EARTH AS A RAW MATERIAL

Soil is the result of the transformation of the underlying rock under the influence of a range of physical, chemical and biological processes related to biological and climatic conditions and to animal and plant life.

A soil is an earth concrete.

Like a concrete that contains gravel, sand and cement as a binder, a soil contains gravel, sand, and, silt and clay acting as binders as well. But silt and clay are not stable under water. Nevertheless, earthen buildings proved that they could last very long, when people mastered the material and when they maintained their buildings.

FUNDAMENTAL PROPERTIES

Soils are composed of solid components, water and air. They are characterized by 4 fundamental properties.

Granularity or texture

It corresponds to the grain size distribution of a soil. It is a percentage by weight of the different grain sizes. The grain size classification adopted by a large number of laboratories is based on the ASTM-AFNOR standards:

Pebbles	Gravel	Sand	Silt	Clay
200 to 20 mm	20 to 2 mm	2 to 0.06 mm	0.06 to 0.002 mm	0.002 to 0 mm

For building with earth, pebbles should be removed.

Compressibility

It is the ability of a soil to be compressed to the maximum. It is related to the energy of compaction. The Optimum Moisture Content (OMC) defines the compressibility. The OMC is a percentage by weight of water to achieve the highest compression of a soil.

Plasticity

This property of a soil refers to its possibility to be submitted to deformation without elastic failure. It defines its ability to be moulded.

Cohesion

It defines the capacity of soil grains to remain together. This property is strongly linked with the plasticity.

TYPICAL SOILS

The solid components of a soil are gravel, sand, silt and clay. Therefore, soils can simply be classified into 4 typical soils, according to the quantity of its components: Gravely, Sandy, Silty, or Clay soils. They are defined by the percentage of the grain sizes, which influence the soil behaviour. In a sandy soil, for example, the sand proportion influences the most, the soil behaviour.

When another grain size influences the soil to a lesser extent, the classification will need to be more precise:

- A sandy silt soil will be mostly silty with an influent proportion of sand.
- A silty sand soil will be mostly sandy with an influent proportion of silt.

The name of this classification is given by the component which influences the most the behaviour of the soil. Note that the soil has to be evaluated as whole and not as separate components. Therefore, it is necessary to examine how these various components combine with each other. For example, a soil might have more gravel than normal, but if the clay is very plastic and with the proper proportion, the soil might not be called gravely but probably good soil.

A soil will have sometimes 2 components influencing its behaviour: one very influent and another one to a lesser extent. Therefore, a more accurate classification will be defined as follows:
Silty sand soil = Soil mainly sandy with an influent proportion of silt.
Sandy silt soil = Soil mainly silty with an influent proportion of sand.

The quality of the binders, silt and clay, will also influence a lot the soil behaviour and one should understand that the variety of soils is as infinite as human beings. Therefore, it is impossible to give any fixed rule and / or procedure.

SOIL IDENTIFICATION

Identifying the quality of a soil is essential. Not every soil is suitable for earth construction. But with some knowledge and experience most soils can be used. Topsoil and organic soils must not be used. They should be removed and kept for agriculture.

All over the world many laboratories can analyse soil samples for road building. Fewer laboratories can do it for buildings but they acquired vast knowledge and understanding of soils. Nevertheless, this scientific knowledge and these laboratory tests are not accessible by the common man.

Since millennia people have known what to do with their local soil. They developed simple field tests to check the properties and behaviour of their soil. Therefore, the Auroville Earth Institute practices only field tests, called sensitive analyses, to identify a soil's quality. These simple sensitive analyses can be performed after a short training. They follow the four fundamental properties of the earth and they can be practiced by anybody, as we use our senses.

The aim of these sensitive analyses is to identify in which category the soil sample belongs: Gravely, Sandy, Silty, Clayey or combined soil, i.e. sandy clay or clayey sand, etc. Then, according to this classification, one will know what to do with the soil and which earth technique to select.

SENSITIVE ANALYSES

Granularity	Looking and touching	Look at a dry or humid soil and touch it to define the percentage and the size of the grain sizes.
Compressibility	Pressing	Add a little water, if the soil is dry, to get a moist soil and compress it by hand to make a ball. Evaluate how much pressure you need.
Plasticity	Shaping the ball	Add more water and make a cohesive ball. Evaluate how easy it is to shape it and how cohesive it is.
	Stretching the ball	Pull the ball like rubber elastic and try to break it. Evaluate the strength of the ball.
	Sticking a knife	Stick a knife into the cohesive ball and pull it out. Evaluate how the soil sticks on it.
	Cutting the ball	The ball is cut in 2 pieces. Examine the aspect of the cut.
	Water absorption	Print with the thumb a small depression on the ball. Fill it with water and evaluate the time of absorption.
Cohesion	Diluting the ball	Add much more water to the ball and try to loose the cohesion of the soil. Evaluate how much the soil sticks to the hand.
	Washing the soil	Add much more water to the soil and wash away silt and clay. Evaluate the amount of fine sand, which remains in the palm.
Humus content	Smelling the soil	Take some moist soil and smell it.

The aim of these sensitive analyses is to find out in which categories goes the soil sample: Gravely, Sandy, Silty, Clayey or combined soil i.e. sandy clay. Then, according to this classification, one must look into the recommendations for stabilization and soil improvement.

Note that the soil identification should be practiced twice: first on the raw soil, before doing any modification, and also after correcting the soil (i.e. after sieving).

IMPROVING AND STABILISING SOILS

According to the original soil quality, adding materials like gravel or sand can do some easy improvement. Note that it is not advisable to mix clay, as the process would be long for an uncertain result. Improvement can also be done by sieving the soil or by mixing different qualities of soil. Stabilising a soil will also improve it.

SOIL STABILISATION

A modern practice is to stabilise the earth, especially for compressed earth blocks (CEB) and rammed earth. It aims originally to stabilize silt and clay against water, so as to give lasting properties when the soil gets wet and with the minimum of maintenance.

Stabilisers

Many stabilizers can be used. The most common ones are cement and lime. Others, like chemicals, resins or natural products can be used as well. The selection of a stabilizer will depend upon the quality of the soil and the requirements of the project. Cement will be preferable for sandy soils and to achieve quickly a higher strength. Lime will be preferred for very clayey soil, but will take a longer time to harden and give strong blocks.

Cement or lime stabilisation of soils will increase the strength a lot, and stabilised earth could be exposed to water or even immersed. The densification of soils by compression (rammed earth, CSEB) or by adding water (shaped, cob, adobe, wattle and daub) will also give cohesion and more resistance. In this case the earth should not remain in contact with water for long.

Percentages of stabilisers

It depends on the soil quality and the particular requirements. The average stabilizer proportion is rather low: 5% for cement (3 to 8%) and 6% for lime (2 to10%). These low percentages are part of the cost effectiveness of CSEB and stabilised rammed earth.

When to stabilise

The stabilisation is dependent upon the soil quality and the technique. It is not always needed, especially when the material is not exposed to water. The stabilisation is not necessarily required when the architecture is well designed and when maintenance will be done.

SOIL SUITABILITY ACCORDING TO THE TECHNIQUE

According to the soil quality, the technique will vary. Some techniques requires more gravely soils than others, i.e. rammed earth when, on the other side, a clayey soil will be more suited to wattle and daub.

SOIL TYPE	TECHNIQUE	REMARKS
Gravely	- Filled in	None
	- Rammed earth - CSEB	It can be used for raw rammed earth if the soil is cohesive enough and if it has enough clay. A cement stabilisation (~ 5%) will increase the cohesion when fresh and the resistance when dry.
	- Poured	If the clay content is enough.
Sandy	- Filled in	None
	- Covered	None
	- Rammed earth - CSEB	It can be used for raw rammed earth if the soil is cohesive enough and if it has enough clay. A cement stabilisation (~ 5%) will increase the cohesion when fresh and the resistance when dry.
	- Poured	If the silt & clay are not too active. A cement stabilisation (~ 5%) will be useful.
Silty	- Filled in	None
	- Covered	None
	- CSEB	It might be improved with coarse sand if the clay content is enough. It requires a cement stabilisation (~ 6 to 8 %).
	- Cob	Mixing a soil slightly more clayey might be needed if the soil is not cohesive enough.
	- Adobe	Mixing a soil slightly more clayey might be needed if the soil is not cohesive enough.
Clayey	- Filled in	None
	- Covered	None

	- Rammed earth - CSEB	An improvement with sand and a cement stabilisation (~6%) will be needed.
	- Shaped	A stabilisation with sand, natural fibres or cow dung might be needed. Lime can be a suitable stabiliser.
	- Cob	A stabilisation with sand or straw might be needed.
	- Adobe	A stabilisation with sand or straw might be needed.
	- Extruded	An improvement with sand and a stabilisation with lime (~ 8%) might be needed.
	- Wattle & daub	A stabilisation with sand or natural fibres is needed.
	- Straw clay	None
Clayey gravel	- Cut blocks	Example of soil very suitable: laterite.
	- Rammed earth - CSEB	Some sand might be needed. It can be used for raw rammed earth. A cement stabilisation (~ 5%) will give good results.
Sandy silt	- Filled in	None
	- Covered	None
	- CSEB	It requires a higher % of cement (~5 to 7%).
	- Cob	Mixing a soil slightly more clayey might be needed if the soil is not cohesive enough.
	- Adobe	Mixing a soil slightly more clayey might be needed if the soil is not cohesive enough.
Clayey silt	- Dug out	If the soil is cohesive enough.
	- Filled in	None
	- Covered	None
	- Cob	A stabilisation with sand or straw might be needed.
	- Adobe	A stabilisation with sand or straw might be needed.
	- Straw clay	If the soil is plastic and sticky enough.
Gravely clay	- Filled in	None
	- Covered	None
	- Rammed earth - CSEB	Some fine sand might be needed. A lime stabilisation will be useful (~ 6 %).
	- Adobe	A stabilisation with natural fibres or sand might be needed if the clay content is too high.
Sandy clay	- Filled in	None
	- Covered	None
	- CSEB	Some coarse sand might be needed. A lime stabilisation will be useful (~ 6 %).
	- Cob	A stabilisation with sand, natural fibres or cow dung might be needed. Lime can be suitable.
	- Adobe	A stabilisation with natural fibres might be needed.
	- Extruded	A lime stabilisation will be useful (~ 8 %).
	- Wattle & daub	A stabilisation with natural fibres will be needed.
Silty clay	- Filled in	None
	- Covered	None
	- Cob	A stabilisation with sand or straw might be needed.
	- Adobe	A stabilisation with sand or straw might be needed.
	- Extruded	An improvement with sand and a stabilisation with lime (~ 8%) might be needed.
	- Wattle & daub	A stabilisation with sand or natural fibres is needed.
	- Straw clay	None
Sandy gravel Silty gravel Gravely sand Silty sand Gravely silt	- No technique	Not suitable for earth construction