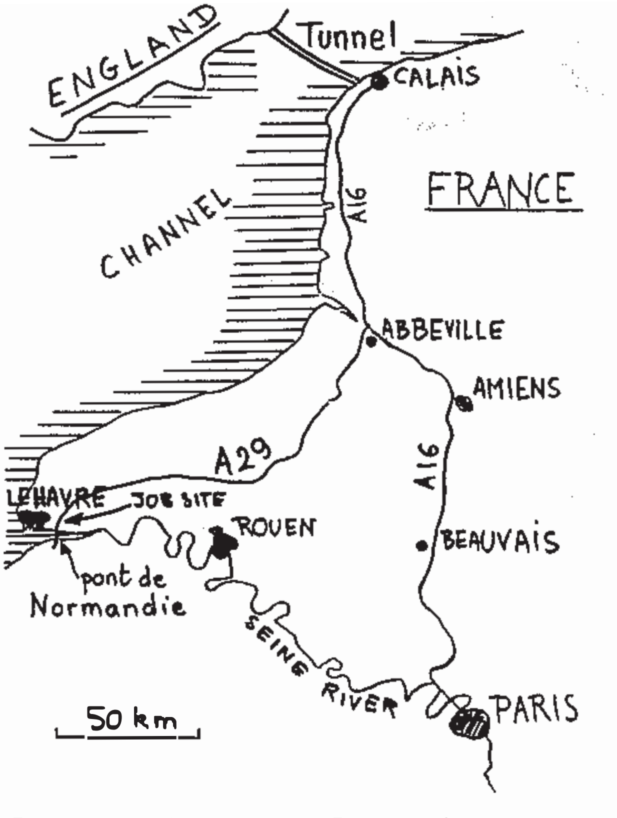


Fig. 1 : A16-A29 as part of France infrastructure

In order to preserve as much as possible the surrounding forest which is listed, the architect designed 24 meter high walls with a 10 degrees batter (fig. 2) and appearance close to that of the natural cliffs.

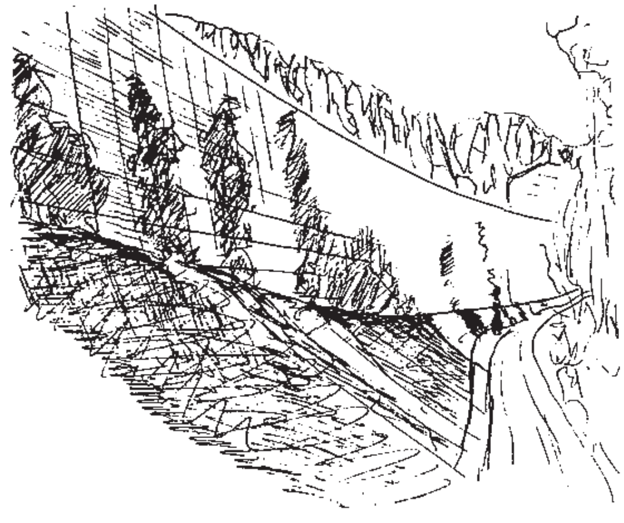


Fig. 2 : View of the 24 m high lower wall of A29.

Terre Armée S.A. the French subsidiary of Groupe TAI proposed an innovative type of facing and strip arrangement in order to fit the architectural and technical requirements .

Many items make this job unique : the stringent aesthetics requirement, the need to use locally available backfill which is normally unsuitable for MSE structures, the fast track of the job where a single day late delivery would represent massive losses for the toll road company and obviously the size of the structures totalling more than 12000 m2 with some wall sections 24 meter high (fig. 3).

3. A29 : A CHALLENGING AESTHETICS

After a study of the cliff features it was decided to try and reproduce some of them in the Reinforced Earth walls :

- the facing was to have a batter of 10 degrees close to the natural batter of most of the local cliffs.
- the colour of the concrete was to be chalk-white
- horizontal "clins" or mouldings where to be embossed on the panels.
- in order not to destroy the visual effect obtained with the "clins" the panels where to be much larger than usual with a rectangular shape instead of the usual cruciform shape.

In order to conform to all these requirements a completely new panel was designed and tested in a trial section. Erection went at a fast pace of up to 350 m2/day with this new panel presented in fig. 4.

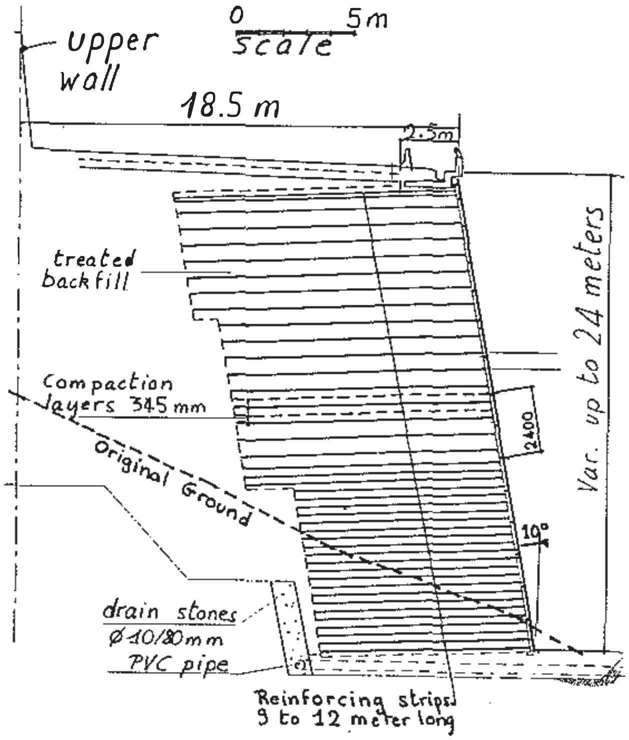


Fig. 3: Cross section of A29, lower wall.

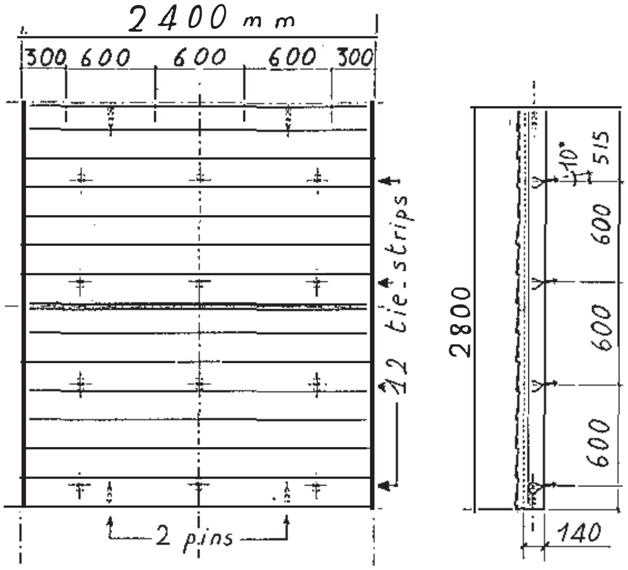
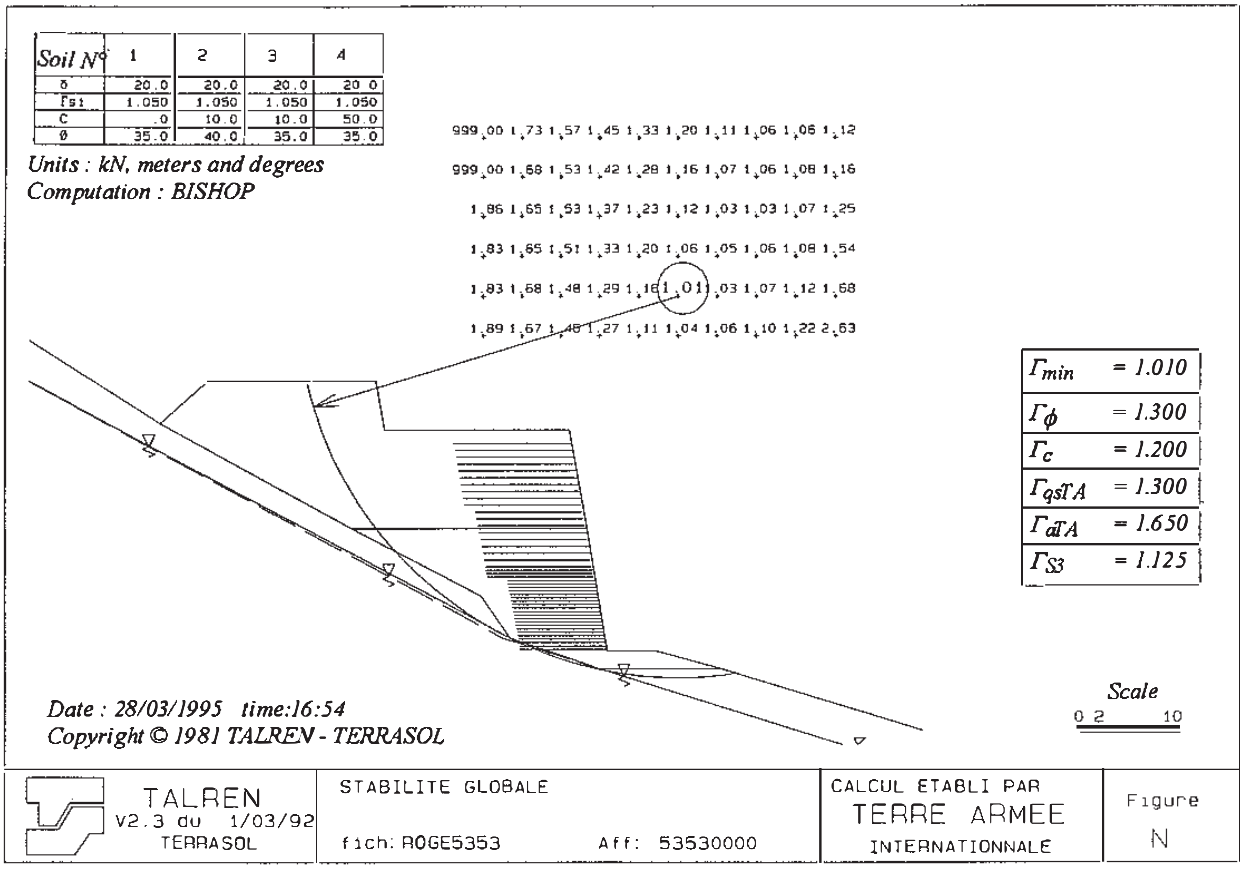


Fig. 4 : special facing panel for A29 walls.



Soil N°	1	2	3	4
δ	20.0	20.0	20.0	20 0
Γs1	1.050	1.050	1.050	1.050
C	.0	10.0	10.0	50.0
ø	35.0	40.0	35.0	35.0

Units : kN, meters and degrees
Computation : BISHOP

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999,00 1,73 1,57 1,45 1,33 1,20 1,11 1,06 1,06 1,12
999,00 1,68 1,53 1,42 1,28 1,16 1,07 1,06 1,08 1,16
  1,86 1,65 1,53 1,37 1,23 1,12 1,03 1,03 1,07 1,25
  1,83 1,65 1,51 1,33 1,20 1,06 1,05 1,06 1,08 1,54
  1,83 1,68 1,48 1,29 1,16 1,01 1,03 1,07 1,12 1,68
  1,89 1,67 1,48 1,27 1,11 1,04 1,06 1,10 1,22 2,63
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Γ_{min} = 1.010
Γ_{ϕ} = 1.300
Γ_{c} = 1.200
Γ_{qsTA} = 1.300
Γ_{aTA} = 1.650
Γ_{S3} = 1.125

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Fig. 5 : global stability analysis using TALREN and limit state design.

4. A29 : A CHALLENGING GEOLOGY

4.1 *Geotechnical study*

The slope on which the main wall was to be built is made of chalk with a cover of clay with a thickness varying from less than a meter to 2.50 or 3.00 meters in some places. Clay pockets several meters in diameter, where also present at places. This clay had to be extracted in order to find a suitable foundation strata for the structure. In addition the upper part of the chalk strata had been weathered and presented E values less than 10 MPa (Limit Pressure from the pressuremeter test 0.5 < PL < 1.5 MPa). Deeper the chalk became quite strong with an E value more than 100 MPa (PL > 4 MPa).

In addition to the usual geotechnical study phicometer tests were performed. The phicometer apparatus records the pull out force versus displacement of a cell analogous to that of a pressuremeter, while it is inflated and imparting a controlled lateral stress to the surrounding soil. This test gives for the strata at the depth tested both the angle of internal friction ϕ and the cohesion c. A summary of the corresponding values is shown in table 1.

4.2 *Slope stability analysis*

The importance of the walls and their height called for a complete set of slope stability analysis in addition to the local internal design of the Reinforced Earth walls. Many sections were studied. Since some of the possible failure surfaces intersected the reinforcing strips the TALREN program from Terrasol, where strip tensile and frictional resistance is taken into account was used for these slope stability analysis (Schlosser, 1984).

Fig. 4 presents one of the cross sections of the structure whose stability were evaluated this way. It can be noted that limit state design with load factors and partial factors of safety in accordance with NF P94-220 (AFNOR 1992) were applied.

Tab. 1 : soil characteristics (c in kPa)

Soil types	*Short term*	*Long term*
Weathered chalk	$\phi = 30°$ $c = 0$	$\phi = 30°$ $c = 0$
Medium chalk	$\phi = 33°$ $c = 20\text{-}110$	$\phi = 33°$ $c = 10\text{-}55$
Hard chalk	$\phi = 35°$ $c = 175$	$\phi = 35°$ $c = 85$

5. A29 : A CHALLENGING BACKFILL

As stated above massive excavations in the chalk strata produced vast quantities of backfill which had to be used as Reinforced Earth backfill, even though they were not acceptable as extracted. In order to make them acceptable the fill had to be improved.

Improvements such as lime treatment or cement were considered and finally LIGEX 2R was used. Table 2 gives the components present within LIGEX 2R.

Table 2 : LIGEX 2R composition and properties.

Components/properties	*Specifications*
Powdered blast furnace slag	*90 +/- 2%*
Anhydrite	*4 +/- 1%*
Quick lime	*6 +/- 1.5%*
Specific surface (Blaine)	*3700 +/- 300 cm^2/g*
Grain distrib. > 128 μm	*0 %*
Grain distrib. > 40 μm	*less than 20 %*

Many aspects of soil improvement by treatment with lime, cement or other agents have been studied since this type of technology was used in Groupe TAI (1979, in Texas, USA). A 7 years durability test launched in 1986 was also reported in a paper by Bastick (1993).

For the present job, additional tests were carried out to verify the adherence capacity of the strips. Pull out tests, in accordance with AFNOR procedure NF P 94 222 (1995), were carried out.

The strips were 45 mm wide with an embedded length of 4.5 meters. Measurements were carried out until rupture of either the strip or the connecting device.

Figure 6 presents the pull-out curves for four strips located at two different levels.

Analysis of these curves shows that :

1) the interaction coefficient μ^* exhibited values between 2.4 and 2.8 for depth around 5 to 6 meters, which is well in excess of the design values. It must however be noted that the tests were performed after the improved soil had time to gain strength and not just during construction.

2) the friction can be mobilised with a very small deformation (few mm) compatible with the alignment requirement of the structure.

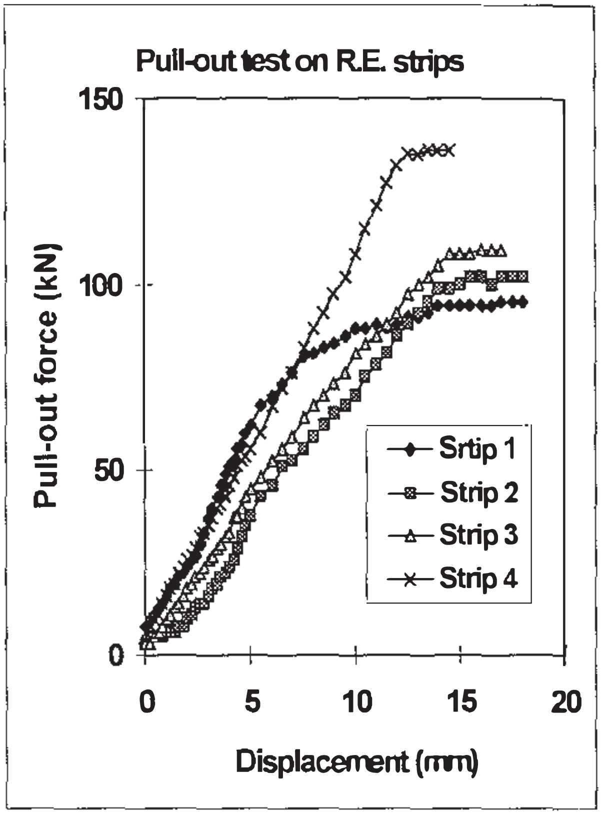

Fig. 6 : pull out test in improved backfill at A29.

6. A16 : MORE AESTHETICS

As can be seen from figure 1, A29 is part of a large global scheme in the northern part of France. It ties to A16 near Abbeville.

A 16, between Amiens and Beauvais was completed very recently. The motorway was constructed in a region were many already existing highways and secondary roads required many over- and under-passes.

For this project, the architect was involved from the beginning in the choice of the aesthetics of the project especially for the abutments and wing walls. Terre Armée, the French subsidiary of Groupe TAI, engineered a specific facing to fit with the architectural requirements. It was adapted from the product known as TERRAFLOR® but with a different shape at the visible face.

TERRAFLOR® is a new patented facing system comprising smaller facing elements than the usual facing panels. It is especially well adapted for walls were access is difficult or for series of small walls as in A16 case where more than 30 bridges required over a hundred of individual wing and return walls. In the present case each element was connected to a strip, except the top ones.

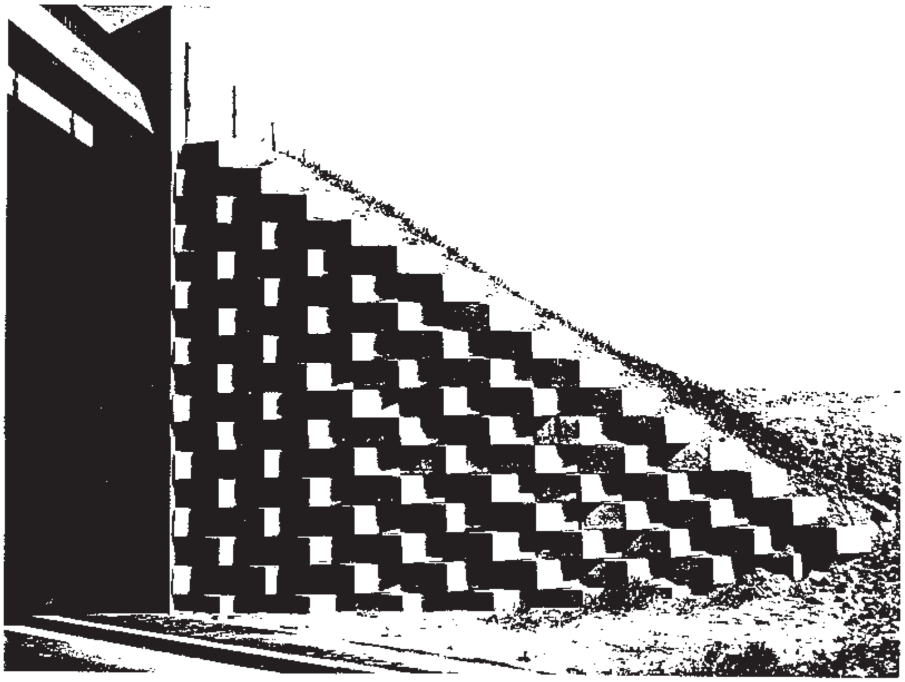

Fig. 7 : A16, example of a wing wall.

The size of the unit elements was 0.33 meter high for approximately 1.00 m width. When used for vertical walls the elements were close to one another, but they could be spaced to provide room for vegetation in the case of inclined facing.

Figure 7 presents an example of an abutment wing wall.

7. CONCLUSION

This article presented A29, a major project incorporating large walls for which large facing panels were engineered. A16 return walls, of a much more reduced size and using smaller facing elements were also presented.

This shows that the type of facing must be adapted to the type of project and that nowadays, solving the technical difficulties, and there were many in A29 project, is no longer sufficient. Architectural requirements are becoming more and more stringent.

This growing influence of architecture with its request for adaptation and variability, clearly conflicts with the need for reliability which is best achieved by rationalising components and testing and optimising them. The solution lies in the design experience that only large teams, used for many years to work in the mechanically stabilised earth environment can deliver.

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