ADDITIVES TO CLAY

MINERALS AND SYNTHETIC ADDITIVES

PRACTICAL ACTION
Technology challenging poverty

technical brief

Introduction

Earth has been used for building for thousands of years throughout the world spanning a diverse range of climates and cultures. Earth itself is a multi-component system usually consisting of stones, sand, silt, clay, water and, near the ground surface, organic humus. Structural stability of earth buildings is maintained by the structural integrity of the sand and stone framework, by the pore filling capacity of the silt and most importantly, by the binding qualities of the clay, which are in turn influenced by the moisture content of the soil.

Figure 1: House with stabilised soil render in Atlas Mountains, Morocco.
Photo credit: CRATerre/EAG

Compared with some building materials earth can be considered to have some disadvantages – it has relatively low compressive strength, tensile strength and abrasion resistance. It may also lose a lot of its rigidity in the presence of water. Nevertheless it is very cheap, very widely available, environmentally friendly, strongly linked to local cultures and traditions and, with skilful construction, can contribute significantly to the aesthetic appeal and user comfort of buildings.

Good quality durable earth buildings can be built provided certain precautions are taken. These precautions will depend on local conditions and structural requirements, but can broadly be classified into four categories:

Soil Selection
Different soils can have very different characteristics. The quality of a soil for building is strongly dependent on grain size distribution and the exclusion of humus.

Soil Preparation and Construction Methods
Builders should be familiar with soil pulverising, proportioning, mixing, maturing and curing as well as masonry techniques.

Building Design
The design should take account of the properties of the raw material by appropriate load distribution and structural dimensions, and by incorporating protective elements against damp, rain, impact and abrasion. Protection could be achieved by adding more durable but complimentary materials at places such as the wall base, roof overhang and the copings, and by using plasters and renders.

Improving the Raw Material Quality
Different treatments or additives, collectively known as stabilisation, can modify the properties of soils to control their shrinkage and swelling characteristics and so improve the binding ability of the clay in the soil. These stabilisation methods are described in this leaflet.

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Compaction

Compaction increases the soil density and hence its strength and resistance to mechanical damage. It also reduces its water absorption, although at the expense of reducing porosity, so possibly reducing durability.
Compaction is done in a mould or form:

- statically (i.e. in a single pressing), with cylindrical rollers, wheeled rollers or presses;
- dynamically (i.e. repeated), with tampers or rammers, vibrating rammers or pick hammers;
- surface, with a beater – mainly for floors or roofs, although sometimes used on rammed earth walls before they dry.

Effectiveness of compaction depends on applied pressure or energy, soil type and water content.

Mineral additives

The first material to be added to a soil, if it has too much clay, is sand and gravel to obtain a more uniform grainsize distribution. This reduces the shrinkage and swelling characteristics as well as giving a better pore size distribution and higher density, with improved cohesion between particles of the soil. Adding an optimum quantity of sand and gravel to a soil often reduces the amount of other, more expensive, additives needed for effective stabilisation. Care, however, needs to be taken when mixing sand and gravel with clayey soil because of the presence of clay lumps. Therefore, if the mixing is carried out in a dry, humid or plastic state, the soil first needs to be pulverised to break up any lumps. The alternative is to mix the soil in a liquid (fluid) state.

Pozzolanas, such as certain types of volcanic ash, are another mineral additive which will improve the properties of soils containing more than the optimum proportion of clay.

Ashes

Ashes often contain calcium carbonate and may have stabilising properties. Ash is normally added in proportions of between 5 and 10% often achieving improvements in dry compressive strength, but having less effect on water resistance, although it can also reduce shrinkage and swelling. Ashes can be somewhat pozzolanic, so when combined with lime, additional improvements are possible. Ash, when added to soils, has also been known to act as a termite repellent.

Synthetic additives

Portland Cement

The reaction between clay and cement is thought to be a three-phase mechanism, hence there is both a long-term and a short-term effect. Cement also bonds with the sandy skeleton of the soil in the conventional way. The cement does not bond with all of the soil particles, but helps to form a stable matrix throughout.

The effect of adding cement is to improve the dry compressive strength, but more particularly, the wet compressive strength. Resistance to erosion, rain and abrasion is much improved. To achieve good results it is important that the cement is well mixed with the soil and that the product is cured properly.

Ordinary Portland Cement is normally preferred, but Portland-pozzolana cement could also be used. Some soils require only a 3% addition of cement, but more usually 5 to 8% cement is added – the higher the shrinkage of the soil the higher the proportion of cement.

Hydraulic Lime

This produces similar effects to Portland cement, but of lesser magnitude. Natural hydraulic lime does not dilute the natural colour of clays.

Hydrated Lime

Principally two effects operate in the reaction between clay and hydraulic lime; a short-term flocculation effect, making the clay more cohesive and a longer-term effect which is a combination of the pozzolanic reaction between lime and clay and a reaction between lime

and carbon dioxide in the air. Stabilisation is particularly effective with soils containing kaolinitic clay. Significant increases in compressive strength are then possible.
Quicklime addition can also be used if the soil is wet as this will help to dry it and break up lumps of clay.

Lime should be added to a soil at least 2, but preferably 8 to 16 hours before use to allow short-term stabilisation to take place making the soil easier to work and compact.
Lime is suited to soils with a relatively high proportion of clay and is added in proportions of 3 to 10% but usually at the upper end of this range. Local artisanal lime can be used but might not be as effective as industrial lime. In addition, a small quantity of Portland cement can be added to give additional stabilisation and reduce hardening time. Lime-pozzolana cement can also be used and the degree of stabilisation is likely to be similar to using hydraulic lime. Excellent results have been obtained with high lime contents (one part lime to three or four parts soil) for thin (approximately 5mm) finishing coats applied on mud plasters and floated smooth.

Gypsum
This is not a common additive to soils. It is not moisture resistant, therefore not suited to exposed wet conditions. Usually it is added in proportions of between 10 and 20% to sandy soils. Because it sets quickly it is best used by mixing small batches of soil and binder.

Soap
Soap is used to waterproof soil because it reduces its sensitivity to water by about 25%. It can either be mixed with the soil or applied as a surface finish. It is generally applied in very small quantities (0.1 or 0.2%) and because it is washed out by water, it needs periodic re-application if used as a surface finish.

Bitumen
Bitumen is added in the form of an emulsion that is in suspension in water or another liquid medium. On drying the bitumen forms a thin film which coats the soil particles. The main effect of adding bitumen is to improve cohesion and water resistance. However, if it is added in excess the compressive strength can be reduced.

Normally the quantity of bitumen to be added (excluding the solvent or water) is 2 to 3% for a cutback (solvent-based), or in the following proportions for an emulsion:
- 4 to 6% for a soil with a high sand content;
- 7 to 12% for low sand content soils;
- 13 to 20% for clayey soils.

The bitumen needs to be mixed with a small quantity of soil before mixing it with the remainder; the mixing needs not to be excessive to avoid breaking down the emulsion and making stabilization less effective.

Specialised Commercial Products
Specially formulated chemicals have been developed for soil stabilisation, generally for road construction applications. The exact formulations for some are commercial secrets. The quantities required are low, 0.1 to 1%, and best results are achieved with mechanised rather than manual mixing. The best known are silicates – sodium silicates, soluble in water, ethyl silicate, potassium and calcium silicate.

The need for additives
It should be noted that there is not always a need to add stabilisers. Soil properties will dictate need and there are many examples across the world of the effective use of unstabilised soil. Stabilisers also add significantly to cost.
If a stabiliser is deemed necessary the choice of which one to use will depend on a number of factors including:
- the part of the building on which the soil is used and its exposure to the elements
- the property of the soil which needs improving; e.g. dry strength, wet strength, water erosion, abrasion resistance, surface protection, etc.
- the level of improvement required
- the quantity of stabiliser required

- the cost and availability of the stabiliser
- whether production of the stabiliser is carried out locally or whether it needs to be imported.

The precise quantities of additives often need to be determined empirically by trial and error for each particular situation. The results of laboratory tests often cannot be transferred directly to field practice, although they do provide useful guidance and a starting point for field tests. In the field, relatively simple and inexpensive tests such as observation of block durability on soaking in water; the use of a simple press to assess the load a block can carry in flexure can provide information on stabiliser requirements. As preparation of soil mixes and their use for building is often carried out under less rigorous conditions than for testing a judicious compensatory increase in stabiliser dosage is recommended.

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