GEOTECHNICAL ENGINEERING
LIGHTWEIGHT SOLUTIONS
WITH EXPANDED CLAY LATERLITE
CONTENTS

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Exclay is a porous inert substance with a limited specific weight. The great quantity of air-filled cavities inside the material determines the creation of two different types of cavities: inter-granules (between granules) and intra-granules (inside the granules). While the first are interconnected and easily saturated when the material is placed under stratum, the intra-granule cavities don’t fill up with water so easily and some of them will never fill up.

Let’s analyze the main features:

1) SPECIFIC WEIGHTS*

We define:

- $\gamma_{\text{ass}}$ = absolute specific weight
  
  The weight a cubic meter of Exclay would have without the cavities between granules (inter-granular) and the cavities contained in each granule (intra-granular);

- $\gamma_{\text{app}}$ = apparent specific weight (or average specific weight of granules);
  
  The weight a cubic meter of Exclay would have without the cavities between granules (inter-granular);

- $\gamma_{\text{m}}$ = specific weight of material in piles
  
  The weight of a cubic meter of Exclay not vibrated and not compressed in any way.

* Note: the Specific Weight ($\gamma$) expressed in Kg/m$^3$ is given by the product of the Mass ($\rho$) expressed in Kg/m$^3$ and the gravity acceleration ($g$). Since in practice both are used indifferentely $\rho_{\text{peso}}$ and $\rho_{\text{massa}}$ the two sizes shall be considered numerically the same in this document.

### COMPARATIVE TABLE OF SPECIFIC WEIGHTS: EXPANDED CLAY LATERLITE AND SAND

<table>
<thead>
<tr>
<th>Material</th>
<th>Expanded Clay Laterlite (0-30) (kg/m$^3$)</th>
<th>Sand (kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute specific weight</td>
<td>≤ 2,500</td>
<td>~ 2,600</td>
</tr>
<tr>
<td>Apparent specific weight</td>
<td>≤ 850</td>
<td>~ 2,600</td>
</tr>
<tr>
<td>Specific weight of material in piles</td>
<td>≤ 450</td>
<td>~ 1,600</td>
</tr>
</tbody>
</table>
GEOTECHNICAL FEATURES

3) SOAKING

The soaking test (according to UNI EN 13055-2 par. 4.8) consists in soaking a dried and weighed Exclay sample in water for a specific period of time (30’, 24h, 90 days). After it has dripped it is weighed again. The difference between the two weights is the quantity of water absorbed.

When Exclay is immersed in water, the inter-granule cavities fill up rapidly, whereas the intra-granule cavities which are often clogged and not inter-connected, fill up slowly. The table shows the trend in time of the soaking coefficient (ratio of the weight of water absorbed and the weight of dry Exclay).

Note: during the project we suggest using a soaking coefficient of 75% of the specific weight of the material in piles.

4) THREE-AXIS TESTS

The three-axis test is performed by vertically loading a cylindrical sample of expanded clay subjected to a radial confinement pressure. A series of drained three-axis tests with confinement pressures of 20, 200 and 600 KPa allowed us to establish that the angle of friction inside Exclay for the main geotechnical applications was approx. 40°.

A testing campaign performed in the soil mechanics laboratory of ISMES (Seriate - BG) in July 1998 showed the following soaking, resistance and deformability parameters of a Exclay 0-30 mixture.

2) MELTING GRANULATION

The types of Exclay commercially available for lightweight road embankments are:
0-2; 2-3; 3-8; 8-20 (request the technical sheet and melting granulation).

The specifically made mixture for geotechnical applications (road embankments, consolidations and drains) is the 0-30.

A testing campaign performed in the soil mechanics laboratory of ISMES (Seriate - BG) in July 1998 showed the following soaking, resistance and deformability parameters of a Exclay 0-30 mixture.

<table>
<thead>
<tr>
<th>UNI mesh</th>
<th>Passing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.5 mm</td>
<td>100</td>
</tr>
<tr>
<td>16 mm</td>
<td>70 - 100</td>
</tr>
<tr>
<td>8 mm</td>
<td>35 - 85</td>
</tr>
<tr>
<td>4 mm</td>
<td>10 - 60</td>
</tr>
<tr>
<td>2 mm</td>
<td>0 - 40</td>
</tr>
<tr>
<td>1 mm</td>
<td>0 - 20</td>
</tr>
<tr>
<td>0.25 mm</td>
<td>0 - 5</td>
</tr>
<tr>
<td>0.0 mm</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Melting granulation 0-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNI mesh</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>31.5 mm</td>
</tr>
<tr>
<td>16 mm</td>
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<td>8 mm</td>
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<tr>
<td>1 mm</td>
</tr>
<tr>
<td>0.25 mm</td>
</tr>
<tr>
<td>0.0 mm</td>
</tr>
</tbody>
</table>

Soaking tests

<table>
<thead>
<tr>
<th>Soaking coefficient</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>at 30 minutes</td>
<td>11</td>
</tr>
<tr>
<td>at 24 hours</td>
<td>17</td>
</tr>
<tr>
<td>at 90 days</td>
<td>44</td>
</tr>
</tbody>
</table>

Exclay type 0-30.

Cell used for three-axis tests.

As indicated in the diagram the value of the angle of friction is above 33° at the various relative densities and for the entire field of confinement pressures tested. If the values considered are lower than 200 KPa (a sinking value over 10 meters) the angle of friction can be at least equal to 40°.

Trend of the angle of friction according to the confinement pressure. If the confinement pressure value considered is of 200 KPa (situation common in most geotechnical applications), the angle of friction can be considered at approx. 40°.
5) TESTS ON PLATES

To determine the superficial rigidity of the layer of expanded clay and quarry mix (as shown below in the example for road embankments) it is possible to use the deformation module Md according to the relative density. The asymptote value which we suggest using for applications that call for it, is ? 200 Kg/cm². This value, tested many times on site, can be obtained using traditional systems and means for the packing of soils, vibrating plates and heavy rollers.

The granules are crushed due to very high concentrated loads of about 0.3 MPa (as certified in the edometric tests) which are never reached either during packing phases or on site.

As the diagram suggests, the plate values (Md) higher than 200 Kg/cm² correspond to a relative density (Da) higher than 70% (optimal packing is reached with ΔR 80% and MD 250).

6) ACCEPTANCE REQUIREMENTS

We can say that the acceptance requirements for the Exclay product 0-30 for geotechnical uses are:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of a pile of dry aggregate</td>
<td>≤ 450 kg/m³</td>
</tr>
<tr>
<td>Granulometric analysis</td>
<td>see table page 4</td>
</tr>
<tr>
<td>Soaking coefficient</td>
<td>&lt; 75%</td>
</tr>
<tr>
<td>Angle of friction (approximate value)</td>
<td>~40°</td>
</tr>
<tr>
<td>Deformation module Md</td>
<td>≥ 200 Kg/cm²</td>
</tr>
<tr>
<td>Crushing strength of a pile of granules</td>
<td>&gt; 13 kg/cm²</td>
</tr>
<tr>
<td>UNI EN 13055-2 par. 4.10</td>
<td></td>
</tr>
</tbody>
</table>

As concerns the specific weights of the Exclay 0-30 mixtures, for calculation purposes, we suggest using, for the various operating conditions, the following values for mixtures with a specific weight in a pile of dry aggregate of 450 kg/m³:

<table>
<thead>
<tr>
<th>Type</th>
<th>γ (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-8</td>
<td>380</td>
</tr>
<tr>
<td>8-20</td>
<td>330</td>
</tr>
<tr>
<td>3-20</td>
<td>400</td>
</tr>
</tbody>
</table>

As the values in the table suggest, a filling made with Exclay even in the worst case of strong packing and saturation during immersion, is still very light. Just above 1,000 Kg/m³ against the 2,000 Kg/m³ of the solution with traditional materials. There is a saving of a ton per cubic meter!
The planning of new road embankments or the expansion of existing road embankments, located on soils with poor mechanical properties, is generally very difficult. They are often damaged and the costs to prevent damage to the roads are very high. Thanks to Exclay the costs for stabilizing the base soil can be avoided totally or in part. In fact by exploiting the incredible reduction of the weight of the road embankment it is possible to carry out several interventions using the load compensation technique. This technique enables to build the road embankment without increasing (or just slightly increasing) the loads on the soil, thus keeping the original stretch balance unchanged.

Various systems are available to contain the road embankment as shown in the figure below.

For over 30 years now Exclay has been used the world over to create road embankments on freezable or soft soils.

**ADVANTAGES**

The main advantages of a compensated load solution are:

- At the end of the process and the packing, the light Exclay road embankment significantly reduces the absolute and differential sinking.
- The use of Exclay considerably increases the safety coefficient calculated with reference to the final limit of the road embankment.
- The compensated load solution for logistic-technological reasons, is often the only possible one. In fact often pre-loads are not necessary in most cases.
- Thanks to Exclay longer and expensive construction techniques are often useless.

**Types of containment of a road embankment:** the figure shows the most used systems for the containment of a road embankment with the relating “overall dimensions of the angles” (just an indication).

Excellent results from a technical and construction standpoint have been reached especially with the Reinforced Soil system and the soils reinforced with geo-clays and geo-synthetics.

The latter, as a solution without containment, must be covered with a superficial layer of quarry mix (at least 40 cm) to protect against erosions and then covered with soil for planting grass and plants.
The figure shows certain types of commonly used lightweight aggregates. First of all there are two categories: the lightweight road embankments without compensation (A and B), and lightweight road embankments with compensation (C and D). The first case exploits the beneficial effect given by the lower specific weight of the material which means a lower load on the soft underlying soil. In the second case, part of the soil with poor carrying capacity is replaced in order to improve its mechanical features and balance in part or completely the over-load due to the new road embankment. To pack Exclay it is necessary to place layers of mixed quarry granules inside the road embankment, and then start packing the material using a roller, and geo-synthetic layers as separating elements to avoid the blending between the mixed granules and Exclay. The layer of mixed granules under the road stratum must never be lower than 300 mm, for the evident problems associated with the cyclical/dynamic loads acting on the surface (traveling means).

Controls against sinking

If we take into consideration a non-compensated road embankment created on a layer saturated with sinking clay, not very resistant, with limited thickness and set on a resistant sub-stratum, two possible break mechanisms could occur:

- final condition for the extrusion of the foundation soil (E);
- final condition for global break of the road embankment-foundation system (F).

A simplified analysis carried out comparing the lighter Exclay solution with a road embankment made with a traditional quarry inert material highlighted that:

- the most probable break, in both cases, is associated to non-drainage conditions and to a break for extrusion of the foundation soil;
- in all the cases considered, the use of Exclay enables to increase the safety coefficient by approx. 20%.
The problems linked to making roads lighter becomes even more important in the applications on slopes with risk of landslide. The reopening or construction of roads on soils subject to active or potential sliding often call for road embankments made using Exclay besides reinforcement structures (as for example walls on pies). The lightness of the material combined with its static functionality (control of internal stability) means the slope can be relieved from the excess loads and hence prevent the sparking off or re-activation of gravitational movements. The analysis of the problems of the interaction between slope and road embankment is very complex because it revolves around the study of stability and durability of the work. Of course, since the work consists basically in making it lighter, the opportunity of using light materials according to the location of the construction on the geometric profile of the slope must be correctly assessed. Basically, this type of intervention is not recommended by the foot of the slope.

EXECUTION MODALITY

The construction modalities of a light road embankment on a slope are the same mentioned on page 11 for road embankments on soils with poor carrying capacity. Hence, layers of Exclay and stabilized mix will be laid on site and the rolled flat. The anti-contaminating geo-textile put in-between can be combined with reinforcement geo-grids (according to the project sections) if a reinforced soil solution is foreseen. In the other cases the non-woven geo-textile, that no longer has a structural purpose, shall be used to prevent the fine parts from sliding into the underlying Exclay. Particularly interesting, especially for the crest expansion, is the intervention in reinforced soils with geo-grids that besides assuring the stability of the work, allow for the total cultivation of the soil, hence perfect integration in the surrounding environment.
COMPENSATED FOUNDATIONS

In case of soils with poor carrying capacity which would generate unacceptable differential sinking, it is possible to create compensated foundations with Exclay with traditional foundations. The principle of compensation consists in replacing a mass of natural soil with an equivalent mass of Exclay so that the load of the new construction plus the load of the filling with Exclay do not exceed the load removed by excavation. If the project parameters allow for it this solution can be used along with and sometimes even replace a foundation on piles.

MODALITÀ DI ESECUZIONE

The execution modalities are the same as for lightened road embankments. After determining the depth of compensation, a non-woven geotextile is laid on the bottom of the excavation (highly suggested if there is a water bed). Afterwards a layer of Exclay and quarry mix is laid and then pressed (see page 11). A non-woven geotextile must be placed in-between to avoid blending through percolation of the fine mix into the underlying Exclay. The maximum thickness of the Exclay layers is 60 cm to assure an even packing during the rolling phase. Higher thickness (up to maximum of 2 meters) can be reached if every 40 cm a vibrating plate is passed to press down the material. The intermediate mixed layers should be of about 15 cm whereas the final layer will be thicker (as foreseen by project – minimum 30 cm packed).
PREPARATION OF LAYING SURFACE

After completing the excavation, it is necessary to lay a non-woven geotextile on the bottom of the excavation as an anti-contamination separator between the natural soil and the filling material. The laying surface must be regular, with the non-woven geotextile well-pulled and adherent to the surface and with integral sheets and regularly overlapping. Then filling materials can be set in.

HOW TO LAY

In general Exclay is laid in various layers, with in-between a layer of mixed granular, whose thickness after packing should not be less than 200 mm. The thickness of the Exclay layers varies in relation to the type of section (approx. 60 - 80 cm). If in particular cases it is impossible to create layers of Exclay lower than 80 cm, it is possible to increase the thickness by doing as follows. Maximum every 50 cm, it is necessary to pack the material using the vibrating plate up to a maximum thickness of 2 meters. This intermediate process shall be completed using a static and dynamic roller.

The first layer of Exclay will be set by pushing the excess material forward with a tracked vehicle. The vehicles will unload the Exclay on site or in nearby areas specifically prepared. Especially in the wider lanes the non-woven geotextile can be laid only along the sides. The central part of the lane, which is protected by the bituminous layer, is not affected by mixing through percolation of the mix from the upper layers into the underlying Exclay.

The intermediate layer of granular mix will be set with the same modalities described above for Exclay unloading them from the vehicles on site or in nearby areas and then pushed with the proper means to form the layer of the required thickness. Exclay will then be packed by crushing the layers of granular mix using smooth drum rollers both vibrating and non-vibrating, with weight and frequency to be defined according to the height of the layer.

Bear in mind that the correct packing of Exclay corresponds to a volumetric drop of about 17% (against 25% of traditional quarry mix).
A ton less per cubic meter

RATION OF LAYING SURFACE

1. Excavation of existing soil.
2. Laying of non-woven geotextile against soil.
3. Unloading of expanded clay.
4. Laying of first layer of Exclay.
5. Laying of non-woven getotextile over Exclay.
6. Alignment of quarry mix with grader.
7. Packing of first layer and laying of second.
8. View of layers from filed line.
9. View of finished work.

Roma-Civitavecchia highway
A light road embankment was created on this highway (from Km 0.300 to Km 2.500) using approx. 100,000 m$^3$ of Exclay. The intervention was done on both the North and South lane by the Company Pavimental, and after about 15 years of use it has not shown any sign of significant sinking.
**REFERENCES**

**1970-1990**
- Hameenkyla (Finland) – Renovation work;
- Tapiola (Finland) – Superstrada Haage Hetsala;
- Finland – Helsinki – Lahti highway;
- Switzerland – State road n. 1 north of the city of San Gallo;
- Finland – Massby Boxby beltway;
- "La Défense" (Paris) – Expressway g 14 on R.E.R.;
- Hinterberg (Switzerland) – Hhighway 4; 
- Schönbühl - Railway embankment by station;
- Tattarisjarju - Järvenpää beltway - Finland. Year of execution 1972 - 50,000 m$^3$;
- Nice - Exclay embankment;
- Cavazere - Exclay and Reinforced Soil embankment;
- Mandelieu - Reinforced Soil embankment;
- Cannes - Reinforced Soil embankment “flower holder” type;
- Roma - Napoli highway - 2 Reinforced Soil embankments (Caianello, Capua), 3rd lane north and south;
- Mandelieu - raised ramp on embankment (S.S. Mandelieu);
- Rome - Roma - Civitavecchia highway embankment;
- Rome - Mobil Oil Gas station;
- Rome - Agip Gas station.

**1991-2006**
- Rome - Leonardo da Vinci airport - Fiumicino - expansion of Charly taxiing and west satellite circulation lanes; renovation of Delta taxiing; long-stay parking road system;
- Rome - Airport of Rome - Urbanization east area 1st section of Cargo - City exit;
- Rome - Expansion to 3 lanes of highway ANAS Rome - Fiumicino 1st lot, 2nd lot and 3rd lot;
- Varese - Provincial road Varano Borghi - Varese - embankment in mixed technique “Exclay and metal tubes”;
- Bologna - Expansion to 3 lanes of highway Bologna - Firenze;
- Genoa - Underground filling on slope with “reinforced Exclay” in via Ausonia;
- Ferrara - Lightened foundations in Porto Maggiore, company Coop. Costruttori;
- Messina - Palermo - embankment on slope and access junctions;
- Cremona - alignment embankment with bridge on sinking soil;
- Atena Lucana - Highway junction Salerno - Reggio Calabria - south lane - m$^3$ 13,000;
- Latina - A.N.A.S. Monti Lepini road - alignment ramps with dry bridge;
- SS 7 Appia - Light embankment;
- Salerno - SS A.N.A.S. Caselle in Pittari - re-establishment of landslide and light embankment;
- Rome - Interporto Fiumicino - road system on embankment.

- Roma Fiumicino - Expansion to 3 lanes: embankment contained with geoclay - Year of execution 1999 - 120.000 m$^3$;
Cavarzere - road junction
Year of execution 1991 - 4,500 m³

Mandelieu - Reinforced Soil embankment
Year of execution 1991- 12,000 m³

3 lane highway Nice - Aix en Provence
Year of execution 1991 - 7,000 m³

Airport Fiumicino - Rome
Long-stay parking road system
Year of execution 1996 - 25,000 m³

Mandelieu - Reinforced Soil embankment
Year of execution 1990- 12,000 m³

Cremona - Alignment embankment with bridge on sinking soil
Year of execution 2002 - 3,000 m³

Autostrada Messina - Palermo highway
Embankment on slope (Company INC)
Year of execution 2003 - 7,000 m³

SS 7 Appia
Light embankment (Company Della Nova)
Year of execution 2005 - 9,000 m³

Salerno - SS A.n.a.s. Caselle in Pittari
Re-establishment of landslide and light embankment
(Comp. Vangone) - Year of execution 2005 - 4,800 m³

A ton less per cubic meter
When a gravity supporting wall is created to stabilize an excavation, a natural or artificial slope, it is necessary to remove a part of soil upstream. In certain cases it may be convenient to replace this soil with Exclay, and not with a traditional quarry inert mix, to assure lightness, limited bulk and reduce deformations.

Bear in mind that it is necessary to use a granular material for the upstream re-filling of a supporting wall. Soils with poor drainage properties could cause water retention problems and hence a pressure build-up.

Particularly interesting is the use of Exclay for re-filling behind supporting walls that are run-down, damaged or not designed correctly. In all these cases intervening with a light draining material that is easy to lay may avoid having to replace the wall yet keeping the safety coefficients high. Also in the case of supporting walls that must be suitable for the contingent geomorphological situation through an increase in height, it may be useful to pump in expanded clay without excessive waste of labor.

**ADVANTAGES**

Using Exclay means:
- reducing the load of the refilling;
- reducing the push that the upstream soil exercises on the wall;
- reducing the size of the wall used as stabilizing structure;
- assuring constant drainage (approx. 30% of cavities).

The easy-to-supply pumping method helps limit the costs of labor.
Panel walls are prefabricated structures or structures cast on site that are used to support artificial excavations, either temporary and/or permanent, preventing the soil to flow into the excavation.

In certain particular cases, as in the creation of port structures and infrastructures and artificial islands, the soil that gives the unbalancing push against the supporting structure is deposited artificially. In these cases the use of Exclay enables the use of shelf panel walls with a limited driving depth (D) despite the height of the wall itself (H), hence a higher H/D ratio (see figure).

**ADVANTAGES**

The design of a panel wall is based on the calculation of the pushes that tends to make it rotate around a hypothetical point of instant rotation. By reducing the unbalancing push (active push) it is possible, all other values being equal, to reduce the driving depth (hence the portion of soil that creates the counter-push – passive push) thus allowing the designer to use shorter panel walls.

As regards tensioning walls, using Exclay in certain cases may avoid resorting to this type of solution thus avoiding the complex and expensive work for the creation of anchoring bolts.
In the construction of access ramps to dry bridges, road junctions or embankments aligned with structures, one of the inconveniences that more frequently occur is the formation of differences in height between the quotes of the “rigid structures” (generally made of cement) and those of the fillings normally done with dry material coming from quarries. One of the phenomena, often cause of these inconveniences, is the progressive settling due to the cyclical loads of the inconsistent materials forming the embankment, compounded by the percolation of waters and the consequent variation of the humidity of the mass. The inert quarry mix which is generally used has a variable packing ratio (24-28%) according to the granulation, shape, laying humidity and loads it is subjected to during the packing process.

**ADVANTAGES**

Exclay has variable packing ratios according to the melting granulation and the specific weight foreseen in the project, without ever reaching the values of a traditional quarry mix (approx. -20%). The packing process, even if it is carried out with standard construction site vehicles, gives the Exclay mixture a very high rigidity thus reducing, thanks to the low specific weight, the inconveniences due to settling of the original soil of the foundation.

To prevent packing defects, especially near the shoulder, it is necessary to carry out the packing operations with easy-to-handle machines as for example vibrating plates type 40x70 cm (weight ≥ 70 Kg) and on Exclay layers lower than 50 cm. If there is a risk of poor packing even with light equipment we suggest mixing the expanded clay with cement to obtain a mixture with high rigidity levels, thus limiting the risk of sinking.

Using packed Exclay to build alignment ramps gives the system high rigidity thus reducing the inconveniences due to differential settling.

Construction of a light ramp in Cavarzere (VE).

Construction of an alignment ramp with a bridge over a railway (Roma – Fiumicino highway).
FALLING ROCKS

The risks resulting from rocks falling from potentially unstable walls can be limited with active (actions aimed to prevent detachment) or passive interventions (structures that slow down or deviate the motion of the rock). As concerns the designing of passive protection work, the use of large inert material to slow down or stop the motion of falling rocks is very widespread. These materials in fact are used as dampers, absorbing part of the kinetic energy of the rock during its motion.

ADVANTAGES

Thanks to the low specific weight of the granules, Exclay is highly deformable. Hence the rock tends to sink in it without being able to re-emerge. This is evident if we consider that the quantity of kinetic energy lost during the crash is inversely proportional to the carrying capacity of the substratum and that the carrying capacity of a material directly depends on its specific weight.

Hence, conditions being equal, Exclay is able to dissipate more energy than a heavy material, for example gravel. This feature allows to create reinforced cement structures, filled with loose Exclay, which protect roads, rock protection barriers or tunnels. (Figure A).

In the calculation of cement structures both the dynamic actions with lower impact (for what specified above) and minor permanent loads (thanks to the low specific weight of Exclay) can be assessed.

Another very popular application is the creation of sunken and/or raised valleys filled with Exclay (Figure B). These structures work as dampers and collection basins thus preventing that the motion of the rock continues downstream.

Figure A - Reinforced concrete structure filled with Exclay to protect road: the typical lightness and poor carrying capacity of Exclay make it the right material for the creation of lighter concrete structures with a lower reinforcement level.

Figure B - Sunken valley filled with Exclay: these structures are used as dampers to prevent the rock falling from the wall to bounce and continue down towards the road.

The quantity of kinetic energy lost during the crash is inversely proportional to the carrying capacity of the substratum; the carrying capacity of a material directly depends on its specific weight. Hence, conditions being equal, Exclay is able to dissipate more energy than a heavy material, for example, gravel.
DRAINAGE TRENCHES

Drainage trenches are generally used along the line of maximum inclination to stabilize slime-clay slopes with limited inclinations and suspended strataums. They help decrease the pressure of water inside the slope and consequently increase the safety coefficient. The trench is normally filled using a granular inert material which by nature has a very high permeability level (drainage).

ADVANTAGES

The use of Exclay as filling material confers a further mechanical stabilizing effect to the trenches. If upstream (see figure) they are filled with Exclay - zone A – and downstream with a traditional quarry inert material – zone B – the safety coefficient increases because the load decreases right where it becomes a starting factor for the collapse. Unlike other artificial materials used for the same purpose, Exclay, being a natural material, enables and favors the rapid reforestation of the trenches in order to stabilize the system even more thanks to the presence of the radical vegetation apparatus, that can even be made up of forest trees.

TUBE LAYING

Designing the laying of undersoil tubes can be complicated due to the extreme variability of the operating conditions to face. Besides the different soil typologies, the urbanistic conditions and the limitations resulting from the development of the existing sub-structures, often force to make very expensive choices. The starting point for a correct project lies in the solution of these problems besides in the easy demolition of the materials used to fill the trenches and a suitable resistance of the work loads requested by the system.

ADVANTAGES

Exclay is a lightweight, insulating material and is ideal for drainage purposes. It is easy to remove if used loose and easy to demolish if stabilized with cement hence it is the ideal solution for the safe laying of tubes in trenches. Its rigidity, combined with an effective drainage, makes it the ideal material to use in sub-structures even with high traffic loads such as highways and airports.
BACKFILLING ON STRUCTURES AND RE-PROFILING OF SLOPES

BACKFILLING
Re-profiling slopes or admitting traffic on existing structures, such as old or new tunnels, frequently generates the problem of the over-load that the works must bear. When the thickness of the material to use to reach the project quotes is important, we are forced to over-size the concrete structure that has to support the load of the great mass of filling material thus increasing the costs of the structure.

ADVANTAGES
The use of expanded clay helps reduce the volume load of the filling material (up to a fourth of that of a quarry or other filling material), assures continuous and controllable drainage of the waters that affect the areas to treat thus assuring the possibility to realize any type of system in complete safety. If we use pneumatic distribution, which is possible by using tank vehicles, thanks to Exclay it is possible to easily reach areas that would otherwise be difficult to reach with normal construction vehicles.

RE-PROFILING OF NATURAL SLOPES
The oldest slope stabilization interventions include the redefinition of the profile itself through the removal of part of the soil upstream and its re-positioning downstream. The reduction of the average inclination allows for the stabilization of the deep movements whereas the terracing avoids superficial breaks mainly due to erosio.

ADVANTAGES
The replacement of part of the soil with Exclay helps reduce the load and redesign the profile of the slope in general without having to limit the slope too much.
A technique used to avoid sinking of natural or artificial undersoil cavities is to fill them up with mixtures of granular aggregates and cement grout. This avoids the creation of dangerous concentrations of stress that may cause, due to the lack of ductility of the materials generally affected by these phenomena (tuffs, limestones, soft rocks generally pyroclastic or sedimentary rocks), unexpected undersoil sinking, slides and disastrous effects on the structures on the surface. Undersoil cavities are very common in the subsurface of many historical cities in the center and south of Italy. The consequences of undersoil sinking due to variations of the pressure status are often object of news reports. Unfortunately the real evaluation of the risk is very complex because a precise description of the stratigraphy is often economically too expensive, as the monitoring of the mechanical behavior of the interested materials. Hence, it is better, if possible, to face the problem by directly working on the undersoil cavities by reclaiming them artificially.

**TUNNEL BLOCKS**

During the construction phase of a tunnel (or during the use), we often have to solve problems linked to the presence of undesired cavities along the route. These empty volumes are generated either by unexpected sinking that took place during the excavation or by the erosive action of water that by penetrating in small interspaces between the ribs and rock walls generates real “undersoil cavities” (also called “fornelli”, cavities formed when digging a tunnel).

If the undersoil cavities are arranged on more than one level and the deeper ones cannot be reached, filling the superficial ones with Exclay reduces the risk of undersoil sinking.
ADVANTAGES

Filling undersoil cavities with granular aggregates mostly aims to reestablish the situation as it once was in the subsurface. The empty space that’s been created in fact generates dangerous stress of pure traction along the vertical axis and of pure compression along the horizontal one.

Using Exclay (mixed with cement), thanks to its high resistance to compression, helps avoid the concentration of the stress that in the meantime disappears (traction stress) or moves to wider areas (compression stress).

The advantage of using Exclay is even more evident if there is a system of overlapping cavities, some of which might even be difficult to reach. The features of lightness and resistance make Exclay the safest solution in these cases.

In the light of restoring the original environmental conditions, the fact that Exclay is a natural product with effective drainage is a very important feature. Besides the benefits of static and hydraulic nature, Exclay assures an incredible technological advantage: both Exclay and the cement can be pumped in the cavities separately or mixed (see photo on side and “Exclay PPC” technology on page 27).

In 2002 a research was carried out with the University La Sapienza of Rome aimed to optimize a Exclay conglomerate with physical and mechanical features as close as possible to those of the soils generally affected by karst phenomena (results below.)

Results of the Laterlite research- University La Sapienza of Rome

The research studied the granulation content, the dose of cement and the a/c ratio according to the workability and pumping properties of light porous concrete used to fill caves and cavities. The diagrams below show the results referred to test samples with a/c ratio equal to 0.5 and subject to a test after 28 days. Concrete content being equal, the samples with a wide granulation spectrum with presence of fine material have higher resistance and rigidity values. For these, after exceeding a concrete quantity of 1.5 kN/m³ there is an incredible increase in resistance to compression and rigidity.

Controlling the granulation and the dose of concrete, the final features may be adapted to those of the materials of cavities.

Consolidation of rocks and filling of cracks. Eremo di Chiusi della Verna (AR).
Exclay is a natural product (certified ANAB-ICEA) and remains unchanged in time. Exclay is a lightweight product, with mechanical and fire resistance properties, higher drainage properties and that is easy to lay even when pumped. Exclay is ideal for any kind of filling in the construction, environmental and agricultural field. Below are some examples of the most common uses of Exclay.

**ISOLATING FILLINGS**

To lay a surface on soil it is necessary to create an isolating layer that limits the loss of heat. In civil, industrial and zoo-technical construction Exclay helps create thermal isolation layers on the soil with the right thickness.

**ALIGNMENT AND SLOPES ON DRY BRIDGES**

The construction on bridges and dry bridges and re-alignments cannot always be done with inert stones due to load problems. Exclay mixed with cement or bitumen can be used to make conglomerates between 1,000 and 1,300 Kg/m³ with high physical-mechanical features.

**LIGHTWEIGHT CONSTRUCTIONS ON PREFABRICATED STRUCTURES**

In the construction of undersoil structures to be used as parking or for services, especially in urban centers, the top part is often covered with plants and vegetation. Exclay is the ideal vegetation sub-stratum which combines static needs (lightness on the building) with the easy-to-lay pumping methods.
Exclay is used in endless ways for environmental and soil protection applications. From simple fillings to light and resistant armored and reinforced structures with loose material or blended with cement to increase rigidity, yet maintaining an effective drainage.

Even packed Exclay maintains an effective permeability (percentage of air-filled cavities approx. 30%) which makes it the ideal material for the creation of light and resistant drainage layers. It is also possible to foresee systems with water reservoir in sport facilities or roof-gardens.

To make fuel tanks safe (even disused tanks) using Exclay to fill them up as laid down by public hygiene regulations law no. 626 assures incombustibility and thermal isolation. Exclay is also lightweight and remains unchanged in time. It can also be pumped in and this is a very practical and convenient solution.
HIGH ADHERENCE SURFACES
The adherence of a normal bituminous surface depends on the C.L.A. factor (accelerated polishing coefficient) of the used inert material. This feature does not always remain constant in time to the detriment of safety. Practically, after the superficial removal from the bitumen, the inert material becomes polished through contact with the tires. After a few months of use of the road this phenomenon tends to reduce its adherence.

10% of weight of Exclay added to the mixture of a road surface assures the C.A.T. values (transversal friction coefficient) in time of about 60 and a reduction of the braking space from 10 to 25% in relation to the speed of the vehicle.

The company AUTOSTRADE after carrying out specific studies and control has been using Exclay for the past 10 years. Mixtures with Exclay can be made both in continuous and discontinuous plants without modifying the productive cycle. The use of low percentages in a normal mixture assures high adherence features with the surface.

Exclay spread evenly in the mixture assures C.A.T values higher than the minimum required and for the entire technical life of the road surface. The laying techniques for mixtures with Exclay are the same normally used for other mixtures. We suggest an optimal packing at a temperature between 140 and 120°C.

SOUND-PROOF SURFACES
Exclay’s special structure reduces noise thus considerably reducing the reflection of the acoustic wave. These features combined with a well-studied granulation curve, confers good noise absorption values to the mixture. Acoustic controls with different control methods have been carried out in Italy and abroad. The documentation is available upon request.
OTHER ROAD APPLICATIONS

PASSIVE PROTECTION SYSTEMS
As regards road systems, one of the main problems is the protection of dangerous points: sharp junctions, piles, banisters, guardrails and constructions (toll booths, booths in general, etc.). The ExclayShock shock absorber is made up of three cubic elements and a fourth with a semi-circular surface side. Every element of the standard kit has a base of 120x120 cm and height of 100 cm.

EXPANDED CLAY LATERLITE AND THE MANAGEMENT OF GARDENS
Forced plantations by tunnels, barriers forced by traffic dividers, closeness to road lanes, generate unnatural stresses to plants and vegetation by roads. When planting trees and plants along roads Exclay is used because it is an extremely lightweight, strong and thermally insulating material. It assures an effective protection to the garden base, an adequate presence of oxygen in the soil and good water retention. Used as mulching between new jersey rails it protects the roots from fast temperature changes, forced ventilation (passage of vehicles) and slows down the growth of harmful plants or weeds. Furthermore it is non-combustible so it does not spread flames in case of fire.

SOUND-PROOF BARRIERS
With the intense increase in traffic on our roads and the consequent increase in the noise level produced, a solution adopted in combination with the above-mentioned sound-proof surfaces is the use of sound-proof barriers. These barriers are the ideal solution for a good acoustic absorption at medium and high frequencies and help keep $\alpha$ values between 0.40 and 0.50, at 500 Hz, and between 0.45 and 0.70 at 1000 Hz. These barriers are made with Exclay blocks of various thickness and design. They can also be used to reach excellent sound-proof levels at low frequencies by combining different shapes and colors.

SOUND-PROOF BLOCKS AND PLATES
Vibrocompressed concrete products of Exclay (density 850÷1400 Kg/m³) have high acoustic absorption values certified at Laboratories and universities both in reverberating chamber and outside. They are used during acoustic renovation interventions in prefabricated concrete panels or as a covering for existing walls.
EXPANDED CLAY LATERLITE CONCRETE

For further information please refer to the publication “Lightweight Structural Concrete” published by Laterlite

LOOSE EXPANDED CLAY LATERLITE
Exclay is available in the following typologies (nominal categories) beyond 0-30.

<table>
<thead>
<tr>
<th>Expanded Clay Laterlite</th>
<th>0-2</th>
<th>2-3</th>
<th>3-8</th>
<th>8-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (UNI EN 13055-1) [Kg/m³]</td>
<td>700</td>
<td>480</td>
<td>380</td>
<td>330</td>
</tr>
<tr>
<td>Crushing strength of granules (UNI EN 13055-1) [N/mm²]</td>
<td>4,5</td>
<td>2,5</td>
<td>1,5</td>
<td>0,7</td>
</tr>
</tbody>
</table>

LIGHT BLOCKS
For all the applications where it is necessary to stabilize Exclay with concrete (filling on slopes, tunnel blocking, filling of cavities, etc.) it is possible to create mixtures in the construction yard pumped with the “Exclay PPC” technology or pre-packaged by concrete mixing plants.

<table>
<thead>
<tr>
<th>Exclay</th>
<th>Concrete</th>
<th>Weight</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed Exclay</td>
<td>3-8</td>
<td>200</td>
<td>650</td>
</tr>
<tr>
<td>REOEXCLAY 25</td>
<td>0-4</td>
<td>350</td>
<td>750</td>
</tr>
<tr>
<td>REOEXCLAY 50</td>
<td>0-2</td>
<td>400</td>
<td>800</td>
</tr>
</tbody>
</table>

EXCLAY STRUCTURAL AND EXCLAY TERRECOTTE
Laterlite produces two other types of lightweight aggregates: “Exclay Structural” and “Exclay Terrecotte” (technical specifications in table); they are mainly used for the preparation of structural concrete in compliance with the regulations (Decree 09/01/96 and relating technical instructions).

<table>
<thead>
<tr>
<th>Exclay Structural</th>
<th>0-5</th>
<th>5-15</th>
<th>0-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (UNI EN 13055-1) [Kg/m³]</td>
<td>800</td>
<td>650</td>
<td>730</td>
</tr>
<tr>
<td>Crushing strength of granules (UNI EN 13055-1) [N/mm²]</td>
<td>10,0</td>
<td>4,5</td>
<td>9,0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exclay Terrecotte</th>
<th>0-6</th>
<th>6-12</th>
<th>0-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density [Kg/m³]</td>
<td>950</td>
<td>800</td>
<td>900</td>
</tr>
<tr>
<td>Crushing strength of granules (UNI EN 13055-1) [N/mm²]</td>
<td>12,0</td>
<td>7,0</td>
<td>7,5</td>
</tr>
</tbody>
</table>

EXPANDED CLAY LATERLITE CONCRETE
According to need (supporting walls or other interventions) various mixtures can be created some of which are indicated in the table.

<table>
<thead>
<tr>
<th>NON-STRUCTURAL CONCRETE</th>
<th>INERT Dose in volume of inert</th>
<th>CONCRETE</th>
<th>S.F.</th>
<th>APPROX. DENSITY</th>
<th>AVERAGE RESIST.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25% sand 0-3</td>
<td>35% Exclay 0-2</td>
<td>40% Exclay 2-3</td>
<td>350 (type 32.5)</td>
<td>NO 1000</td>
</tr>
<tr>
<td></td>
<td>15% sand 0-3</td>
<td>35% Exclay 2-3</td>
<td>50% Exclay 3-8</td>
<td>350 (type 32.5)</td>
<td>NO 1200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STRUCTURAL CONCRETE</th>
<th>INERT Dose in volume of inert</th>
<th>CONCRETE</th>
<th>S.F.</th>
<th>APPROX. DENSITY</th>
<th>AVERAGE RESIST.</th>
</tr>
</thead>
<tbody>
<tr>
<td>30% 0-3 sand Exclay</td>
<td>30% Exclay 0-2</td>
<td>40% Exclay 2-3</td>
<td>350 (type 42.5)</td>
<td>SI 1400</td>
<td>20</td>
</tr>
<tr>
<td>20% sand 0-3</td>
<td>80% Exclay 0-2</td>
<td>40% Exclay 2-3</td>
<td>350 (type 42.5)</td>
<td>SI 1600</td>
<td>30</td>
</tr>
<tr>
<td>40% sand 0-3</td>
<td>60% Exclay 0-2</td>
<td>40% Exclay 2-3</td>
<td>400 (type 42.5)</td>
<td>SI 1800</td>
<td>40</td>
</tr>
<tr>
<td>30% sand 0-3</td>
<td>35% Exclay 0-2</td>
<td>35% Exclay 2-3</td>
<td>360 (type 52.5)</td>
<td>SI 1900</td>
<td>50</td>
</tr>
</tbody>
</table>

S.F.: Super-fluidifying
STR: Exclay Structural
TC: Exclay Terrecotte
DELIVERY MODALITIES

- **LOOSE**
  Any material can be delivered with a dumper (lateral – back). For loads up to 65 m³ according to the granulations. Different granulations can be supplied mixed with one another.

- **PUMPED LOOSE**
  It is possible to deliver loose Exclay with trucks equipped to pump the material in quote or in silos (up to 30 m vertical or 80-100 m horizontal). For loads up to 61 m³.

- **PUMPED WITH “EXCLAY PPC” TECHNOLOGY**
  Through “PPC” technology (Continuous Pneumatic Pumping) Exclay can be pumped on site loose with concrete. The equipment needed is easy to transport and enables the filling of cement grout directly from the truck mixer and of Exclay directly from the truck and full trailer. The average productivity depends on the type of application and can be around 120 m³/days (equal to about 2 truck and full trailer a day) with a cement dose to be established according to the use (suggested value 250 Kg per m³ Exclay).

- **PRE-PACKAGED BY CONCRETE MIXING PLANTS**
  Concrete mixtures with Exclay can be packed directly in the construction yard or at concrete mixing plants. Particularly, pumpable structural concrete and pumpable concrete such as ReoExclay 25 and 50.

- **IN BAGS OR ALREADY PRE-MIXED**
  Granules sized 3-8, 8-20 (at request also 2-3) are supplied in plastic bags of 50 l (20 bags per m³) on disposable pallets of 75 bags (3.75 m³) each. Granule sizes 2-3 and 3-8 can be supplied, at request, even dry (humidity level less than 1%). The Laterlite production also includes other products (made with Exclay) already pre-mixed for different uses in the construction field (setting beds, structural concrete, mortar and plasters, etc.).