COBBAUGE

A GUIDE FOR BUILDERS

www.cobbauge.eu

CONTENTS

1 INTRODUCTION

1.1 What is CobBauge?

CobBauge is a modern, environmentally-friendly way of building solid walls that has been developed from traditional cob construction. It is a bio-composite wall material using two different density mixtures of clay earth and plant fibres built at the same time – a dense inner face that is loadbearing and a light outer face that is insulating.

The guide was produced as part of an E.U. Interreg pro

Watch ***FILM 1: Introduction to CobBauge***

1.2 Who is this Guide for?

This guide is written to help builders already familiar with earth building to adapt to the new CobBauge technique. It is part of a package of information to support the use of CobBauge, which also includes a Guide for Designers, a suite of short demonstration films on Youtube, typical design details, an NBS specification, and ECVET units of leaning outcome.

This guide is written for builders who have skills, knowledge and competence at VET Levels 3 and 4, and practical experience of building with earth materials, specifically cob. This is important as it directly relates to the structural performance of CobBauge. Prior experience of light earth construction, which relates directly to the insulating part, is less important. Experience of rammed earth, which is loadbearing and utilises formwork, is also relevant.

While the principal purpose of this guide is to provide practical guidance to professional builders with prior experience of earth construction, it will also be relevant as technical guidance to design professionals, and as an educational tool to students.

1.3 What Does the Guide Cover?

This guide describes typical processes for successfully sourcing, testing and mixing materials, using formwork and constructing walls in standard site conditions for typical building designs using CobBauge. It does not provide comprehensive information for all circumstances and ways in which CobBauge might be used.

It does not give guidance on making and constructing prefabricated panels of CobBauge, or of using spayed methods of construction. These are both possible, but outside the technical scope of this Guide.

This is a guide for building, there is a separate guide for design.

1.4 Copyright

This Guide has been produced as one of the outputs of the CobBauge research project, which involved six British and French partners with complementary expertise:

- Plymouth University (UK): Lead partner of the project
- Graduate School of Construction Engineers of Caen, (ESITC) Caen (FR)
- Regional Nature Park of the Marshes of Cotentin and Bessin, (PnrMCB) (FR)
- Earth Building UK and Ireland, (EBUKI) (UK)
- University of Caen Normandy, (LUSAC) Laboratory (FR)
- Hudson Architects, Norfolk (UK)

The INTERREG VA France (Channel) and England co-funded by the European Regional Development Fund (ERDF) through the Specific Objective 2.1: Low carbon technologies.

Further information can be found at the project website http://www.cobbauge.eu/en/

1.5 Liabilities

The contents of this document are intended to be used as a resource in training to improve the skills and knowledge of builders using CobBauge. The authors accept no responsibility for the design or construction of any individual projects which may be produced.

2 KEY THINGS TO KNOW AT THE START

2.1 Skills, Knowledge & Competence

If you are an experienced cob builder you should have no difficulty adapting to building with CobBauge, though you should take time to understand the aspects of process and materials that are unfamiliar and gain practical experience before embarking on your first job, though a training event.

If you are another type of experienced earth builder, there is more to learn, but your knowledge and experience is a good basis for developing this skill. Again, practical training is important.

If you have no experience of earth building, CobBauge is not an appropriate place to start and you should develop a general knowledge before developing this specialism.

2.2 Working with Consultants

It is likely that the Architects and Engineers who have designed the building are new to CobBauge and are also developing skills, knowledge and experience as designers. Further, they may be unfamiliar with earth construction generally.

It is beneficial for contractors to work closely with design consultants to ensure that they share a common understanding of the design, materials and processes involved in producing a CobBauge building. This will avoid misunderstandings and aid job efficiency.

The design team may look to the contractor to comment on design details, to advise on materials sourcing and mixes, to provide test samples and to advise on project programming.

2.3 Project Programming

CobBauge relies on air-drying on site, which depends on seasonal climatic conditions and site-specific variables. It is wise to avoid planning for construction during periods when weather conditions are cool, damp or otherwise unfavourable to air drying.

It can take some time to assess materials, define the specification, source and process materials. This may involve making and testing samples and should be undertaken sufficiently in advance of the construction stage.

Consideration should also be given to the movement, storage and processing of materials, as they can be bulky and require controlled moisture conditions.

2.4 Job Efficiency

As with any construction, estimating and managing the works efficiently relies on good preparation, appropriate skills and experience, and coordination with the rest of the project team. If this is your first CobBauge project you should undertake some training to become familiar with the technique and practice to develop your understanding of the rate at which it can be delivered and the options of how to achieve this for a particular job on a particular site.

2.5 Health & Safety

Health and safety regulations and measures applicable to other forms of masonry or shuttered construction are relevant and should be followed accordingly. While the materials tend to be less hazardous than conventional ones, special care should be given to managing dust from processing of dry materials and manual handling of heavy loads and mixes. The vulnerability of the structural strength of these materials to moisture could be seen as an unusual risk.

3. MATERIALS SOURCING & TESTING

CobBauge uses two elements - cob for the load-bearing inner face and light earth for the insulating external face. These are two different mixes of clay subsoil and plant fibres.

3.1 The Key Differences between the two Materials

The cob needs a well graded, clay subsoil that may contain sand, gravel and pebbles. The grading improves mechanical resistance and reduces shrinkage. Fibres for the cob mix may be waste from a number of different agricultural processes, typically straw, although using hemp or flax fibres will give stronger mixes.

For light earth, it is necessary to have a clay rich subsoil for strong adhesion between the earth and fibres and to limit the proportion of aggregate in the mix. Fibres, or more properly shivs, of hemp, reed or flax, are the best bio-aggregates for use in the light earth mix.

3.2 Sourcing Subsoils on Site

If there is adequate access, time and suitable geology, then it may be possible to use subsoil dug from site as the earth material. This potential is best assessed by site investigations and testing.

Field tests are perfectly adequate to assess smaller works, while larger and more expensive contracts will probably require a mix of field and lab testing.

Watch ***FILM 2: Sourcing Soils***

3.3 Field Tests for Earths

There are many kinds of field tests for subsoils and it is the combination of the results that can gauge subsoil suitability for the two CobBauge materials.

3.3.1 Sensory Tests

- Smell – to detect organic material, reject topsoil with an organic, musty odour.
- Visual - to discern the presence of large elements, stone, pebbles or gravel.
- Touch – to indicate the presence of clay, sand and silt. A golf ball sized piece of soft damp subsoil, (plastic state) can be squashed to see if it cracks (sand/silt dominate) or flattens smoothly (fines and clay dominate). A smooth bladed knife can be passed over the sample to leave a shiny surface indicating clay content. A fine silty soil will have a duller finish. It is also more difficult to wash clay from the hands after handling a sticky clay rich wet mix compared to a more silty one.

  Watch ***FILM 3: Sensory Soil Tests***

3.3.2 Cigar Test

To establish clay type and content (cohesiveness).

Plastic earth is shaped into a long even cylinder 3 to 4cm in diameter, up to 1m in length. If there are stones or large amounts of grit present these should be removed first, by hand or sieving.

The end of the cigar is slowly pushed over the edge of a table until a piece breaks off. This is repeated several times to give a number of similar sized pieces which are measured to find the average length.

An average length of less than 5 cm indicates very low clay content (needs extra clay). A cigar of 10 to 20cm may be used for cob. Beyond 20cm, the soil is likely to be clay rich and usable for light earth, but needs correction for cob.

Watch ***FILM 4: Cigar Test***

3.3.3 Shrinkage Test

To assess the risks of cracking during drying.

Test A - a quick preliminary test that works for fine or sieved subsoils without coarse aggregates. This tests can also be done with the final mix of soil and fibres for cob.

Make a 12cm long flattened length of plastic soil 1 cm wide and mark with a straight line with lines scored across it at the end of the 10cm line.

Test B will give a more accurate result using a larger sample and can be achieved with a coarser soil sample but stones should still be removed first.

Create a wooden shrinkage box (eg 50cm long, 5cm square in section) and fill to the top with plastic soil (this box is also useful to measure shrinkage of cob mixes).

In both cases, shrinkage can be measured when the soil is dry. Strong shrinkage indicates fine soil, high in silt and clay which will crack significantly during drying. For Cob, such soils require gauging with gravel, sand or fibre to achieve the target shrinkage of 1%. For light earth, this sort of soil maybe suitable.

Watch ***FILM 5: Shrinkage Test***

3.3.4 Breakage Test

To assess strength and clay content.

Mould a simple disc of plastic earth (remove larger aggregate first) in a PVC ring 5cm in diameter and 1cm thick. Once dry, the disc can be broken using the fingers. Easy to break means a low proportion of clay and/or a less strong clay type, hard to break, means clay rich soil or a strong clay type.

Watch ***FILM 6: Breakage Test***

3.3.5 Ball Drop Test on Soil

To assess plasticity and cohesion.

The plastic mixture used for testing the cigar can be used to form a ball 10--17 cm in diameter. This ball is left to dry for several days. Once dry, this ball is dropped from a meter high on a hard surface. If the ball does not break, the clay content is very high. If it breaks into a multitude of pieces, the earth lacks cohesion and therefore the proportion of clay is probably quite low.

Watch ***FILM 10: Drop Ball Test***

3.4 Laboratory Tests

The analysis of the earth can also be done in the laboratory using liquid sieving and sedimentation to determine particle size distribution and clay content. Plasticity and liquid limits can also be determined with the Atterberg test. Combined with the blue methylene test, this allows the type and activity of the clay particles to be determined.

In general cob mixes require 12 - 20% clay and light earth 60% or more of clay content (see NBS specification), but clay type and bond strength will also have a bearing on suitability of subsoils for each method.

Reading and understanding these raw laboratory results requires training and experience to relate them to building practice. But they provide a useful comparison with field tests and should be carried out whenever possible.

Engineers require a crushing strength typically given by a compression test.

CobBauge builders may be asked to prepare test cubes of different mixes to assist the design consultants in determining the mix specification.

3.5 Fibre Sourcing - Issues & Impact

Cereal straws are the traditional form of fibre for cob and do not require cutting prior to mixing. The CobBauge project has also shown the advantage of working with flax or hemp fibres for the cob element when this can be cut into short strands 10 to 20cm long. These two fibres perform better in mechanical strength in both tension and compression when compared to the cereal straws traditionally used. However, this does not prevent the use of other, more local straws by adapting the design of structures to lower strength

For the light earth element hemp shiv has particular advantages for mechanised mixing, speed of construction and reduced thermal density.

Straw is available from cereal farms. Hemp SHIV is also readily available as horse bedding. Other fibres and waste products from agriculture may be available locally or through commercial suppliers.

All fibres should be fresh, dry, with no decomposition, clean, free of seed heads, roots, leaves, flowers, insects, grasses and other contaminants.

The objective of mixing is to obtain a homogeneous material where the fibre will be completely coated by the soil in a plastic, viscous or liquid state depending on mix and placement in the wall system.

*Watch **FILM 7: Sourcing Fibres***

3.6 Aggregate Sourcing - Issues & Impact

It may be necessary to add aggregates to clay-rich soils to obtain good grading for the cob. Due to the negative carbon, pollution and biodiversity impacts of sand extraction, it is preferable to recycle waste aggregate, use local sandy or gritty sub-soils for gauging rather than new processed quarried materials. Ballast products can also be obtained from quarries which are less processed. These aggregates and subsoils can also be tested by sedimentation methods to guide optimal ratios for gauging.

*Watch **FILM 8: Sourcing Aggregate***

4 PREPARING THE COB MATERIAL

The inner face of the CobBauge wall is a load-bearing cob - a mixture of earth and plant fibre. Depending on the local, social and economic context, mixing can be carried out with animal or human feet, manually or mechanized.

4.1 Cob Material Preparation

Sub-soil can be sourced, dug and tested well ahead of the contract and may benefit from frost action during the winter months to aid mixing in the spring/summer. Subsoils may need to be covered if work is delayed to avoid seeds and organic material contaminating the mix.

Watch ***FILM 9: Preparing Cob Material***

4.2 Gauging Cob Mixes with Sand & Fibre

Once the field and lab tests for soils have narrowed down the selection of raw materials it is important to work through a range of mix tests and samples using different ratios of clay sub-soil, aggregate/subsoil and fibre. It is also possible to build small test walls ahead of the contract to test a final selection of mixes on a larger scale.

4.3 Ball Drop Site Tests for Mix Plasticity & Cohesion

To assess the plasticity of the mix, 2 litres of the cob mix is measured in a jug, shaped into a ball and dropped from 1metre onto a flat surface. The desired diameter for the cob mix splat is 21cm, give or take 1cm. This assesses the consistency of the Structural CobBauge mixture.

A suitable mix will have a diameter of 15cm for a firm piece of cob to 17cm for a softer piece. Both these mixes are useable but may have different attributes depending on the placement within the wall and site conditions.

Watch ***FILM 10: Drop Ball Test for Mix***

4.4 Box Gauge Site Test for Shrinkage

To test a mix for shrinkage, a wooden box (e.g. 50cm long, 5cm square in section) is filled to the top with cob mix (minus stones). Shrinkage can be measured as a percentage of the length of the box when the soil is dry. For cob we are aiming for less than 2% shrinkage, less than 1% is better.

Watch ***FILM 11: Shrinkage Test for Mix***

4.5 Measuring Material for Cob

in general the materials needed for cob will be 1.3 times the volume of the finished wall and approximately double that amount when measured by weight in damp materials. So 1 cubic meter of finished cob will be equivalent to 1.3 cubic meters of subsoil (1.5 tonnes by weight of dry soil, 2 tonnes of wet soil). These amounts will vary according to subsoil type and should be confirmed by weighing and measuring small samples ahead of ordering materials.

Straw amounts are approximately 1.65% of the weight of the damp subsoil.

4.6 Mixing Machinery for Cob

Various plant and machinery can be used: high-power paddle or forced action mixers allow water, soil and fibre to be combined in a few minutes, but in a relatively limited volume, typically 50% of the mixer volume.

For large quantities, like those needed to build cob walls, the operation has to be repeated several times. Depending on the volume and power of the mixers, they can be stationary on a site dedicated to the production of the mixture, or transportable to construction sites.

Site mixing has a positive impact on the carbon footprint of the mix, reducing the transport of materials. In terms of carbon footprint, the lowest impact during mixing is possible using site-based tractors, loaders or diggers. Crushing and blending of the mix can be achieved by repeated impact from tyres or using the digger bucket. This is also useful for gathering and moving the mix. This plant operates well on a clean concrete slab or within a shallow pit cleared of top soil. Other hard surfaces can be used but might compromise the mixture by adding extra aggregates. A digger with a long arm and bucket offers the greatest versatility in use, making it possible to extract the raw material on the site and to mix the various materials with relative precision by volume.

Mechanical loading and unloading machinery of the mixer may also be needed.

Watch ***FILM 12: Mixing Machinery for Cob***

4.7 Cob Mixing Method

It is often easier to start mixing with soil and water until you have a smooth, viscous mixture like a soft thick paste, then add fibre by scattering it over the top. Depending on the absorption capacity of the fibres, the mixture will firm up as the fibre is added. Large, dense lumps of fibres should be avoided as they will be difficult to breakdown and blend evenly.

It is often easier to mix the fibre in several phases. The bottom of the bucket allows you to crush, spread and knead the soil and fibre mix, similar to working bread dough. Alternating movements, bringing the mixture together and then spreading it out creates a homogeneous mixture quite quickly.

Once the right plasticity has been obtained and checked by the ball drop test. It should be gathered into a compact and homogeneous pile, then covered with a tarpaulin to protect it from the weather.

A one-day rest period allows the clays to activate their cohesive power more effectively, to soften the fibres and make the mixture more workable. After several days of rest, it may be necessary to re-mix briefly before building. Mixes can sit for a month or more if protected from the weather. In terms of binder content, their quality may improve due to the addition of cellulose by fermentation. However, as the straw will breakdown, there could be a loss of tensile strength so it could be necessary to add more fibre prior to building.

Watch ***FILM 13: Cob Mixing Method***

5. PREPARING THE LIGHT EARTH

The outer face of the CobBauge wall is light earth – a mixture of clay slip with plant fibres.

In the CobBauge process, we are looking for good insulation and sufficient mechanical resistance so that the light earth is self-supporting and well adhered to the structural cob. Using clay rich soil allows the fibres to be effectively bonded with as little earth (and weight) as possible. As well as having sufficient clay content (60%+) the breakage test in 3.3.4 can illustrate which subsoils are most suitable for light earth with or without processing.

5.1 Preparing Light Earth Material

This high proportion of clay may need long soaking in water and preparing the slip can be difficult work. Where quarried raw earth is used, it may be necessary to sieve the soil to remove larger grains (sands, gravel or pebbles).

In humid climates it may be easier to use liquid sieving: The extracted soil is soaked in a large container filled with water. After several days with regular stirring, more thorough mixing can be carried out with a paddle or belle mixer, then poured through a sieve over an empty tank. The mixture passing through the sieve will be used as the gluey slip, to bind the light earth while the coarser grains can be added to the cob mix or rejected.

It is also possible to use clay processed by others. These have generally been dried, crushed and sieved, or may be sludge washed from quarry sand. After checking the clay content these can be soaked in a tank with water.

Watch ***FILM 14: Preparing Light Earth Materials***

5.2 Slip Test for Light Earth

Light earth needs a test to check the viscosity of the slip before mixing it with the fibre.

This test is done using the sieved wet slip or slip prepared from sieved powdered earth. The procedure is simple and consists of taking 100ml of the freshly mixed slip using a measuring vessel.

The 100ml is gently poured onto a flat surface focussed on a central point. The flat surface must not be knocked or vibrated or it will impact the natural spread of the slip. The diameter of the disk is then measured.

A consistency suitable for the light earth in the CobBauge process will form a disc 14cm in diameter. More than 14cm and the slip is too diluted, which would give a loosely cohesive, friable earth, possibly usable as infill in a frame, but not suitable for a self-supporting element, well adhered to the cob and capable of carrying a coating. Below 14cm, it will be difficult for the slip to properly coat all the fibres. That risks using more slip than necessary and therefore more earth in the mix, which will alter the desired insulation properties.

Whatever the preparation technique, the viscosity of the slip must be checked before its use with the fibres. The activation time of the clays, especially when prepared from dry soil, may affect the viscosity. If it is too liquid, it can be left to settle and any clear water on the surface can be gently removed. If it is too viscous, water can be added until it has the desired consistency.

Watch ***FILM 15: Slip Test***

5.3 Measuring Material for Light Earth

In general, the volume of the wall will be equivalent to the volume of compressed hemp shiv required plus 5%. So 1 cubic metre of light earth will need 1.05% cubic metre of hemp shiv in a compact bale.

The rich clay subsoil required for this amount of hemp will be approximately 210kg of dry soil but this can be confirmed by mix tests:

Weigh a given quantity of slip, both wet and dry, to ascertain the water content by weight. Also weigh a given volume of compacted dry fibre (similar to the compaction in the final wall).

Once these materials are combined and have dried out, we are aiming for a density of 350 to 400 Kg /m^3 in the CobBauge process. This test may help eliminate soils that are not sufficiently clay rich, or where the bonds of the clay are weak. In any case measured and weighted samples of light earth are vital to make sure the materials are suitable for the job – i.e. durable and light enough and sufficient in quantity.

Watch ***FILM 16: Measuring Light Earth Material***

5.4 Mixing Method & Equipment for Light Earth

Once calculations of material amounts have been made, mixing of the light earth can be achieved using a rotary belle mixer. Fibres and slip should be loaded alternately to allow good coating of fibres. Then the mixture can be unloaded and stored, wrapped in a tarp or similar, on a clean non porous surface. Ideally it remains protected in this way for 24 hours to allow the mix to become softer, stickier and more workable in the formwork.

Watch ***FILM 17: Mixing & Storing Light Earth***

5.5 Testing Mix Samples for Light Earth

In the CobBauge process, the lightened earth mixture must be self-supporting and cohesive enough to avoid surface crumbling. For this, the mixture will be sufficiently loaded with slip to allow the plant fibers to clump and stick together. The slip must therefore be sufficiently sticky, and have suitable quality clays present.

The mix must also be rested time of the mixture before being used. Making the mix at least a day before using it, firms up the mixture and makes it more sticky, by evaporation of the water and absorbed by the plant fibers. A ball of mixture thus squeezed between the hands must stay stuck together, even under slight pressure from the fingers.

6. MAINTAINING THE QUALITY OF THE MIXES

Cob and light earth use soil from plastic to liquid state. Between these two extremes, the variations in workability can be significant so the optimum for each of the techniques is assessed by experience.

Depending on the earth used and the site conditions, variations in water content may change and have an impact on the mixing and the quality of the work achieved. Clay soils containing significant amounts of silt require the addition of a lot of water to see a significant change in how soft and workable the material becomes. A clay soil with sand predominating, on the other hand, will require very little. Preliminary soil tests (see 1.1 and 1.2) will therefore make it possible to assess the impact when water is added to the mixtures.

Even if small variations in water content don't seem to affect the build much, these variations can have consequences; on formwork removal, on shrinkage cracks, on the binding action of clay, or on the desired insulating properties of the system. So, it is necessary to maintain control procedures to ensure the final quality of the process and the work.

6.1 Maintaining the Cob Mix

With cob, the aim is to be sufficiently soft for compaction by foot, by manual rammer, or by hand, to drive out air voids and to fill tightly against the formwork. To assess the plasticity of the mix, the ball drop test can be used (2.5).

Beyond the test range of values, the cob will be difficult to use - either be difficult to compact and may require a pneumatic ram to remove the voids, or too sticky and soft meaning the formwork has to stay in place longer for the wall to harden. More significantly, it might also crack and lose mechanical resistance due to the loss of density.

While it is important to monitor and maintain the mix, many factors will effect the consistency and workability of materials including weather extremes, variability of ingredients within a batch of subsoil and human variability in mixing. All these factors will need a flexible and dynamic response to ensure quality control throughout a job.

6.2 Maintaining the Light Earth Mix

As long as suitable soil is used, there should be less variation with the light earth component as it is made relatively soon before use, the build process is quicker and therefore, there is less opportunity for the mix quality to change than is the case for cob. Storage from weather extremes, even for a short period, will ensure it remains humid and workable.

7. USING FORMWORK

Traditional cob is generally built without formwork. The plasticity of the material and the presence of fibres make it possible to pile up the cob and shape the wall to a height limit defined by the quality of the soil, the plasticity and fibre content of the mixture, and the width of the wall.

The absence of formwork often requires building the wall overly thick and reshaping it after a short drying time. This work can be monotonous and time consuming and may be affected by weather. The use of formwork voids this task.

7.1 Formwork Types & Systems

Solid-faced formwork complicates cob building; cob hardens by evaporation and not by chemical reaction as for cement concrete and solid faced formwork prevents the evaporation necessary for cob to dry. In addition, the suction effect of the mix on a flat surface such as plywood, makes it very difficult to remove the formwork, even immediately, without the risk of wall deformation.

Light earth, unless sprayed, can only be installed using formwork. Although the mixture becomes cohesive as it dries, it cannot be shaped free-form like cob, the amount of clay in the slip being too low to effectively bond the fibres.

These contrasting needs of the two mixes mean that CobBauge is built using a moveable formwork usually used for concrete, with the normal plywood skin replaced by a metal-framed panel of wire mesh. This perforated skin offers little contact surface with the earth mixes, allowing them to dry within the formwork, enhancing drying times due to increased surface area of wall, and enabling simple and rapid removal of the forms.

*Watch **FILM 18: Formwork Systems and <u>Film 19: Mesh Formwork</u>***

7.2 Formwork Progress & Height

Formwork for CobBauge can rise vertically, but it is not possible to form and install a full height section of wall as the mesh tends to prevent the shrinkage and settlement of the earth which occurs during drying.

At most, a height of 1.2m -1.4m, that’s two lifts of formwork 0.75m high, is possible.

Horizontal progression with formwork is possible and allows earlier lifts to dry and harden before building up further. The forms are positioned to pinch or hold the plinth or lower lift, which defines the width of the base of the wall. Ties sit directly on the wall section below. Horizontal and vertical adjustments are necessary to ensure the proper execution of the work. The formwork must be properly supported on the sides by props (push-pull or similar).

7.3 Formwork Ties, Tightening & Removal

When materials are loaded into the formwork care must be taken not to shift it out of plumb.

Ties and spacers should be placed at the top of the formwork directly above those on the wall below. Some of these can removed once the formwork is filled. Tie rods do not need to be protected from binding with the mix and can be removed before the soil is completely dry. After freeing with a simple tap (mallet or hammer) they can then be easily pulled out.

It is preferable to leave the formwork in place for at least one week, ideally three, particularly if the cob has been mounted over the full height of the formwork, ie 60cm. The formwork can even remain in place longer if additional clearance is available, while the next lift is implemented. This avoids any risk of deformation during the drying period. But this makes it more difficult to recut the cob wall in particular, especially if you want to leave the cob exposed and rework its surface.

Formwork can be safely removed when the cob mix is at between 13% to 15% moisture content. The moisture content can be measured using a Clegg tester. Alternatively, a core may be taken from the centre of the wall and a sample weighed, dried and weighed again to ascertain the percentage of moisture.

The testing of moisture is most critical in lifts which will be built upon, the ultimate lift which won't have more CobBauge added is less at risk than those that do.

*Watch **FILM 20: Formwork Removal***

8. BUILDING WITH COB & LIGHT EARTH

The CobBauge construction method aims to simultaneously install load-bearing walls and insulation using cob and light earth.

For good durability the external light earth must adhere properly to the internal load-bearing cob. The aim is to slightly overlap the cob with the light earth in successive layers of about 200mm in height. This arrangement strengthens the mechanical link between the load bearing wall and the insulation.

Watch ***FILM 21: Strength of Bond***

8.1 Using Temporary Falsework

Before filling, a removable falsework form is placed inside the formwork to set the thickness of the cob and produce an angle on the internal cob face. This allows the light earth to partially overlap or 'tooth' with the cob. When the next layer is made, the cob will in turn partially cover the light earth, thus creating the desired key.

Watch ***FILM 22: Using Temporary Falsework***

8.2 Blocking Out for Openings & Services

Blockouts for opening may be built in a number of ways. Briefly blockouts have either to be collapsable after use for removal or planned in such a way to allow them to be slid out. As with the formwork sides blockouts faced with a mesh allow openings to dry at the same rate as the sides of the walls. Care should be taken to remove blockouts in good time not to prevent particularly vertical shrinkage.

Watch ***FILM 23: Blocking Out Openings***

8.3 Loading & Compaction of the Cob Mix

Once the intermediate falsework is in place, the cob mix can be dropped into the formwork using a front-end loader, a telescopic bucket or by manual means (bucket, shovel). The mixture is then tamped in place by foot or tamper to expel voids and ensure density.

A visual check can be made through the mesh to check that the mixture is well compacted at the edges and faces and that there are no voids remaining. This check is especially important if the wall finish is exposed without coatings.

Once the first layer of cob has been filled and compacted, the temporary falsework can be removed. The outer edge of the cob can be pushed back onto the layer below as removing the falsework sometimes lifts it slightly.

Watch ***FILM 24: Loading & Compaction of Cob***

8.4 Loading & Compaction of the Light Earth Mix

The space adjacent to the cob made by the falsework is then filled with the lightweight earth mixture. Light earth is easier to load manually with a shovel from a storage area near the formwork, on the scaffolding, or from the bucket of a telehandler. This mixture should be lightly tamped. Too much tamping makes the mix dense and less thermally efficient.

Watch ***FILM 25: Loading & Compaction of Light Earth***

8.5 Quality Control on Compaction of Both Mixes

The damp cob is not compressible in itself. The trampling of this mixture in the formwork, or use of a wooden rammer, simply drives out air creating a more homogeneous material. It is the regularity of the thickness of the cob (layer about 10cm thick) which makes it possible to avoid keeping voids. Visual control can be exercised through the mesh of the formwork. If voids are seen, further compaction is required.

With the light earth, it is also the regularity of the thicknesses of the layers of mixture that avoids creating voids. Regular, light compaction until a rebound effect is felt, ensures the regularity of the density of the mixture.

8.6 Speed of Build

The thinner the layers, the more rapidly the mixes will dry, sufficient for another layer to be added. In tests, makings layers 30cm thick reduced the drying time by a third. This technique can therefore speed up the build process, in particular if the building is large enough for the circumference of the walls to allow continuous assembly.

On-site measurements show that full-level, mechanized installation requires approximately 6 hours/person/m² of wall. This time increases to 8h/m² when the build is done manually on the ground floor, or on an upper floor.

8.7 Finishing & Cleaning Surfaces

Once the light earth has been compacted to the same level as the cob, the temporary falsework is replaced to begin a new layer.

Check and clear any light earth that has fallen onto the cob to avoid creating a weak point in the load-bearing element.

The process is repeated until the top of the formwork is reached. For each layer it is necessary to ensure that the surface of the cob and light earth are level to allow the installation of the formwork for the next lift.

It's also necessary to remove any surplus cob that may have squeezed out of the mesh panel with a scraper or a trowel. This operation makes stripping the formwork easier. The same operation can be carried out on the light earth side, removing longer fibres from the face of the mesh, but it poses less of a problem in the formwork stripping phase.

Watch ***FILM 26: Surface Preparation & Finishing***

8.8 Building in Lintols

The light earth does not in itself have the capacity to take up the loads transmitted by a lintel. It is therefore necessary to transfer the loads of the lintel onto the load-bearing cob. To do this, several solutions are possible and shown in the drawn details.

One option shows brackets perpendicular to the facade at the top of each opening jamb, covering both the cob and the lightened earth. The lintel, made up of several pieces of wood, is placed on these plates. The weight of the cob placed above the lintel will prevent the latter from leaning too much on the lightened earth.

Another solution is to make the lintel using marine plywood covering the entire surface to be crossed and the supports on the jambs. Reinforcement with several solid wood lintels are fixed on top of the plywood. The sections of these parts are to be calculated by an engineer

Watch [***FILM 27: Building in Lintols***]()

8.9 Doors & Window Openings

Openings are made using formwork placed inside the mesh formwork. Complete formwork should be avoided. This rigid formwork will indeed prevent settling and shrinkage of the cob during its drying and will cause the appearance of cracks at the ends of the lintels, as well as making it very difficult to strip the formwork from the openings. It is better to provide a formwork the height of the mesh formwork which can be removed at the same time as the main formwork as the elevation progresses.

It is necessary to provide something to fix the door or window to. The fixings can be directly screwed into the cob using large screws (20cm minimum). This requires a cob without too many stones which could obstruct screws. Another solution is to embed pieces of wood anchored in the wall in the cob, dovetail shape to resist pull-out.

If the window must be placed in line with the light earth, the window must be fixed in through the light earth into the cob. The light earth alone is inadequate to fix to and fixings have to reach the cob.

Watch ***FILM 28: Door & Window Openings***

8.10 Connections With Other Materials

The main problem with connecting cob with other materials is shrinkage of the cob and settling as it dries. It is necessary to find provisions allowing cob to slide in contact with more stiff materials, or to be connected by fixings flexible enough to move under the action of the settling of the wall. A mechanical link can be provided by making rebates.

This problem of settlement during drying must be taken into account in the design of the building and the organization of the site to ensure that the main settlement is achieved before putting in place the elements resting on the different materials.

Watch ***FILM 29: Connections With Other Materials***

8.11 Managing Drying & Shrinkage

It is important that drying is as regular and homogeneous as possible. Drying will vary according to the exposure of the walls to the wind and sun. You should avoid water hitting the walls. Protection of the wall heads is therefore necessary during the construction phase until the completion of the roof. Once the roof is in place, the drying process must still continue. If the building is enclosed too quickly, drying will be slowed down. It is important to maintain active ventilation of the interior or to increase the circulation of air by using fans. Heating does nothing compared to air circulation.

Watch ***FILM 30: Managing Drying & Shrinkage***

8.12 Integrating Services

With electrical networks, it is possible to set conduits within the cob during its build. The compaction being light, the risk of crushing the conduit is very low. The conduits must be covered with about 10cm of cob to avoid cracking during drying. The conduits can be connected to a standby box fixed to the grid of the formwork in its final location.

Another method is to fit cables later into the dry wall. A channel can be cut out 4-5cm deep. The cables are pressed against the back of the channel and fixed. The channel is then filled using an earth mortar. It will be necessary to mesh over to avoid cracking in the plaster

Watch ***FILM 31: Integrating Services***

8.13 Secondary Fixings

In a cob with few stones, it is possible to fix by direct screwing. It is necessary to provide large screws to dig deep and resist pull-out. It is possible to build in wooden dooks during the build to fix to. This requires anticipating locations and settling and shrinkage during drying. It is also possible to push in wooden dowels after having pre-drilled the cob to a slightly smaller diameter.

Watch ***FILM 32: Secondary Fixings***

9.0 FINISHES & AFTERCARE

Watch ***FILM 33: Finishes & Aftercare***

9.1 Internal Finishes

WARNING: Any finish applied to CobBauge must have a high level of vapour permeability in order to maintain a stable moisture content. If impermeable finishes are applied they could compromise the structural strength of the wall, as well as its thermal performance.

CobBauge can be left fair-faced internally, without an applied finish. This will leave a tough, grid-textured finish. A clear glaze could be applied if surface dusting is a problem due to soil grading.

It is also possible to slightly re-cut the surface of the cob so as to remove the relief left by the mesh of the formwork. It is necessary to avoid beating the wall as in the traditional technique. This threshing on the still plastic cob creates vibrations in the wall which can contribute to separating the light earth and the cob.

A wide range of vapour permeable coatings can be applied to CobBauge internally, including lime and clay plasters and breathable paints. The texture of a CobBauge surface provides a good key of plaster, but educes paint coverage.

9.2 External Finishes

WARNING: Any finish applied to CobBauge must have a high level of vapour permeability in order to maintain a stable moisture content. If impermeable finishes ae applied they could compromise the structural strength of the wall, as well as its thermal performance

CobBauge cannot be left fair-faced externally as the light earth is insufficiently robust.

A wide range of vapour permeable coatings can be applied to CobBauge externally, including lime and clay renders. Breathable paints on their own are not an adequate finish, as they require a render to be applied first.

Timber and other forms of cladding can be used on CobBauge walls, but cannot be fixed directly to the light earth, requiring a timber subframe to fix to.

9.3 Aftercare

After the CobBauge walls have been built, it may be necessary to protect them during the subsequent construction stages to prevent accidental and weather damage. The need for this should be assessed according to the individual conditions of a project.

The site manager and other contractors should be made aware of the vulnerability of the external face to impact damage and to the wall as a whole to water damage.

9.4 Maintenance

CobBauge walls require minimal maintenance. They should be periodically inspected:

- to ensure they are protected from sources of moisture
- to identify any impact damage
- to monitor the condition of finishes