LIGHTWEIGHT MATERIALS IN ROAD CONSTRUCTION – THE SITUATION IN ITALY

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ABSTRACT

The use of very light material can help to avoid, either fully or in part, the costs involved in stabilizing foundation terrain. In fact, making use of the considerable reduction of the weight of the filling materials, one can carry out several operations using the technique of "load compensation". This technique allows one to build the embankment without increasing the loads on the terrain (or increasing them only slightly), thus keeping the original balance of stress unchanged. The main advantages provided by a compensated load solution are the following:
- when the placing and compacting are finished, the lightweight embankment considerably cuts down absolute and differential settlements;
- the use of lightweight materials perceptibly increases the safety coefficient, calculated with reference to the last limit state of the slope;
- due to logistical and technical reasons, the solution applying a compensated load is often the only one which can be used: in most cases, in fact, surcharges are not required;
- in many cases, the use of alternative lightweight materials makes it unnecessary to much longer and more expensive techniques.

This memo analyses the more recent experiences in Italy involving the use of different kinds of filling material: light expanded clay aggregate, Expanded Polystyrene - EPS for building lightweight embankments. These technologies are analysed and compared, from a technical and financial point of view, with traditional road construction methods.

KEY WORDS

ROAD BED / LIGHTWEIGHT / ALTERNATIVE MATERIALS.

1. INTRODUCTION

The techniques to make the road bed lighter developed over the last years envisage the use of ad-hoc manufactured materials (EPS Expanded Polystyrene, expanded clay, steel pipes, lightweight reinforced concrete), industrial scrap (slag and blast furnace slag) and recycled materials (shredded tyres, wood fibre, fly ashes, concrete fragments). Table 1 shows a synthesis of the main characteristics and construction problems of the most commonly used materials among those mentioned above.
In Italy, the techniques meeting with greater success, owing to the greater availability and quality of the materials used, mainly resort to expanded clay and Sintered Expanded Polystyrene (EPS).

Table 1 – Main techniques to make the road bed lighter.

Material	Bulk density (kg/m^3)	Compression strength (kPa)	Young modulus (kPa)	Cost	Implementation problems
EPS	10÷40	100÷300 at 10% deformation	6.5×10^3	70 €/m^3	• Floating • Dissolving in the presence of oil by-products (bitumen, petrol, etc.) • Flammable • Differential Icing
Expanded Clay	< 450 lump ~ 600 compacted	1.2×10^3	4×10^4	25÷30 €/m^3	• Floating • Sensitive to icing • Water absorption • Differential Icing
Wood Fibre	720÷860	$10 \div 12 \times 10^6$	$10 \div 12 \times 10^6$	0.7÷1 €/m^3	• Spontaneous combustions • Decomposition
Fly Ashes	1200÷1700	1.2×10^3	$10 \div 11 \times 10^6$	6.5 €/kN	• Wind erosion
Shredded Tyres	320÷530 melted 720÷900 compacted	Shear strength ~ 42 kPa with σ_v = 80 kPa	350 ÷ 820	2.0 €/kN	• Possible release of pollutants

2. LIGHTWEIGHT TECHNIQUES IN ITALY

The most meaningful interventions implemented to make the road bed lighter in Italy over the last 15 years are illustrated below.

2.1. Embankment in expanded clay, A12 Motorway, Rome – Civitavecchia route

In 1989, along the A12 Rome – Civitavecchia route, near the Leonardo Da Vinci Airport, the traditional embankment of the South roadway was replaced by an experimental embankment in expanded clay totalling 75 m in length. The aim was assessing the operating conditions of the structural solution with a view to the full replacement of the traditional embankment totalling approximately 2,500 m in length. During the 20 year useful life of the traditional embankment, remarkable sinking had become apparent, leading to meaningful variation in the project geometry of all the road bed. During such period the interventions to restore the project gradients and the consistency of the road surface never went further than re-gravelling the existing paving. In 1986 a geo-diagnostic survey revealed that the laying ground was composed of slightly over-consolidated silt clay layers alternated with peat and organic silt layers interspersed with numerous gas pockets. Sinking estimates were produced which showed that during the next 10 years the ground was to sink for additional 14 cm since, due the overload implemented by the traditional embankment, the primary consolidation sinking was still under way. The analysis of progressive sinking and the residual consolidation percentage suggested the reduction of the load on the ground to reach a 30kPa stress on the laying ground, so as to stop the primary consolidation and part of the secondary sinking. Of all the various proposals, the most appropriate solution was judged to be the building of an expanded clay embankment.

To acquire the most suitable laying technique, the optimum processing thickening and humidity and the resistance parameters were calculated. The study showed that the maximum thickening value could be achieved through vibration according to the ASTM D-2049 method; the optimum bulk density, for different granulometric distributions, ranged between 7 and 8 kN/m^3 with optimum humidity ranging between 50 and 60% and the CBR index ranging between 30 and 40. Moreover, it was ascertained that an assortment with sizes smaller than 25 mm ensured a good thickening capacity for the material.
The building of the embankment was preceded by the reclamation of the laying ground (30÷40 cm) and the laying of a non-woven geotextile (*GTXnow*) blanket and anti-contamination function. On the geotextile, the first 60 cm of expanded clay were laid, then the *GTXnow* was turned to restore the slopes and another sheet of *GTXnow* and a layer of aggregate mixture (20 cm) were laid to ensure the load distribution, upon which thickening was carried out by means of light vibration rollers. Finally, a 120 cm layer of expanded clay was laid, also protected by a *GTNnow* geotextile, covered by a layer of appropriately compacted aggregate mixture.
To date, the results of the measuring instruments implemented to identify sinking and mechanic characteristics have fully met with expectations (Moretti, 1990).

2.2. Expanded clay embankment, A12 Motorway, Rome – Fiumicino route

Owing to the progressive decay of the service level of the A12 Motorway in the 1990s, the need emerged to enlarge the roadway along the 12 km route connecting Rome to the "Leonardo Da Vinci" Airport. The intervention envisaged a symmetric enlargement by enlarging the emergency stop lane, building a third lane and inserting the New Jersey barrier into the central traffic divider, thus bringing the road width from 22.60 m to 33 m. In the area affected, the geotechnic survey showed that clay soil alternated with peat layers, marked by limited shear strength. Since the existing embankment was to be enlarged, to ensure that the sinking of the new structure would be compatible with that of the old structure which, after many years, had settled, the use of expanded clay was opted for both in the new embankment and in the road foundation. The new embankment was built according to the partial load compensation technique, by reclaiming the natural support ground by means of 1.05 cm of expanded clay laid on a geotextile and covered by a 15 cm protective layer of aggregate mixture compacted by means of static and dynamic rollers. The surface embankment was built by means of 45 cm expanded clay layers alternated with 15 cm of aggregate mixture. To contain the shape of the new embankment, in the light of the problems deriving from the occupation of nearby areas, and to provide the expanded clay with the necessary boundaries during the compacting stage, the project envisaged the construction of a 60° inclined facing built with lath panels anchored to the existing embankment by means of reinforced earth technologies.
To test and streamline the executive and check procedures, a test field was developed. The results of experiments showed that, during the plate load test (CNR BU n. 9/67), to achieve Md deformation moduli compliant with those envisaged in the specifications, action was required as regards three factors: the compacting procedures, limiting the dynamic procedure to two 16 t rollers rides and the static compacting to 16 rides; the aggregate mixture composition, envisaging the use of puzzolanic material; and the geotextile, to be laid on the reclamation excavation. The plate load tests carried out according to such principles led to Md values (measured during the first load cycle at 0.5÷1.5 MPa interval) ranging between 30 and 40 MPa for the first layer and between 40 and 50 MPa for the second layer (Caraffa, 1999).

2.3. Expanded clay embankment, Messina – Palermo motorway

During the summer of 2001, while building a stretch of the Messina – Palermo motorway, a potentially unstable mass was identified covering an area approximately 150 m long and 20÷25 m deep (fig. 1). To stabilise and consolidate the landslide, a series of interventions were envisaged including the modification of the roadbed section and the insertion of expanded clay inside the embankment, so as to reduce the loads bearing on the unstable mass. To reshape the embankment section, three successive vertical facings in reinforced earth were built so as to reduce the total volume coming into play, although the planimetric and altimetric position of the roads involved was left unchanged. To fill the top facing, the used of expanded clay was envisaged alternated with approximately 15 cm layers of natural aggregate mixture matching with the anchoring reinforcements. A further weight reduction was to be achieved by building an expanded clay core, laid over 70 cm layers alternated with 20 cm layers of aggregate mixture.

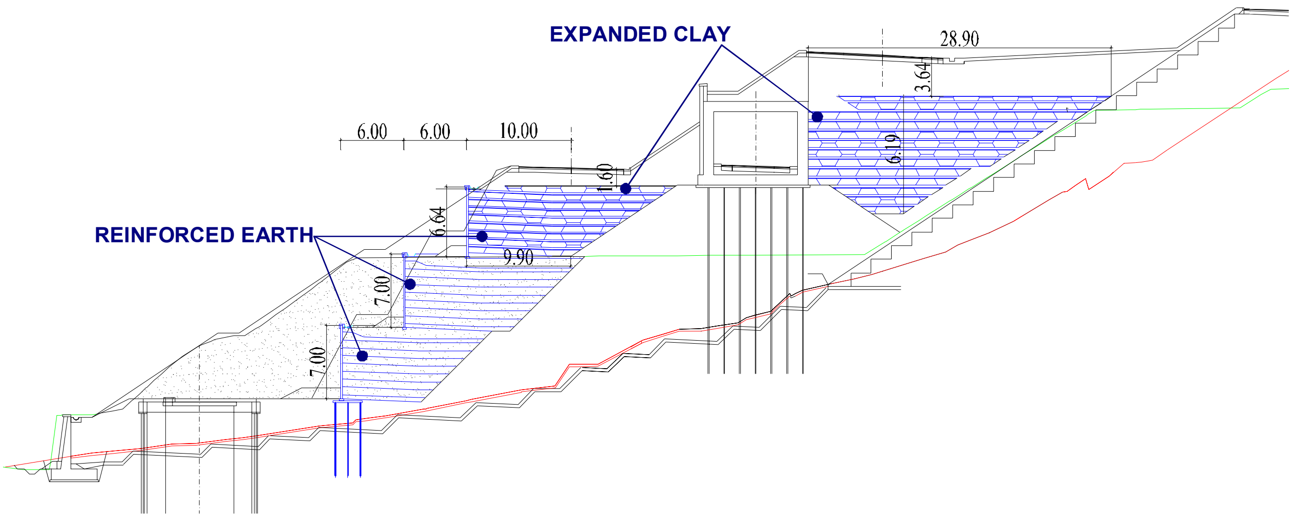


Figure 1 – Stabilisation of the Messina – Palermo motorway

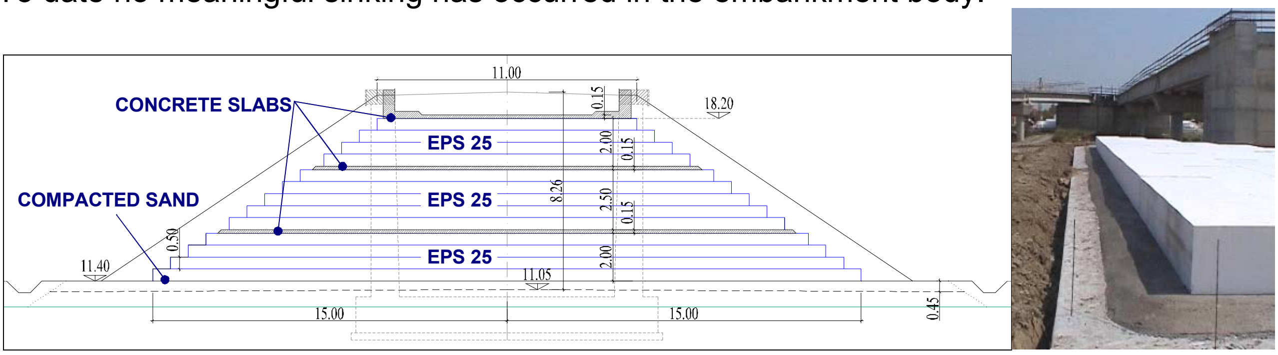
2.4. EPS embankment, Cagliari – Decimomannu railway line

Along the Cagliari – Decimomannu railway line, in Sardinia, a three-span box-type bridge was built, laying on a large reinforced concrete slab. At the beginning of the 1990s, sinking became apparent owing to the lack of bearing capacity of the foundation ground, which is of lake and river origin (bulk density 15 kN/m^3, c_u = 30 kPa). Sinking led to stretching damage to the wing walls and lowered the railway structure by 50 cm. Therefore, the material of the old embankment was replaced with EPS protected by high-resilience polyethene sheets and covered by a reinforced concrete slab. During the restoration, the railway traffic was ensured by building a provisional iron girder. The new embankment was built in a very limited time as compared to a traditional construction and the building costs were reduced by 1/5 (Buonanno, 2001).

2.5. EPS embankment, 16 “Adriatica” road junction

One last important example of the implementation of the techniques to make the roadbed lighter by means of EPS can be seen near the Adriatic coast. The territory is marked by subsidence, and geotechnic surveys revealed the presence of warps, randomly alternated with clay, lime-clay, silt-sandy and sandy seams and layers, alternated with organic sediments. Tests conducted with a static penetrometer on the plastic strata achieved resistance to collapse values lower than 300 kPa, pointing to normal consolidated soils with definitely poor mechanic characteristics. Dynamic penetrometric tests on sand layers led to N vales ranging from 6 to 43, showing only locally thickened soils. To implement a

crossing at different levels, an approximately 10 m high road bridge was planned. However, a sinking of the laying ground was estimated near the abutments in the tune of 40 cm. Under those circumstances, the foundation piles of the bridge abutments undergo a remarkable negative friction jeopardising its bearing capacity and stability. The traditional solution envisaged filling the road bridge abutments with traditional material, but is was discarded and the final choice, in the light of the size of sinking, envisaged the use of EPS. Blocks were used measuring 1.00 x 0.50 x 4.00 m with a bulk density amounting to 25 kg/m^3, compression strength amounting to 170 kN/m^3 at 10% deformation and a stretch modulus in the tune of 6 MPa approximately. This solution ascertained that in the case of maximum operating stress values, deformation is limited to the elastic field. A 35÷40 cm sand layer was laid on the laying ground and a non-woven geotextile was laid upon it, totalling 200 g/m^2 (*GTXnow*), acting as contamination prevention. Then three series of EPS layers were laid, carefully protected by a heat-sealing geotextile (*GTXnow*) weighing 500 g/m^2 and alternated with a 15 cm thick reinforced concrete slab to provide stiffness and load distribution (fig. 2). The top slab laterally turns into two 0.85 cm high kerbs the size of which was calculated to support the stress on safety barriers. The blocks were horizontally anchored by means of grippers.
To date no meaningful sinking has occurred in the embankment body.



Picture 2 – Cross section and building details of the road bridge abutments, Route 16

3. CONCLUSIONS

The use of lightweight filling materials proves a solution to many problematic situations which normally would be difficult to solve technically by means of the traditional building methods. The practical uses of expanded clay and EPS described above range from the construction of lightweight embankment to decrease primary and secondary sinking, to the enlargement of the roadbed, the restoration of sliding slopes, the implementation of backfilling for bridges and road bridges. Lightweight materials have proven their technical value in Italy too, both in the executive stage and during the useful life of the infrastructure, and often provide the only solution economically viable for specific planning problems.

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