MOTORWAY A29 AMIENS / SAINT-QUENTIN
OPTIMIZATION OF THE EARTHWORKS
IN A SUSTAINABLE DEVELOPMENT PROSPECT

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SUMMARY

The motorway A29 between Amiens and Saint-Quentin, 63 km long was opened to traffic in June 2001. It spreads over rich agricultural lands of the north of France (plateaux of Santerre, of Vermandois) crossed by the valley of Somme. Geologically, the chalky substratum (senonian chalk, superior Cretaceous) outcrops locally in certain dry, small valleys with a silty cover the thickness of which is very variable. The surface formations are mainly made up of silts of plateaux (quaternary), silty and chalky colluviums, sands from Thanetian and clays from Sparnacian constituting some pilot hillocks.

At the design stage, the project was optimized by developing to the maximum materials of the site (treatment of the silts and chalks) for re-employment in capping layer, upper part of earthwork (PST), technical blocks close to the structures.

Several scenarios of earthmoving were studied in order to have a perfect control of risks of this type of building site (geotechnical, meteorology, yield coefficient of materials...) leading thus to a balance. This balance is obtained for each scenario, by adaptation of the project (modification of the longitudinal profile, extra width of certain cuts), and excluding recourse to stock-pile and borrow-pit which would have been of a higher cost and badly accepted taking into account the high quality of the arable lands.

During the building site, optimization was continued and the longitudinal profile was modified along 10 km long to take account of a material yield coefficient of the silts, different from the basic assumption.

The PST, made up either of silts (90 % of the layout) or of chalk, was systematically treated.

Along half of linear, a 0,35 m-thick capping layer in silts treated in a stabilisation plant, by hot lime and cement, made it possible to obtain a formation PF4. On this formation, the structure of roadway is made of an asphaltic concrete for wearing course (BB) (7 cm) and of a road base asphalt (GB) (10 cm).

Along other half of linear, 40 cm-thick sand treated in a stabilisation plant constitute the capping layer/road base, which is surmounted by a 2 cm-thick anti-cracks layer made of sand-asphalt and 8 cm-thick BB. These layers are the road structure of the motorway.

The maximum exploitation of on-site materials for the capping layers or capping layer/road base not only made it possible to minimize the external material contribution to construct the roadways but also to avoid any recourse to borrow-pit or stock-pile for a 63 km long motorway and more than 4,5 million m^3 moved soils.

1 - The motorway A29, need for adapting the characteristics to the awaited traffic

The interurban motorways supporting middle and strong traffic are almost carried out in France.

Now, it is envisaged the construction of motorways of regional need on which, the awaited traffic is moderate in complement of the motorway axes with strong traffic.

These motorways with moderated traffic, generally financed in concession by toll, require a design and an exploitation adapted in order to reduce the initial investment and the costs of exploitation, while offering the level of service normally awaited on a motorway section.

A new adequacy between the design of the infrastructure and the needs to satisfy (traffic, speed, safety, comfort and economy of displacements) must thus be found.

This adequacy passes by the search for savings although complying with the great principles of a motorway, in particular as regards safety, namely: grade-separated junction, traffic segregation, geometrical characteristics allowing high speeds and long distances, facility for overtaking.

On the Amiens / Saint-Quentin section of the motorway A29, this adequacy was sought by SANEF, concessionary company of the work, while respecting the essential characteristics of the project.

1.1 - For a motorway of regional need,

63 km-long, the Amiens / Saint-Quentin section of the motorway A29 is divided into two sections with differentiated traffics:

- between Amiens and the A1 motorway which ensures a continuity of the interregional and international net in direction of Belgium by A1 motorway, then A2 motorway whose traffic (daily traffic of annual average) should be, at 2010 prospect, about 9 000 vehicles per day including 15% of heavy lorries (PL);
- between A1 motorway and Saint-Quentin with a traffic of 5 000 vehicles per day including 8% of PL, for which the prospects for evolution will remain on regional traffic and an economic activity scale of the saint-quentinois area.

1.2 - By an adequacy of the geometrical characteristics,

By reducing the width of the block on left to 4 m made of a 3,25 m-broad expresslane and of a levelled down, 0,75 m-broad band of left (BDG), whereas the normal characteristics are respectively 3,50 m and 1,00 m.

For central reservation (TPC), the device of reserve is double barrier made of adhesive concrete (DBA), of width 0,60 m at foot, which leads, with the retained widths of BDG, to a TPC width of 2,10 m (instead of 2,60 m minimum).

By reducing the characteristics of the surfaced emergency lanes (BAU) while replacing by an extra width of roadway of 0,50 m and a hard shoulder carrying the total width occasionally suitable for vehicles to 2,50 m on the Amiens / A1 section more charged, in particular as regards the traffic of heavy lorries, and to 2,00 m on the A1 / Saint-Quentin section.

1-3 - By economic structures,

For the current works, the savings from bridge deck surface result directly from the transversely reduced profile of the motorway like that was indicated above.

For the viaduct of Sommme, this work of 460m length, was built to 2 X 1 lane with a central reservation DBA, taking into account the weak traffic awaited on the A1/Saint-Quentin section (with a deceleration of the authorized speed from 130 to 90 km /h).

1-4 - By adapted equipments for exploitation,

The service and rest areas were twinned with the interchanges. This twinning reduced :

- right of way, the key plans being more compact;
- access roads to the motorway and the whole of the roadway systems;
- expenses of connection to the networks;
- expenses of road marking.

In addition, because of the toll-stations on interchange had a weak awaited traffic, the cost of exploitation of a traditional station with uninterrupted-present personnel would have been disproportionate compared to receipts of toll. SANEF thus developed an entirely automatic system accepting, in addition to the electronic tolling and the magnetic cards using, the payment in cash or by cheque on a terminal of prepayment. A remote supervision allows all the operations of current exploitation from a main station.

1-5 - But mainly by an optimization of the earthworks and structures of innovating roadways related to materials of the site.

2 – Optimization of pavements

In an area badly provided with noble materials for roadways (massive rocks in general), the search for economy in the construction of the roadways of a motorway passes by the use of local materials.

Accordingly, the preliminary studies identified two potential sources of materials:

- sands of Thanetian,
- silts of plateaux.

The performances of these materials could be evaluated on trial areas carried out in 1996 on the A16 motorway between Amiens and Abbeville.

Two great types of structures of roadways were studied:

- the structures known as " traditional ", it acts of the structures dimensioned in accordance with the Handbook of Design of the Roadways of Motorways, revised by Scetauroute in 1997,
- " reduced " structures known as, because of their minimized dimensioning (course wearing on underlays in treated silts or sands). These structures present an initial capital cost lower than that of " traditional " structures but a higher risk of damage. In addition, their implementation is more delicate: the significant thickness of the underlays made of treated materials can require adaptations of the implementation methods (to obtain acceptable compactness in the lower part of layer, for example).

The assumptions of re-employment of materials in capping layer were defined in accordance with the technical guide of construction of the embankments and the capping layers, Ministère of the Equipment, Housing and Transport, September 1992 (GTR).

The determination of the formation classes, the checking with freezing / thaw and the establishment of scenarios for maintenance were carried out in accordance with the Handbook of Design of the Roadways of Motorways (Scetauroute, 1997).

For each of the two sections of the Amiens/Saint-Quentin motorway, various structures of roadways were proposed with the tender documents to companies corresponding to strategies of different dimensioning and maintenance:

- traditional structures on PF4 formation obtained with a 0,35 m-thick capping layer in silts treated in a stabilisation plant with hot lime and cement, produced within the framework of the earthworks–cleansing contract ;
- innovating structure (fitted reduced pavement) on PF2 formation obtained by the treatment of the upper part of earthworks (PST) realized within the framework of the earthworks–cleansing contract. This solution does not comprise a capping layer, the structure of roadway being implemented directly on the PST. For this solution, the longitudinal profile of the project is different from that of the traditional structures, in order to rebalance the variation of 300 000 m^3 of materials for capping layer.

2 –1 - For the Amiens / A1 section

The choice between traditional structures and reduced structures (on-site, developed materials) took account of costs of the various scenarios of maintenance and the initial investment. Five scenarios were put in competition by taking of account the couple earthwork-pavement, three traditional structures and two reduced structures. Not to distort the judgement of the offers, the cost of the scenarios of maintenance of the reduced structures was included in the financial comparison of the offers.

The structure finally selected was the following reduced structure: 8 cm asphaltic concrete (BB) / 2 cm anti-cracks sand asphalt layer / 40 cm of sand treated with hydraulic binders (SH).

2-2 - For the A1 / Saint-Quentin section

The invitation to tender " pavement " envisaged three solutions:

- Two solutions with traditional structures on PF4 formation, according to GTR :

  1 - BB 0/14 (7 cm thick) / road base asphalt GB 0/14 (10 cm thick);

  2 - BB 0/14 (7 cm thick) / GB 0/14 (8 cm thick) / not treated graded aggregate of B class GNTB 0/14 (10 cm thick).

- a solution with a innovating structure on PF2 formation :

  BB 0/10 (4 cm thick) / BB 0/14 (6 cm thick) / sand treated (SH) in a stabilisation plant (40 cm thick).

The adopted solution, at the end of these consultations, was finally the following traditional structure: 7 cm asphaltic concrete (BB) / 10 cm road base asphalt (GB) on formation PF4.

Because of the weather constraints and to respect the completion periods, it was decided to construct, on certain zones, the capping layer by in-situ treatment (instead of a treatment in a stabilisation plant) what made it possible to obtain only a PF3 class for formation instead of PF4.

The in-situ treatment relates to a 33 cm-thick layer of silts treated after compaction, with lime and a road hydraulic binder.

Consequently, the structure of roadway was adapted while carrying from 10 to 12 cm the thickness of the road base asphalt GB 0/14.

3 - Optimization of earthworks

3-1 - Context of the project

The geological formations met on the layout, are silts, silts with flint, residual formations with flint observed in the roof part of chalk formation and chalk.

The thickness of the silty cover is almost non-existent in certain places, to reach 5 to 6 metres at other places.

The plateaux of Santerre and Vermandois concerned with the motorway A29 are rich agricultural areas, because of the presence of very fertile silts which is favorable to production of cereals, sugar beets, potatoes. The vegetable cultures are locally significant.

3-2 - Objectives

In this geological and geotechnical context, and taking into account the agricultural context, the following principal objectives were laid down for the study of this motorway project :

- maximum valorization of on-site materials as well for the realization of the earthworks as of the roadways. Indeed, this area is badly provided with noble materials for roadways (not massive rocks for less than 100 km far from the layout) and search for savings, in a logic of sustainable development, requires the maximum local material re-use for the construction of the pavement of a motorway ;
- minimizing impacts to the agricultural environment by a minimal consumption of right of way, by avoiding temporary occupations, by limiting external transport to the building site in construction phase and by prohibiting any stock-pile or borrow-pit.

3-3 - Studies

At the design stage, the re-use as fill of extracted materials does not give rise to particular problem. On the other hand, these silts classified as A1-A2 and these chalks classified as R12-R13 (GTR classification) are soils sensitive to water. It is thus particularly interesting to carry out the earthworks under favorable weather conditions in order to optimize the re-use of materials and to limit the use of lime to treat the soils used as fill.

With optimized proportionings of binders, these silts and chalks are usable in PST, capping layer and technical blocks close to the structures.

Silts and sands are present less than one kilometer far from the layout. They were evaluated by previous trial areas carried out on the motorway A16. The results obtained made it possible to retain assumptions of dimensioning for the structural analysis of the roadway.

3-4 - Assumptions of the earthmovings

For the section Amiens / A1, two assumptions thickness of layer for roadway / capping layer were studied to fix the earthwork volumes :

- 50 cm thickness with a capping layer / sub-base of 40 cm made of treated sands, 2 cm of sand asphalt as an anti-cracks layer and 8 cm as a wearing course, above an AR2 class of sub-formation (classification of the sub-formation according to GTR).

- 62 cm thickness with a 35 cm-thick capping layer made of treated silts, 10 cm-thick sub-base in GNTB, 10 cm-thick base course in GB, and 7 cm-thick wearing course in BB.

In order to seek for a balance of the earthmoving for these two assumptions, two projects were fixed.

3-4.1 - Top soil stripping

The assumptions for the top soil stripping were precisely studied according to the needs, which resulted in not pickling as soon as the height of the embankment was higher than 1 metre.

3-4.2 – Stock-pile and borrow-pit

The only tolerated deposits were in the rights of way themselves (i.e. inside the loops of the access of service, of the interchanges or as constitutive of earthmodelling layout for acoustic protections).

3-4.3 - Yield coefficients

Yield coefficients (Cr: ratio of the cubic metres compacted as fill / cubic metres of in-situ soils in cut before extraction) assigned to the cubic metres of cut before extraction, make it possible to evaluate the cubic metres of compacted fill. These yield coefficients take into account the expansion, the compaction settlement and also the various losses on building site (transport, taken again materials, tracks...). For the met soils, the coefficient presents an uncertainty related to the building site for an actual value ranging between 0,90 and 1,00.

3-4.4 - Weather conditions

The chosen assumptions of weather conditions are as follows:

- favorable weather conditions: drop by 1 to 2 % of moisture content in the superficial soils- compared to the average weather conditions.
- unfavourable weather conditions: the moisture content of the most sensitive soils of surface increases few points compared to the average weather conditions.

According to these two conditions, the percentages of re-use, with or without treatment of excavated materials, were estimated.

3-5 - Earthmoving

For the section Amiens / A1, long of 30 km and a given longitudinal profile (suitable with one type of structure of roadway), four scenarios were studied with the following assumptions for each scenario:

Scenario a: Cr of 0,95 for the silts and Cr of 1,00 for the chalks (favorable weather assumption),

Scenario b: Cr of 0,95 for the silts and Cr of 1,00 for the chalks (unfavourable weather assumption),

Scenario C: Cr of 0,90 for the silts and Cr of 0,95 for the chalks (favorable weather assumption),

Scenario D: Cr of 0,90 for the silts and Cr of 0,95 for the chalks (unfavourable weather assumption),

For geometrical volumes, respectively from 1 992 000 m^3 of cuts and 1 680 000 m^3 of fill, the following results are obtained, complying strictly with GTR requirements i.e. the too wet materials are laid out in deposit, in particular if unfavourable weather conditions :

- for scenario A: surplus moreover 180 000 m^3 of excavated materials,
- for scenario B: it would miss nearly 104 000 m^3 after placing as deposit more than 300 000 m^3 ,
- for scenario C: surplus of 85 000 m^3 ,
- for scenario D: it would be needed nearly 204 000 m^3 of borrow and a placing as deposit for more than 300 000 m^3 of excavated materials.

In favorable weather conditions, it is thus a volume of materials ranging between 85 000 m^3 and 180 000 m^3 which it will be necessary to put in stock-pile as deposit.

On the other hand, in unfavourable weather conditions, volumes to be put in deposit are about 300 000 m^3 but it would be necessary in this case to find volumes of borrow ranging between 104 000 m^3 and 204 000 m^3 .

With these issues of scenarios, and taking into account the planning of work, the search for optimization of the project was carried out by taking as assumption the scenario C (favorable weather conditions and yield coefficient of soils of 0,90 for the silts and 0,95 for chalks). The project under these conditions is balanced with a margin of 85 000 m^3 .

One will note the importance of the yield coefficient for soils, parameter difficult to evaluate in project phase, bus if the coefficients prove to be of 0,95 in the fine grained soils and 1,00 in chalk, one will have approximately 100 000 m^3 of additional materials to put out as deposit. A variation of 5 % of the yield coefficients of the soils results in a difference approximately 100 000 m^3 in the assessment of the earthmoving.

However, in order to control the risks, several mitigation methods were designed to lead the building site operations :

- if surplus: possibility longitudinally to modify the profile in significant cut zones and embankments where the structures were not affected,
- if borrow : in unfavourable weather conditions, possibility of widening certain cuts, allowing to gain nearly 100 000 m^3 and to put as deposit an equivalent quantity in the loops of interchanges and access of service.

3-6 - Operations

3-6.1 - On the section Amiens / A1

One took care in the course of work to control the beginning of the building site according to meteorology to avoid the least favorable scenarios.

Quickly, the checks on the ground showed that the yield coefficients were higher than 0,90 for the silts.

Under these conditions, the real scenario met was closer to studied scenario A. It was thus necessary longitudinally to modify the profile on four quite distinct zones (nonaffected by the presence of structures) representing nearly 10 km, that is to say more than 30 % of linear of work. These modifications related to nearly 10 % of the volume of extracted cut. To note, that the weather was not favorable, which involved treatments of materials definitely more significant than scenario A (in volume and quantity of binders).

3-6.2 - On the section A1 / Saint-Quentin

Mainly embanked under unfavourable weather conditions, the fitted balance of the earthmovings could be found by widening certain cuts, in spite of treatments more significant than envisaged. Taken by assumption 0,95 for the fine grained soils for this section, Cr appeared lower than 0,90, it is thus a variation of more than 5 % due to the yield coefficient which was compensated by this cut widening.

4 CONCLUSION

In spite of an unfavorable meteorology, the objectives for the construction of this motorway were achieved, in particular by an earthwork control and a maximum optimization for re-employment of on site soils.

- Control of the earthworks was obtained by upstream very detailed studies on the re-use of materials and by the development of scenarios of earthmovings making it possible to decide options to retain according to the actual met situations (in particular the influence of the meteorology and the yield coefficient of materials) during the building site. The modification of the longitudinal profile along 10 km approximately, corresponding to about 10% of extracted volume from cut was thus decided during the building site operations.
- Optimization of on-site materials employment by submitting to tender two types of roadway structures (reduced and traditional). The differences of pavement thickness (and of re-employment of in-situ soils) induced a cut volume variation nearby 300 000 m^3 . This variation is completely compensated by a suitable longitudinal profil for each type of roadway structure.

Generally speaking, it was proved on this motorway section the search for a just balance of the earthmoving is possible without borrow-pit or stock-pile, on condition to keep possibility to optimize the project through the all design and construction phases : studies, strategy for tenders and mainly earthworks control.