VALORIZATION OF LOCAL MATERIALS ON THE MOTORWAY SERVING THE PORT TANGIER MED

M. CHOUH
Société Nationale des Autoroutes du Maroc, Maroc
chouh.mohamad@adm.co.ma and chouh.mohamad@gmail.com

ABSTRACT

During the development of the project of the motorway serving the Port Tangier Med, one of the principal constraints that the persons in charge for this project asserted themselves is the attenuation of its environmental impact. Thus, a series of actions were undertaken to achieve this goal, of which most important is the valorization of local materials for the construction of the Higher Part of Earthworks (PST) of the motorway platform.

For this project, the remoteness of lodgings able to provide noble materials incited the managers to think of an alternative solution more ecological than the basic solution which consists in opening a new quarry, to extract a considerable quantity from materials, approximately 800.000 m3, then to transfer it onto 50 km.

The solution adopted to avoid nuisances with the ecosystem is the use of the marl extracted from the project spoil , which should normally be rejected, and to re-use them for the construction of the PST with the help of a lime treatment which allows the improvement of the characteristics of this material, initially nonreusable.

In addition to the impact, easily perceptible, of this solution on the environment, it made it possible to reduce the cost of the project.

1. INTRODUCTION:

The project of the Motorway serving the Port Tangier Méd, a 54 km length (see Figure 1), envisaged the recourse to the soil stabilization with the lime to improve the performances of the higher part of the earthworks (PST). This technique never adopted before on a Moroccan motorway even less with evolutionary materials as the hardened marl kind.

Usually we use for the PST, in the north of Morocco, the granular materials insensitive with water by requiring a 50 cm thickness instead of 35 cm adopted by using the lime treatment of the soils coming from spoil.

The area of the project being characterized by its noble natural material shortage, being able to meet the requirements of a granular material PST, it was decided to adopt the solution of lime treatment. This innovating solution, in addition to its economic advantage, since it made it possible to reduce the cost of the PST of more than 60%, it also took part, with other measures taken on building site, to notably attenuate the impact of the project on the environment.

Figure 1 - Situation of the noble material lodgings

2. THE SPECIFICATIONS OF THE PST:

The characteristics necessary for the higher part of the earthworks are:

2.1. Case of untreated materials:

The materials must be insensitive with water within the meaning of the Guide Road Earthworks (GTR), they must guarantee obtaining a minimal value of the module 50Mpa measured with a "***Plaque***" on a solid mass compacted into multi-layer a height of about 1,50 m with a material carried with a water content of at least equal to Wopn + 1.

The mechanical performances to obtain during the execution of the granular material PST a 0,50 m thickness are: Ev2 ≥ 40 Mpa and EV2/EV1 < 2 and this for 95% of the controlled points. These performances make it possible to classify the Earthworks' levelling course between classes AR2 and AR1 (AR1-2).

All the materials being in the influence of the project and even those of the neighbouring lodgings do not answer these requirements. The closest careers being able to provide materials valid for a granular PST are with more than 50 km of the site of the project.

2.2. Case of materials treated with lime:

The treatment of materials to lime for the improvement of the levelling course of the earthworks is carried out in accordance with the technical guide of the SETRA-LCPC. The treatment will have to make it possible to stabilize and improve the mechanical characteristics of materials and to make them not very sensitive to water. After treatment these materials must have an IPI (Immediate Capacity Index) higher than 15% and the ratio:

$$\frac{ICBR\ (after\ four\ (04)\ days\ of\ immersion)}{IPI}$$ must be at least equal to 1.

The mechanical performances of bearing pressure to be obtained on the level of the PST are EV2≥40Mpa. As for the granular option the performances necessary for the PST treated with lime make it possible to classify the Earthworks' levelling course between AR2 and AR1 (AR1-2).

All the families of materials coming from spoil of the motorway were the subject of tests of characterization and studies to appreciate their aptitude for the lime treatment.

3. JUSTIFICATION OF THE OPTION TREATMENT:

In the absence of granular materials answering the required specifications, in the influence and the lodgings surrounding, the project staff decided to use the soil stabilization to lime instead of working out materials starting from the careers open in the calcareous dorsal being to approximately fifty kilometres (50 Km) of the motorway in question.

3.1. Economic justification:

The treatment option was selected for the following reasons:

- Valorization of local materials: This process allows the use of materials in place without having recourse to materials of loan or coming from career which are often more expensive. This solution reduces at the same time the quantity of materials to be put in deposit;

- Reduction of the hauls: The use of local materials lowers the cost of transport between the point of extraction and the point of implementation. Indeed, the haul for the local materials does not exceed 4 to 5 km compared to the distance of 55 km since the career nearest if the PST is not treated. Thus, the adopted solution reduced on the one hand the cost of the project and on the other hand the emission of gases for purpose of greenhouse.

Table 1 - Comparison of the two options for section 1 length a 22 km

Solution PST	PST materials		Definitive deposit		Material Transportation		Lime for treatment		TOTAL COST (KDH)
	Quantity (m3)	Cost (KDH)	Quantity (m3)	Cost (KDH)	Distance (Km)	Cost (KDH)	Quantity (T)	Cost (KDH)	
without treatment	220 000	13 200	130 000	325	52	22 880	-	-	36 405
with treatment	150 000	2 475	-	-	4	1 200	9 000	9 000	12 675

Table 1 above allows the evaluation of the variation in term of cost between the solution of the 50 cm thickness untreated PST carried out with a material insensitive with water, and the solution of a material PST, extracts of spoil of the project, treaty to lime. For this last option, it is advisable to indicate that the adopted thickness is 35cm.

This analysis reveals that the granular PST would return three times more expensive than the PST treated with lime.

3.2.1. *Technical justification:*

In addition to the economic aspect, the treatment has an ecological interest, since the valorization of the local material resources limits the opening of the careers and the deposits, thus attenuating the impact of the project on the natural environment. The treatment takes part, in the optimization of the movements of the Earths, with the reduction of the harmful effects caused with the residents and fauna and the flora by decreasing transport outside the building site.

To achieve the goals of the treatment that passes ineluctably by a good control of the quality of the product finished and especially by a control of the basic study, components, mixture, chain of production since the preparation of materials until the implementation.

The mix composition results from a formulation of level 2 in accordance with the Technical Guide of the Soil Stabilizations from the L.C.P.C, this first phase which is fundamental in the process ends in a knowledge of materials likely to be treated, the definition of the sample representative by class GTR and the execution of the studies of formulation at the laboratory specifying the optimal water content and minimal dosage of lime making it possible to guarantee the performances of bearing pressure fixed by the terms of references.

3.2.1. *Characterization of materials:*

The definition of various natures of materials apt to the treatment on the project spoil was stopped after the execution of a campaign of in situ recognition and laboratory tests: Proctor - IPI - CBR, whose results are drawn up in table 2 below:

Table 2 - Characterization of materials in the section 1

Spoil	Class	CBR	Fr	Dg	50 mm	2 mm	0,08 mm	Wn	IP	Vbs	Wopn	dm	IPI
D1/D2/D3/D4/D5	R32	5	5	18	Marl–Calcareous Rock			6	27	-	12	1,92	8
D4/D6/D9	R31	4	5	22				6	26	-	15	1,88	7
D6/D9	R34	2	8	-				6	32	-	14,5	1,87	13
D12/D14	A2	-	-	-	100	95	78	15	23	2	16	1,83	17
D11	A3	-	-	-	100	90	60	18	30	250	17,5	1,81	12

These results show that the materials of R3i class are characterized by a state in place on consolidated semi rock with very dry hydrous states; the materials of A3 class are characterized by a strong plasticity and a very wet hydrous state.

The success of the treatment of these materials to lime is conditioned by; evolution of granulometry towards fine grained soils, the modification of the very dry hydrous state to reach the middling state even the wet state and the stability of these materials during the implementation.

3.2.2. *Tests of aptitude for the treatment:*

The tests of aptitude for the treatment were carried out on representative samples by class of soil according to standard NFP94-100. The results obtained are drawn up in table 3 following:

Table 3 - Aptitude of materials for the treatment

Soil Class according to GTR	Type of treatment	voluminal Swelling	Aptitude of the soil
R31	3% of Cao	9%	Doubtful
R32		5%	Apt
R34		9%	Doubtful
A2		2%	Apt
A3		8,5%	Doubtful

These results show that for the classes R31, R34 and A3 there is possibility of voluminal swelling, but the correct development of the pozzolanic catch will be appreciated at the time of the study of treatment whose results are summarized in table 4 below:

Table 4 - Study of treatment

Soil Class	Proctor		IPI	CBR	Granulometry Analysis						IP	VBS
	W opn	D max			50 mm	20mm	10mm	5mm	2mm	0.08mm		
R 31	16	1.84	15	20	100	100	99	89	61	19	16	0.6
R 32	13.5	1.95	17	22	100	100	98	90	62	16	18	-
R 34	16.5	1.75	22	23	100	100	100	94	80	44	17	1
A 2	19	1.71	25	45	100	100	97	88	80	56	16	0.63
A 3	18	1.75	22	24	100	100	97	90	70	37	-	0.56

These results confirm that for the various classes, there was a pozzolanic effect of lime with an increase of 400% of index CBR.

However for the classes R34 and A3, the ratio of index CBR after four (04) days of imbibitions compared to immediate value bearing capacity is very close to 1 and since the tests of aptitudes considered them doubtful for the lime treatment, these materials were discarded.

At the end of these studies, the only materials selected to be treated with lime are those of classes GTR R32 and A2. To test them under real conditions of execution, it was preceded to several boards of tests by class of soil.

3.2.3. *Boards of tests on the class R32 and A2:*

Several boards of tests were carried out for materials of class R32 and A2 in order to adopt the procedures of execution leading to the optimal results. The process of execution adopted on building site for the execution of these boards of tests is as follows:

- Display of materials during several days with closing of surface to allow their degradation;

- First watering operation to increase the water content of materials, which are in a dry state, with the passing of the mixer to split up and degrade materials mechanically;

- Second watering operation to bring materials to water contents between Wopn+1 and Wopn + 2;

- Display of lime, with control of dosage;

- The second mechanical mix up to mix the lime with the soil and to split up it more to bring back it under the conditions of moulding of the laboratory;

- The compaction is assured mainly by V5. Ten (10) passes were adopted and the maximum length of treatment not exceeding 80 ml;

- The treatment of a small surface imperfections such as laminating is done by grader and compactor with tire.

Controls of reception led to the results appearing in table 5 below:

Table 5 - Results of the boards of tests

Soil Class	Dosage	Compaction	Thickness	Wn (%)	Ic (%)	EV 2	K	IPI	ICBR	G * (%)	Wn * (%)
R 32	3 % of lime	10 passes	0.35 m	14, 5	≥ 99	≥100	< 2	19	20	0,8	15.5
A 2		8 passes	0.35 m	22	≥ 95	≥ 70	< 2	15	33	0,2	22

- ***Measure of swelling and of water content after four (04) days immersion in water.***

The controls boards of grinding are drawn up in table 6 following:

Table 6 - Control of grinding

Soil Classe	Situation	20 mm	10 mm	5 mm	0.08 mm	IP	VBS
R32	Before	100	98	90	16	18	-
	After	99	89	78	33	29	1.1
A2	Before	100	97	90	37	-	0.56
	After	100	93	87	64	19	1.03

This table shows that the size range of materials is 0/20 mm what is in conformity with the representative sample of the laboratory.

4. REALIZATION OF THE PST TREATED WITH LIME:

4.1. Techniques of execution:

During the construction of the motorway serving the Port Tangier Méd, the PST treated was implemented according to an average rate day labourer of about 2.500m3 that corresponds to approximately 400 ml per way and day.

This activity starts with the display of materials during several days so that they undergo a natural evolution; preliminary watering and under the traffic of the engines the soil is fragmented more. In the end of this step the soil has the aspect of a fine grained soil.

Lime used is quicklime in conformity with standard NFP98-101, the provisioning of the worksite is ensured since the factory by delivery cement trucks of 22 tons capacity, delivery orders attest the arrival of lime on worksite. The lime contents are poured in two mobile semi cisterns equipped with feed pumps, they have filters to reduce the rejection of dust. The cisterns move easily on carriages towards the places of treatment, the storage period of lime is limited to two days to avoid its deterioration by the ambient air.

The materials used for the treatment of the PST are the soils classed R32 or A2 according to the GTR; they have geotechnical characteristics similar to the samples tested at the laboratory.

These materials will be conveyed since the hillock envisaged by the specific Earth Movement Plan for materials intended for the treatment. A mechanical action and a thermal action are carried out to transform these rock semi materials into non-cohesive soils.

To the level of the levelling courses of spoil we proceed to geotechnical receptions which recommend localised or generalized purging when we meet the unsuitable materials to the treatment.

We proceed thereafter to the geotechnical reception of the levelling course for the establishment of the axis and the limits of the ground entries.

The display of materials to be treated is done several days in advance to initially allow the natural decomposition of this type of ground at the semi-rock state, the first watering with closing of surface is carried out to increase the water content of materials. Machines of mechanical fragmentation: bulldozers, tractor with ploughshares and compactor to tamping foot intervene to reduce materials to a grinding of class 0/20 mm, the quantity of water necessary is gauged by the measurement of the water content of the ground in place. The water content is brought back by watering to fixed slope to a value ranging between Wopn+1 and Wopn+2.

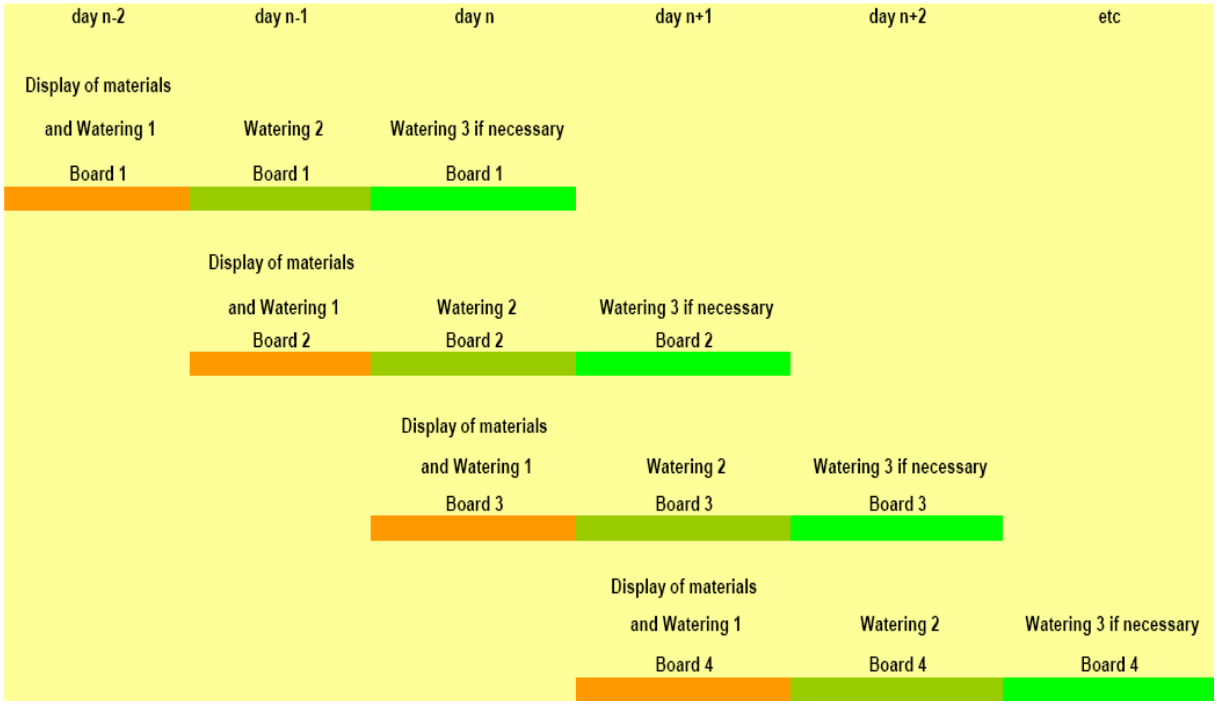
Lime is displayed on the surface of the layer to be treated regulated beforehand and delimited so as to control lime proportioning and the depth of treatment. The equipment of spreading is a spreader with gravimetric measuring, controlled at the rate of advance; it is equipped with a system making it possible to have a coefficient of longitudinal and transverse variation lower than 15%. The spreader has supple skirts channeling the binder to the surface of the ground to be treated.

Malaxation is ensured by mixers with horizontal tree cover of a bell and allowing a homogeneous mixture between lime and materials to be treated on a depth of 35 cm. Malaxation is carried out in two times by bands with covering of 20 cm to more reduce the grinding of materials to classes lower than 0/20 mm (0/10 even 0/5 mm).

The compaction of the treated soils is ensured by a V5 compactor carrying out the same number of passes as that of the boards of tests (10 passes). Then a tire compactor is designed to ensure compactness the bottom of layer and to deal with the problem of laminating. The treated PST is carried out according to the method of excess embankment. The levelling course is controlled topographically to make sure that its crossfall is 4%.

To lay out, before treatment, of a material with the water content is near the objective and especially homogeneous, it was adopted on the worksite a procedure making it possible to prepare the boards several days in advance, as indicated on Figure 2 below.

Figure 2 - Process of humidification of materials



It is obvious that the implementation of a process of this type led to an increase in means of watering, because each day are held in addition to a workshop of provisioning and a workshop of treatment, two workshops of humidification.

This procedure, to be effective, was accompanied by Means of control of the water contents in order to calibrate the best additions of water to implement.

The operations of humidification of materials are done at night or early morning to minimize immediate evaporation. And a closing after humidification - malaxation by a compaction with a compactor smooth without vibrating, limits evaporation during the day.

Figure 3 below illustrates the various stages of implementation of the PST treated with lime:

Figure 3 - Workshops of implementation

Atelier d'humidification

Atelier d'épandage

Atelier de malaxage

Atelier de compactage

4.2. Plan of control:

On site, the quality approach adopted ensures, during all the phases of realization of the treated PST, that the provisions taken guarantee compliance with the required specifications, while protecting the environment against dust emissions and without compromising the pace of work that should remain consistent with the timeframes fixed by the General Program of Work.

This approach is based on a series of checks, some are topographical and others are tests either in situ or in laboratories. The parameters to be controlled are:

- The base of the treated PST;
- Spreading of lime;
- Watering;
- Malaxation;
- Quality of lime;
- Depth of malaxation;
- Thickness of the treated PST and the coast of the levelling course.

The criteria to be satisfied in all points of the PST are as follows:

- Rate of compaction ≥ 95% D opn,
- Bearing capacity: Ev2 ≥ 40 Mpa,
- IPI ≥ 15%,
- The ratio: $\frac{\textit{ICBR (after four (04) days of immersion)}}{\textit{IPI}} \geq 1$.

At the end of the motorway construction, the synthesis of the actions of quality assurance is intended for the establishment of the project final report which contains in particular:

- Possible anomalies, their causes and their mode of treatment;
- The assessment of the quantities of treatment product according to the results of control of proportioning and cumulated statements' of the data of the delivery orders;
- The nature of materials of treatment;
- The collection of the weather events: pluviometry, temperature, wind… etc;
- The methodology applied for the piloting of dosage.

4.3. Encountered problems:

During work of treatment of materials to lime, the building site knew four (04) principal problems:

- The nature of the R32 materials, which are after extraction in the form of blocks consolidated of marl (semi-rock state), while the study of treatment is made on a sample of these materials but fragmented to reduce their size until a class 0/20 mm.

- To bring back these rock materials to a granulometry range of 0/20 mm, the process adopted consists with a transformation of the blocks of marl by a display of several days to the free air, under the action of humidification by watering to change their water content and under the action of the machines as bulldozers, compactors with feet tampers and mixers; the final grinding of materials is satisfactory. One arrives at the end of this process at a class 0/10 mm even 0/5 mm. Without this transformation of granulometry the treatment can not succeed on this type of materials;

- The very dry hydrous state of in situ materials before the treatment required the recourse to a source of water (dam) located near the project site. It was necessary to bring back the materials water content from 6% to 14% even 16%. To optimize the consumption of water, in particular during the summer season, humidification was made either late the evening or very early the morning, and the length of the boards to be treated hardly exceeds 80 ml per workshop of compaction, in order to limit evaporation during the compaction;

- The phenomenon of lamination which causes the decomposition of the surface treated on a surface film of 5 cm was treated by a planing with the grader, light watering and compaction with the tire or the tamping foot;

- The east wind which characterizes the area of Tangier rises several times per month and blocks the operation of treatment during several days because of the lime proportioning which can not be managed under these conditions, and the harmful effects that can affect the environment because of propagation of the lime dust.

CONCLUSION:

In the absence of quarries, near the Motorway serving the Tangier-Med Port, which can provide natural materials meeting the requirements of a granular PST, one has used the alternative of treatment to lime; this solution can be implemented in good conditions of trafficability, compaction and homogeneity of the platform. In addition, the technique of lime treatment has many advantages; the most important are listed below:

- The treatment of the PST in place to lime has a notable economic advantage. Indeed, the reuse of materials in place reduces the project overall cost since it diminishes the amount of spoil, the stockpiling of materials, the production of aggregate and their transportation. The absence of transport of aggregates or spoil to be put in deposit contributes to the preservation of the road network located in the vicinity of the project site and allows a reduction in the indirect impacts, as the nuisance of the residents and the users of the road network near the project site. Also, the soil stabilization in place is a very economic technique, in particular because of its shorter duration of work compared to a traditional solution.

- The reuse of materials in place, with the recourse to the treatment to lime, limits the exploitation of the aggregate quarries, natural resources non-

renewable, and reduces the opening of new deposits and quarries. What attenuates considerably the impact of the project on fauna and flora, thus it contributes to preserve the environment. Finally it would be advisable to note that this experiment allowed the popularization of the technique of treatment to lime, ever used before on Moroccan motorways, which can be adopted on other project where the noble materials are rare.

REFERENCES:

1. Guide of the Road Earthworks, realization of fill and subgrades, booklets I and II, GTR SETRA-LCPC 2nd edition July 2000;

2. Technical Guide of soil stabilization to lime and/or hydraulic binders LCPC - SETRA, January 2000;

3. French norm NF P 94-100;

4. French norm NF P 98-101;