HYPERBRICK®
Economical Building Around the World

ANALYSIS OF SOILS

This paper is destined to the workers on the site itself.
Rather than a guidebook, this booklet gives you some "tricks" to recognize without any mechanical device the type of soils you are dealing with.

INTRODUCTION

The first concern of a builder is to determinate if a certain soil suits to such or such method of construction according to the HYPERBRICK Process.

The purpose of this chapter is to indicate the means which each can dispose to recognize a soil. They consist either in analysis of soil which, after samples, are made in laboratory, or in identification tests easy to realize, which give a sufficient idea of quality of soil we intend to use.

We will first treat the constitution of soil; afterwards, we will give the methods of analysis used by laboratories and we will finally show the test feasible on the site.
We will, eventually, go deeper into the explanation of the HYPERBRICK Process.

1. CONSTITUTION OF SOIL

Superficial part of earthly crust comes of times from the mechanical and chemical alteration of rocks under the action of climatic phenomena and of alive organisms. Of a very variable thickness, it presents always about the same profile.

The vegetable earth or agronomists soil, rich in organic material, surmounts the mother rock, more or less altered. When they are movable and contain a little part of organic material, the superficial levels are utilizable for earthen construction. They are called, in geotechnics, soils and the study of their properties depends upon mechanics of soils. Soils are constituted with mixtures of proportions in four sorts of elements: gravels, sand, muds, and clays. The comportment of each constituent is specific and, for example, when they are submitted to dampness variations, some change their volume, others do not.

The former are unstable and the latter are stable. This notion of stability that means of aptitude to support dampness or dryness alteration without variations of properties, is fundamental for a material of construction.

1.1. Gravels

Are constituted by pieces of more or less hard rock which size is between 5 and 100 mm approximately. They are stable constituents of soil. Their mechanical properties do not sustain any sensible modification in presence of water.

1.2. Sands

Are constituted by mineral grains which size is approximately between 0.080 and 5 mm. As stable constituents of soil, they do not have cohesion when they are dry. However they show a solid internal friction, which means a great mechanical resistance of rubbing to the relative movements of the particles of sand. When they are slightly damp, they show an apparent cohesion due to the superficial tension of water occupying the empty spaces between the grains.

1.3. Muds

Are constituted by grains which size is between 0.002 and 0.080 mm approximately and do not show cohesion when they are dry.
Having a resistance to rubbing generally feebler than this of sands, they show, when damp, a good cohesion and they can, when their dampness changes, sustain sensible volume variations, distension and retract. Gravels, sands, and, to a lesser degree muds, are characterized by their stability in presence of water. Dry, they do not show any cohesion at all and therefore cannot be used alone as materials in the making of edifice constitutive elements.

1.4. Clays

Which constitute the finest fraction of soils does not have the same characteristics as the other granules. The most grains that constitute them are small microscopic minerals amongst which we will retain the Kaolinites, the Illites and the Montmorillonites. The clays particles are encircled by an absorbed water film and the grains smallness makes that their weight is feeble compared to the forces exerted by the superficial tensions developed at the absorbed water film level. The volume forces are feeble compared to the surface forces.
The absorbed water film, very adherent to the plates, forms axles between soil micro particles, which gives to the clay his cohesion and the essential of his mechanical resistance. It can just be eliminated by a deep desiccation. Clay gives to soil his cohesion: it acts as a sort of binder between the grossest elements, which constitute the skeleton.
Nevertheless, at the opposite of sands and gravels, muds are unstable, sensible to the dampness variations. They possess a great affinity for water and when their holder in water grows, the absorbed water films become thicker and the total apparent volume of clay increases. Inversely, by retract, when drying, fissures can appear in the mass of clay and enfeeble its resistance. During a new dampness period, the fissures will give passage to water up to the heart of the material. The "distention-retraction", variations of clay soils volume with water holder, that is the enemy !!!

Clay can just exist in limited percentage in the MARMOOR material: less than 2 %

2. RECOGNITION OF SOILS

2.1. Samples abstracts

We can make then with a shovel, in pits or trenches. Good earths belong to movable superficial level poor in organic matters. We will extract the vegetable earth, which is improper due to the presence of organic matter.
We extract samples of each founded soils, in sufficient quantity. Each sample will be put in a tight bag. Each bag will be evidently labeled. Place and depth of extract will be noted. The nature of soils can change notably from one point to another, on a small surface. It will be convenient to draw representative extract sufficiently closer, which is not always easy. When this operation is finished, we can start the tests.

2.2. Laboratory tests

2.2.1. Granulometry

The granulometry analysis allows to determinate the respective quantity of different elements composing soil (gravels, sands, muds, clays). The results of analysis appear graphically under the form of "granulometric curve" traced on a special diagram (granulometric diagram) containing in abscissa, the thickness of grains and, in ordinate, the percentage of cumulated siftings. This percentage expresses the proportion in weight with regard to the weight of dry sample which size is inferior to the size measured in abscissa.
The thickness of grains is measured following two different techniques:

a) The siftering : used for grains above 0.1 mm, it consists, after having superposed the sifters, in decreasing opening order (the finest below to filter soil. It is practiced, should the occasion arise, under water steam, what helps the fine particles to cross the meshes. As the operation finishes, we collect the refused grains of the different sifters and wee weight them.

b) For the big particles, instead of siftering with square meshes, we can use circular strainers with meshes.

2.2.2. Sedimentometry

At the end of siftering we collect the particles that have crossed the sifter opening 0.1 mm. As it would be very long, tedious, and indeed impossible to try to do them crossing thinner sisters, we measure their thickness by sedimentometry.
This method uses the speed difference of particles fallen from soil, previously put in suspension in water. The biggest particles drop first and the finest after. We measure the variation of density of suspension in time at a definite height (the density reduces when

the liquid clarifies). Knowing the fall speed of particles according to their size, it is then possible to calculate the proportions of grains of different thicknesses.

A simplified variant of this process is the method of siphonage.
We use in this case earth crossed through the siftering of 2 mm or 6 mm, to which we add water.

To assure the dissociation of grains we incorporate a deflocking product. For example, 20 ml of sodium silicate at 31 Baume or 50 ml of an arabic gum solution at 45 gr. gum in powder for one liter of water. We verse this mixture in a vessel provided with a magnetic agitator, which we act during one minute.
We leave then the mixture decant during 20 minutes.
Afterwards we introduce with precaution, in test tube, a metallic disk up to contact the deposit material.
This operation is made to separate the deposit material from the one in suspension.
We siphon then the material stayed in suspension with a flexible tube.

We dry this abstract and weight it; then, with sifter of 0.25 or 0.5 mm and 0.074 or 0.080 mm we sifter the part of soil staying at the bottom of the test tube.

- the fraction retained by the sifter 2 to 5 mm is gravel
- the fraction retained by the sifter 0.25 or 0.5 mm can be considered as being thick sand.
- the fraction crossing the sifter 0.074 or 0.080 mm and which has been siphoned is clay.
- the fraction crossing the sifter of 0.074 mm and which lays is mud

2.2.3. Optimal granulometry

The evocation of the "mechanic role of components" of soil, at the beginning of this chapter, permitted us to have an idea of the fashion for gravels, sands, muds, and clays, to interfere in MARMOOR structure. The elements are gravels and sands are resistant elements of material. Nevertheless, the clays assure a cohesion of the whole and muds have an intermediary function not so distinct.

In determinating an optimal curve, we will try to take advantage of qualities of soils elements.

The regrouping of granulometrical specification permit to define this optimal granulometry. We present it graphically under the form of an "ideal curve" surrounded by its two limit curves (inferior and superior).

2.2.4. Remillon spindle

To reply the exigencies of an optimal granularity, a soil destined to the confection of MARMOOR must reply to the following conditions:

a) its granulometrical curve must be continuous in the limit spindle

b) it must be nearest possible of the ideal curve
c) it must be approximately parallel to the limit curves and to the ideal curve, particularly in the region of muds.

If these limit spindles guarantee a certain security, this does not mean that out of this spindle it is impossible to build in earth. There will be important problems to resolve.

2.2.5. Atterberg limits

The granulometrical study of soil is limited to the analysis of the thickness of constitutive elements which conditions strongly its mechanical properties, but is not the single parameter.
It is so that independently of their granularity, clays can present physical and mechanical properties very variable according to the mineralogical or chemical nature of particles.
It will be then necessary to complete the granulometrical analysis of clays by complementary tests.

2.2.6. Consistence conditions

Atterberg has defined a line of normalized tests, which permit to analyze the consistence variations, of thin triturated soils with their water holder.
As for granularity, statistic studies have been made in order to define the Atterberg limits "ideal" for MARMOOR.
The knowledge of these Attenberg limits so to foresee quickly the constructive possibilities of a soil.

Reminder of consistence conditions

Following its water holder, a soil can be "liquid, "plastic", or "solid".
The Atterberg limits determine conventionally the frontiers between these different conditions:

Dispersion condition	
Liquid condition	
	Liquidity limit Wl
Plastic condition	
	Plastic limit Wp
Solid condition with retract	
	Retract limit Wr
Solid condition without retract	
	MARMOOR

The determination of Atterberg limits is practiced on the thin part of soil called "Mortar" which regroups the fraction crossing the sifter of 0.4 mm.
They are in fact the only elements on which water acts in changing the consistence.

2.2.6.1. Liquidity limits Wl

It marks passage from the plastic condition to the liquid condition. It is measured with an apparatus (CASAGRANDE apparatus).

2.2.6.2. Plasticity limit Wp

It marks the passage of the plastic condition to the solid condition and is defined by the water holder of a small roller of soil which breaks in morsels when his diameter arrives to 3 mm.
We measure it in making a earth pellet which we roll on a plane glass or marble plate with the palm or with a plexiglass plate.
Earth is at the limit of plasticity when the obtained roll for a diameter of 3 mm breaks up in small morsels of 1 to 2 cm length.
If the roll breaks up when his diameter is superior than 3 mm, we must add some water.
If it arrives to 3 mm without breaking up, we must dry it a little and start again.
After drying up in a drying room, we calculate the water holder corresponding (water weight on dry weight)

2.2.6.3. Plasticity sign Ip

When the plasticity and the liquidity limits are determined, we calculate the plasticity sign: Ip = wl - wp

2.2.6.4. Retract limit Wr

The retract limit corresponds to the water holder on side of which the volume stays constant. To determinate it, we dry up in a drying room a soil sample having a water holder near Wl and we measure the volume and mace variations of it. When the water holder reduces by evaporation, the volumes grows shorter nearly linearly.
When grains are in contact, the volume stops to decrease then the water holder continues to go down.

2.2.6.5. Absorption limit Wa

To those three Attenberg limits, it is interesting to add for fabrication of MARMOOR, the absorption limit, which corresponds to the water holder at which starting the water does no more penetrate in material. We measure it in making a water drop fall on as well as homogeneous paste. If the drop is absorbed in less than 30 seconds, we make the paste homogeneous by increasing the water holder and we start again up to drop of water does not penetrate on an horizontal facet before 30 seconds. The water drop makes then a brilliant spot. The absorption limit is inferior to the retract limit which makes material immune to distension.

2.2.7. Proctor tests

The compactage is the best way to improve the resistance of a soil. To be effective it must be realized on a material possessing a water holder assuring the lubrication of soil grains and permitting then to readjust in order to occupy less place as possible.
The object of the Proctor test is to determinate this water holder called "optimal water holder".
This water holder corresponds to the largest volumetric possible mace with hyper compressing energy used.
Test principle is as follows: we place in a cylindrical mould, of known volume, a sample of earth which water holder we know.
We crown this sample in respecting the operative process. We measure after that the weight and control the water holder of the compacted sample.
We deduct the dry volumic mace which we put on the Proctor diagram with the corresponding water holder.

2.2.7.1. Standard Proctor Test

* Crown : mace of 2.496 Kg - Diameter 5.08 cm
* Cylindrical mould: volume 949 cm3, height 11.70 cm, diameter 10.16 cm
* Necessary earthen mace per measure point: 1.5 Kg
* Unitary energy: 6 joules per cm3
* Thickness of the coasts: about 4 cm
* Number of coasts: 3
* Height of the crown fall: 30.5 cm

2.2.7.2. Interpretation of the Proctor test

If it obtained dry volumenic mace at the T.E.O. is included between 1650 and 1760 Kg/m3, the result is fairly mediocre, between 1760 and 2100 Kg/m3, the result is very satisfactory, material is clayed enough.
Between 2100 and 2200 Kg/m3, the result is excellent (material rich in big elements).
Between 2200 and 2300 Kg/m3, the result is exceptional.
We remind you that MARMOOR obtains densities from 2.38 to 2.42 in all cases after Hyper-compression with T.E.O 6 %.

2.2.7.3. Rapid estimation of the optimal water holder (T.E.O.) on land

In order to estimate on yard the optimal water holder, we can take an earth handle and make it falling from 1,10 m on a hard surface.
If, arriving on soil, it desegregates in 4 or 5 morsels, the water holder is correct. If, on the contrary, it becomes flat without desegregation, it contains too much water. When it pulverizes, the water holder is not sufficient.

2.3. Land tests

Tests in laboratory, perfectly defined and normalized, need a special equipment. The tests which will follow, on the contrary, need no specialized tools and can be done on land, during the abstract of samples. Helped by the experience, they furnish qualitative indications permit a fairly fine classification of soils and a direct appreciation of the use possibilities. We present them in an arbitrary order, starting by the most simple.

2.3.1. Odor test

The organic soils have an odor of moldiness, especially when we have just extracted them. The odor of those soils is amplified when we damp or heat them. In principle, they are not used for construction.

2.3.2. Bite tests

It is a rapid fashion to state presence of sand, mud or clay: take a pinch of earth and crush it between teeth.

2.3.2.1. Sandy soil

The particles of sand, hard, grind disagreeably between teeth. It happens also with a very fine sand.

2.3.2.2. Muddy soil

The particles of mud are much smaller than the sand ones and though they grind between teeth, it is not disagreeable. Mud grinds neatly less than sand.

2.3.2.3. Clayed soil

The particles of clay do not grind. On the contrary, clay appears to be soft and mealy between teeth. A pastil of dry earth containing much clay is gluing if you put your tongue on it: it snaps the tongue

2.3.3. Brightness examination

Take a small ball of earth slightly damp and cut it in two with a knife. If the surface of the cut is glittering, the earth is plastic clayed; if the surface is dull, the earth is then muddy.

2.3.4. Touch

The obtained impression when touching permits to determine on place, with a sufficient exactness, the basis component of a soil.

We take a sample from which we extract the largest particles, superior to 5 mm (small gravels). We malaxate this sample between fingers and palm what permits to evaluate the dimensions of the component.

2.3.4.1 Sand

The particles of dry sand give, when touching, give an impression of rugosity.

2.3.4.2. Mud

Dry mud give also an impression of rugosity but not so accentuated. The plasticity of damp mud is medium.

2.3.4.3. Clay

Dry clay appears in clods or grains enough voluminous and offers a very great resistance to crushing.

Damp clay is plastic and pastes to fingers, the sandy-clayey soils give, when triturate them between fingers near ear, an audible grinding.

2.3.5. Hands washing

When washing hands with earth as we could do with soap, we obtain a certain number of indications. Damp, the clayey soils give an unctuous and soapy sensation and it is difficult to rinse the hands. The clayey soils appear dusty and it is not very difficult to rinse them. The sandy soils are difficult to rinse.

2.3.6. With eye examination

It permits to have an idea of the proportion of the size of particles of the most voluminous constituents, and, by deduction, of the particles of the finest ones. However, the finest visible particles with eye, are those of 0.080 mm, clay grains and mud are invisible.

2.3.7. Simplified sedimentation test

We choose a transparent glass flagon, with a large enough opening, but which we can block up with hand.

This flagon must be cylindrical, have a flat bottom, and a capacity of half aliter. We fill it with earth up to the quarter of its height and we complete with salted water.

When closing the flagon with the palm we shake hard the mixture and we leave it quiet on an horizontal surface.

After one hour, we shake again and leave it decant. After 45 minutes, we state that sand is laying on bottom, surmounted with a thickness of mud. Above, we find a clay suspension.

After 8 hours, we measure the height of the different coasts: total height of sediments being in flacon; total height of each sedimented coat. We obtain then an indication of the proportion of each soil constituent.

2.3.8. Tests on thin components

The following tests being made on thin components, these will be, previously, isolated by sifting or by decantation.

2.3.8.1. Decantation

This test begins by the "simplified sedimentation" test as above. We shake hard the flagon containing sample of earth and leave it decant 30 seconds. With a rubber tube, used as a siphon, we deduct immediately water and materials that it contains in suspension and collect all that in a flat recipient. We leave this mixture decant up to the time the water is clear. After that, we empty water in keeping earth sample in the recipient. The excess of water that is still contained in sample is eliminated by evaporation.

To facilitate the siphonage, it is recommended to fill completely the rubber tube that works as siphon and to block both terminations with fingers. After you have just to introduce one of those terminations in the flagon, looking to the fact the other one is lower than the flagon.

2.3.8.2. Shakes tests

We deduct a portion of the sample of the decanted sample, which we roll in hand to make a bowl of 2 to 3 cm of diameter. Earth must be sufficiently soft so that bowl does not glue to fingers.

We flatten lightly the bowl in palm horizontally bent and with sharp of this hand we strike several times vigorously on the other hand. The shakes make water coming out on surface of sample and at this moment, the aspect of the earth between thumb and index of this other hand and we observe the aspect modifications of the bowl.

a) Quick reaction: 5 to 10 strockes are enough to make water coming at surface. Pressing sample, water disappears immediately and surface becomes mated. If we press harder, the sample becomes exhausted. A very fine sand or a thick mud is in question (a mud without organic materials).

The presence of a feeble clay proportion suppresses this reaction.

b) Slow reaction: 20 to 30 strokes are necessary for water appearing on surface. Afterwards, when we press, the sample does not crackle and does not exhaust as a mastic bowl.

This indicates mud lightly plastic or muddy clay.

c) Very slow reaction or no reaction: the more the soil is clayed, the more the reaction is slow. When we press sample, its surface stays glittering.

2.3.8.3. Cord tests

These tests bring supplementary precisions to the shake test. It is not justified if the last one has given a "rapid reaction".

Take a morsel or earth as an olive, making it damp just enough to model it easily by hand, without a cord pushing on it just enough to make it thin progressively.

If it brakes before being reduced to a diameter of 3 mm, earth is too dry and we will add some water. When the water holder is correct, the cord cutes into fragments just when is arrived at a diameter of 3 mm.

If the morsel of earth crumbles easily and if we cannot obtain a cord, whatever is the water quantity, soil contains little clay. If we can obtain a cord, as soon as it breaks to morsels of 3 mm diameter, reconstitute a bowl with those and crush it between thumb and index.

a) Hard cord : If the bowl is difficult to crush and if it does not fissure and not crimble, soil content much clay. Without doubt we cannot use it alone in fabrication of MARMOOR.

b) Half-hard cord: When pressing bowl between fingers, it fissures and crumbles. Soil could be good for MARMOOR.

c) Fragile cord: When soil contains much mud or sand and not much clay, it is impossible to remake a bowl without it breaks or it crumbles. This soil is convenient for MARMOOR elements.

d) Soft and spongious cord : Sometimes cords and bowls are soft and bowls have, between fingers, a spongious comportment. In this case, it is organic earth, not convenient for construction.

2.3.8.4. Ribbon test

This test is complementary to the cord test. Take enough earth to make a roll as a cigar of 12 mm diameter. This earth must not be gluing but sufficiently damp to make, by rolling, a cord continuum of 3 mm of diameter, as in precedent tests.

Put the roll in palm and, starting at the extremity, make it flat in pressing it between thumb and index to form a ribbon of 3 to 6 mm thickness. Manipulate sample with precaution to obtain the longest possible length.

Measure the length we can obtain without breaking the sample.

a) Long ribbons: With certain soils, the ribbon can attain from 25 to 30 cm without breaking. This indicates that the soil contains much clay. It can be used but must be stabilized.

b) Short ribbons: If we can obtain, with difficulties, a ribbon of 5 to 10 cm, it is the fact that soil has a feeble or medium holder in clay. It will be analogous to those giving a half hard or fragile cord. This earth will certainly make good walls.

c) No ribbon: With certain soils we cannot realize ribbons. They will make very good walls.

2.3.8.5. Dry resistance tests

These tests are also made on fine components of the soil. Prepare two or three pastils of soft earth of about 12 cm thick and 25 to 30 cm diameter. Make them dry under sun and then in bakehouse.

Break the pastil and try to reduce it in powder between thumb and index.

a) Great resistance: It is very difficult to break the pastil, it breaks with a clap as a dry biscuit. It will not be possible to crush it between thumb and index. It is there a nearly pure clay.

b) Medium resistance: It is not difficult to break the pastil. Without too much efforts, we can reduce it in powder when pressing it between thumb and index. It is muddy and sandy clay.

c) Feeble resistance: The pastil breaks without problem and reduces very easily in powder. It is there either a mud, or a sand very thin, or a soil containing a feeble quantity of clay.

3. RAPID IDENTIFICATION TEST OF CLAYS

The test proposed by Emerson is made on a morsel of earth as a bean.
We place a morsel in a recipient full of water distilled or of rainwater.
It is important that the morsel of earth has not been worked before its immersion.

After ten minutes immersed, the morsel of earth can stay intact or disaggregate, the observation of its behavior allows a rudimentary determination of the nature of the clay. This test, which we have not personally controlled, could not in any cases replace a rigorously mineralogical analysis.

Madame SIERRA RUBIO Concepción – P.D.G.

Monsieur BRIDE Michel - Ingénieur Conseil

✉ Urbanización Prado de los Robles
40500 - RIAZA - Espagne

☎ Téléphone1 : 00 (34) 92 155 11 63
☎ Téléphone2 : 00 (34) 609 173 633

Fax : 00 (34) 92 155 11 63

E-Mail1 : hyperbrick@hyperbrick.com
E-Mail2 : michelbride@hyperbrick.com
E-Mail3 : commercial@hyperbrick.com
E-Mail4 : technique@hyperbrick.com

WEB : www.hyperbrick.com