# WPT1

# An innovative mixing and building method

## Parc naturel régional des Marais du Cotentin et du Bessin

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## 1 – Mixing

### 1.1 Current techniques

The traditional mixing of the cob was generally carried out by foot treading, by men or animals. In modern times, several methods have been used to make it easier to prepare the volumes of mixtures required. They have generally been developed according to the volume to be prepared and the economic model of the construction project.

Mixing with animals – Meti School worksite Rudrapur Bangladesh – Anna Heringer architecte

The inventory carried out makes it possible to distinguish the achievements made in a conventional economic framework from those carried out in a participatory or self-construction framework, accompanied or not. Regarding the latter, the mixing processes often remain close to traditional techniques, mainly foot treading. A tarpaulin on the ground allows the mixture to be turned over, which a small group of individuals then trample on.

Mixing by foot on a tarpaulin, cob training, april 2018, Les Grands Ateliers de L'Isle d'Abeau

In a particular implementation principle known as “caillibotis” (duckboard) (Brittany) or “gazon” (turf) (Normandy), the mixture is more basic, consisting of alternating a layer of straw, a layer of earth then a layer of straw simply trodden then underfoot to amalgamate straw and earth into a slab 5 to 10cm thick.

Mixing for caillibottis – Building site Terre crue Gihslain Maetz,  St Germain sur Ile (F)

In the case of work requiring little volume, foot mixing can be used by craftsmen. But some have developed the use of the concrete mixer. This technique works with firm mixtures or on the contrary very viscous and made with short fibres (less than 10cm long). Viscous mixtures may require standing time for the mixture to loose water and firm up.

Mixing with a concrete mixer - renovation Dartmoor (UK)

For larger projects, companies have tested several techniques

Tractor/loader:

The principle consists in using the relief of the tires of a vehicle, associated with its own weight. The back and forth on the mixture allows to crush water / earth and fibres. Construction machinery equipped with a bucket can collect the mixture if necessary and turn it over regularly. This technique is generally used on a clean slab of the silage slab type. This avoids the contamination of the mixture by topsoil for example.

Mixing with a loader – building site Les Frères Bon, St Hymer (F)

Mixing with a tractor on a silage slab – Cob oven training course PnrMCB, Marchésieux (F)

Digger, excavator:

The mixture is no longer carried out with the rolling equipment of the machine, but using the bucket mounted on the arm of the excavator. A kneading movement is performed by the pilot allowing crush, regroup the mixture. The mixing area consists of a simple stripping of the topsoil, or in the hole left after extraction of the earth, like a mixing pool.

Building site Kevin Mc Cabe, Keppel Gate Devon (UK)

 Chantier Michel Capon, St Georges de Bohon (F)

Mixers :

Planetary mixers are also used. They can be mounted on a carrier vehicle, an agricultural tractor for example. In this case, mixing is often done at the construction site. They can be fixed in a production site, brickyard or depot of a masonry company. In this case, the mixture is transported to the building

Mobile planetary mixer – Renovation site, Daviaud open air museum (F)

Cob/daub planetary mixer – Brickyard Lagrive, Glos (F)

A brickyard mixer with twin horizontal augers has also been tested in Brittany by IFSTAR and “Collectif des Terreux Armoricains” for the production of a firm mix with a low water content. This process met these objectives with regard to the water content, but did not work properly with the addition of fibre (wheat straw). Tests have not been made for more viscous mixtures, the objective of the experiments being to optimize the height of elevation/drying time ratio.

Horizontal brickyard mixer test, ECOMATERRE R&D project – IFFSTAR et Collectif des Terreux Armoricains, Nantes (F)

Tests on a horizontal shaft mixer of the helical screw type were also carried out by the Manchoise company "Les Frères Bon" in 2009. They were not conclusive. Mixing with long straw fibres was bad, with the fibres getting stuck around the continuous helical blades to the point of jamming the mixer.

Tests also seem to have been made with mixing bowls, agricultural equipment for mixing fibres to prepare animal feed. As part of this study, we have not had any feedback, but the contacts made within the framework of cobbauge with manufacturers have alerted us to the fragility and the risk of premature wear of equipment designed for knead vegetable fibres, and not to resist a heavier, viscous and abrasive mixture like earth.

## 1.2 Tests carried out within the framework of cobbauge

Following the first compressive strength results indicating good performance of mixtures made with raw hemp straw or raw flax straw, the PnrMCB undertook, as part of its full-scale tests, to make mixtures using different types of material. A total of five tests were carried out.

### <u>1.2.1 Excavator and long hemp straw</u>

In this test, an excavator traditionally used during training course by the PnrMCB to prepare traditional mix of earth and straw, was mobilized. The fibre tested was for this first trial raw hemp straw, that is to say long (between 1 and 2 m in length), provided in the form of a round baller.

In the usual case of mixing with straw, mixing with the bucket makes it possible to crush, cut the fibre to amalgamate it homogeneously with the plastic soil. In the present case, this fine mixing could not be obtained. The hemp was quickly separated from the fibre and broken into smaller pieces by the mechanical action of the arm and the bucket. But the released fibre did not cut, and agglomerated in tangled clusters totally impossible to dislocate. Mixing has become extremely difficult to the point of damaging the excavator engine. The mixing could not be carried out until a homogeneous mixture was obtained. The inhomogeneous mixture was partially implemented on a test wall.

Observation: Long hemp fibre is too strong for mechanical mixing with an excavator to redivide the fibres. The mixing process becomes much more difficult, straining the material excessively. The mixing time becomes too long and dangerous for the material. The mix with its imperfections is extremely complicated and physically taxing. The test is therefore not conclusive on a long resistant straw.

### 1.2.2 Excavator and cut hemp straw

Following this first test, a second one was carried out with a similar excavator, but working with raw, cut hemp straw. After an exchange with the hemp supplier (Agrochanvre), he provided us with a straw from a round baller cut into 8 parts using a cutter, the only cutting equipment his production line had. The strands obtained oscillated between a length of 10cm and a maximum length of about 60-70cm.

Observation: the mixing could be done in a slightly more homogeneous way. But it was long and painful for the machine which again gave way under the demands of power. But the phenomenon of agglomeration of the fibre separated from the hemp shiv also recurred, on a smaller scale, but enough to make use and implementation difficult. The mixe was used for two of the scale 1 wall tests.

The test remains inconclusive with regard to the time spent (nearly 2 hours for 2.5m$^3$ of mixe), the energy consumed and the difficulty of working the mixe afterwards. On the other hand, the test suggests that the use of hemp straw cut into short strands of less than 10cm is probably a good alternative. Those are indeed the still long strands of more than 30cm which caused the amalgams in balls

Excavator kneading test with cut raw hemp straw – balls of poorly mixed fibres are noticeable

Following this test, contact was made with the hemp supplier to study the feasibility of a different cut of the raw straw to obtain strands 10-15cm long. In the current state, the organization of the Barenton's production chain (F – 50) does not allow the raw straw to be cut so regularly. The only proposal made is to supply loose fibre separately, the strands of which measure between 7 and 20 cm long, and hemp, produced respectively for insulation and insulating coatings. While there is no doubt about the ability of hemp wool to be mixed properly (pieces 1-2cm long and not stringy), the doubt is greater on very stringy hemp wool, with rough fibres s clinging to each other, therefore more difficult to "card", to separate from each other for a homogeneous mixture. The risk of forming clusters, balls remain major.

### 1.2.3 Mixing bucket and raw flax straw

The bibliographical research on the mixing processes used in the agricultural and construction fields has made it possible to identify mixing buckets as an avenue to explore. The interest lies in this type of equipment in the possibility of managing with a single carrier machine the loading of the mixer, the mixing and the dumping on the construction area of the work, including at height. We immediately eliminated mixing buckets with helical blades because of the known experience on this type of device. This eliminates much of the material available from manufacturers for Public Works. Three manufacturers were contacted, two on agricultural equipment, and one on construction equipment.

Mixing bucket Melodys 50– EMILY

Bucket desilter mixer with vertical screw BMV – ROBERT


Mixing bucket BB610 – WARZEE

Only the bucket supplier TP (WARZEE) responded and put us in touch with a farmer in Normandy who had equipped himself with this equipment to prepare his cob mixes to build his home.

We were able to carry out tests with him using the soil he had on site (Courtonne-la-Meurdrac (14)), a fine silty-clay soil, and fibres that we brought on site, raw flax straw, hemp fibre and hemp shives.

The first test was carried out with raw flax straw in 50 to 80cm long strands. After loading the bucket with earth and water, mixing began to obtain a viscous mixture. Once the correct viscosity was obtained (judgment by eye in the absence of tests on this soil) the flax straw was added. The mixer connected to the arm of the tractor made it possible to reverse the direction of rotation of the blades.


Mixing soil and flax straw with Warzee mixing bucket

The first observations show a good ability to knead these fairly long straws, which are easier to break than hemp. The inversion of the rotation makes it possible to regularly release part of the straws remaining attached to the blades and in particular to the planes fixed at their ends. But there is still a fairly large amount. We can mention on this point the low power of the tractor feeding the mixer. The latter probably does not rotate at maximum capacity, which probably limits the tearing effect of the fibres caused by the speed of rotation and friction, and also impacts the preparation time (although already short compared to the mechanical excavator test) or here 15-20mn not optimized for 300l of mixture with two operators (1 at the control of the tractor to manage the rotations, and one at the fibre loading).

The bucket is easily emptied by tilting and rotating the blades to unhook the mixture. A modest part remains stuck to the blades.


Emptying the mixer

A second mixture was made by trying to incorporate hemp shive and hemp fibre added one after the other. The mixture with the hemp shives is done without any problem, in a very homogeneous way. But the addition of fibres made more problems, the fibre remaining in a ball difficult to separate. The rotational movement and the friction orient the balls into long cords winding around the axis or the blades and difficult to break. The mixture is therefore not very homogeneous, complicated unloading with more loss, part of the mixture remaining clinging to the elements of the bucket.

Mixing of soil, hemp and hemp tow with Warzee mixing bucket

### 1.2.4 Stationary planetary mixer and raw flax straw

The third test was carried out within the company Meslin & fils in Le Neubourg (27). The company already produces ready-to-use cob from local silty-clay soil and wheat straw. The mixer is a concrete planetary mixer with a theoretical capacity of 1.5m$^3$, i.e., a maximum potential production of 600l per shift. The mixer is fixed, powered by a three-phase electric motor. The loading is done by an elevator in height, and the unloading by a hatch directly in big bag or in the bucket of the elevator.

Stationary planetary mixer – Meslin Company, Le Neubourg

The mixer has undergone some modifications making it more functional for soil mixtures. A welded cone above the central axis returns the soil to the mixing ring. The blades have been modified to eliminate some of the flat planes. The mixing is probably a little less efficient, but the fibres remain, according to the craftsman, much less stuck on the blades.

The test is done here with raw flax straw, so with a length of strands of around 50-80 cm long. The earth/water mixture is made first so as to obtain here a plastic mixture, therefore firmer than the mixture made with the mixer bucket

Mixing of soil and flax straw with planetary mixer – Meslin Company, Le Neubourg

Straw is incorporated during rotation. It is quite fast. At first, the straw remains punctually attached to the blades, but the speed of rotation and the friction of the firm mixture ends up "cleaning" the blades. The mixture is much firmer than what the craftsman usually does. It “dries up” during mixing, as the strands of straw break, divide between fibres and shives, to the point of becoming too firm and blocking the mixer at the end of preparation.

Mixing of soil and flax straw with planetary mixer – Meslin Company, Le Neubourg

Emptying must be done partially by hand before the mixer can be restarted to test its ability to empty through the hatch. This emptying is done perfectly, leaving the inside of the mixer quite "clean".
La vidange doit être partiellement faite à la main avant de pouvoir remettre le malaxeur en route pour tester sa capacité à se vider par la trappe. Cette vidange se fait parfaitement laissant l'intérieur du malaxeur assez « propre ».

Detail of fibre mix with flax straw

The mixe obtained is perfectly homogeneous. The fibre is cut, separated, forming an extremely fibrous material, almost micro-fibrous like modern ultra-high-performance concretes. The plasticity obtained, extreme for the material, corresponds to the plasticity tested on a construction site in Calvados (realization by the Bon Brothers, Canet architect design, St Hymer) where the cob walls were made in the form of trumeaux walls mounted in 1 day on 2m in height while a traditional cob lifting is generally 80cm in height.

This test is particularly conclusive on the quality of the mixture obtained, its very good volume/mixing time ratio (15 minutes between loading and the end of mixing for 600l of preparation with a single operator)

### 1.2.5 Conical mixer with multidirectional mixing and flax straw

As part of the construction of the test wall at ESITC Caen, we were able to test a fourth variety of mixer. This is a mixer whose tank is conical where the mixing is carried out by peripheral arms and a central axis rotating in the opposite direction and at different speeds. This is equipment designed for concrete, here in a small volume version for the ESITC laboratory.


Conical mixer KNIELE – ESITC Caen

As part of this test, the soil used here corresponds to one of the soils studied by the ESITC, and the flax straw has been previously cut into strands 10 to 20cm long. The principle of mixing makes it possible to obtain a homogeneous mixture in a very short time. Here each mixture is made in nearly 5 minutes, first earth and water, then quickly half of the fibre and the rest shortly after, but on small quantities of the order of 70l of mixture.

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Earth and water mixing with multidirectional conical mixer

The resulting mixture is very homogeneous, with a slight shavings/fibre separation which may be less substantial than in the mixture made in the previous test. This may be due to the fact that the straw was cut.

However, the mixing time reduced to the volume/person mobilized ratio is average. In 1 hour, approximately 600l of mix was prepared by 2 operators. This is largely due to the scale of the mixer, and its feeding principle. Its volume required multiple loading/unloading operations. In addition, the equipment is designed for a supply of dry and fluid materials, with controlled granulometry. The soil used here, although dried and coarsely crushed, could not pass from the loading hopper to the mixer. It was therefore necessary to feed manually through a second cleaning hopper interrupting the mixing at each manipulation. In addition, the principle of multidirectional mixing requires several motor blocks located on a cover above the mixer, which prevents the tank from being fed by a raw dumping of the mixture.
earth. A feed hopper is required

Addition of flax straw with multidirectional conical mixer

The result is therefore a very good quality and efficiency of the mixing itself, but a design of equipment that is not suitable as it is for the use of soil and fibres. Adaptations should be studied with the manufacturer.

Detail of the mixe obtained

A horizontal shaft mixer of the type used by IFFSTAR was available and provided for in the tests. But the Breton experience having already demonstrated the difficulty of mixing the earth and the fibres, the test with the more resistant fibres such as flax and hemp was not considered relevant..

### 1.3 Conclusions

It emerges from these various tests that the fibres tested, hemp in particular, are difficult to use with traditional mixing (foot, mechanical shovels) without prior work of cutting into small-sized strands (10 to 20cm maximum). The contacts made with the processors of the flax or hemp industry indicate that this preparatory work is complicated in the current organization of the sectors. These straws should be cut during harvesting by adapting agricultural equipment such as a corn silage machine. This is something it seems possible for hemp. But the nature of these plants, in particular the silica content, makes the actors of the agricultural world fear a lot of difficulty in the operation and premature wear of the equipment. In addition, with regard to flax, the project made it possible to use flax that was unsuitable for the textile sector, and therefore to recover waste. However, in the process of transforming flax, the determination of its quality of use only occurs once the flax has been cut and retted. There is therefore here a bias to be defined for CobBauge.

As a result, two mixers today seem the most suitable for versatile mixing: the mixing bucket and the planetary mixer. The mixer bucket can be used on site, therefore easy use of local soils. It will be advisable to try this type of material with a more suitable power ratio. It will also be necessary to study more closely in real site conditions the capacity of the carrier machines to manage the loading of the bucket, the mixing and to mount the mixture directly on the wall. It is indeed in this ability to be mounted on a single machine allowing to reach the different workstations that lies the main interest of this tool.

The planetary mixer seems to give the best results in terms of volume/time/quality ratio. But the principle of electrical power makes mobility on site less obvious. The fixed mixer seems, in this configuration, more relevant, but it induces more substantial transport of materials, in particular in the case of the use of earth extracted on the site of the construction site.

It will therefore be necessary to supplement these initial tests with work on the energy consumption of each of the possible configurations so as to determine the most efficient case or cases in terms of reducing $CO_2$ emissions according to the site configurations taking into account the source of the land and the distance between the construction site and the mixing area, and the consumption of the mixer.

## 2 - Implementation

### 2.1 Usual techniques

**Traditional fork implementation**

This principle of implementation requires at least two people. The implementation is done as much as possible standing on the head of the wall so as to control the place and the arrangement of the clods of earth. One person is therefore mobilized on the wall, the second having the task of providing it with forks of soil that are homogeneous, compact and of the most constant volume possible.

The clods of earth are placed by placing them first on the ends and then in the centre. The overlapping of the forks with each other, from side to side and from bottom to top, must be ensured at all times to ensure the homogeneity of the wall and to avoid saber-cut cracks which would create cracks and cracks. weaknesses in the masonry. The plumb on both sides of the wall must be constantly checked so as not to have any irrecoverable hollow afterwards, or excessive overhangs which, in addition to the excessive mobilization of raw material, mainly risk creating a collapse of the wall.

Traditional fork implementation

Once the lift has been completed, it must be beaten again with batons or a tool handle to rectify the plumb and absorb the slight hollows. This also improves the density of the soil on the surface, making it easier to cut the soil after a short drying time.

The cob is left between half a day and two days to firm up on the wall before being recut using a flat spade called a paroir, or a hoe, or even a hay cutter after having taken the final balance of the wall. This work is particularly demanding on the physical level and represents almost a third of the overall implementation time of the wall.

Cutting the wall facings

### Traditional English implementation

L The organization of the site is quite similar. The cob is taken from the ground and is then placed on the wall in a thin bed. The difference is at this point. The mason posted on top of the wall moves what has just been laid if necessary, then crushes the clods laid with his foot to bind them together and densify the wall. Straw can be added on top to limit punching and improve the hold of the still loose cob. The mason works constantly on what has just been laid, unlike the Norman method, which does not return much to what has just been shaped and laid.

Using his spade fork, he will also take care to remove the excess cob from the facings to prevent collapse. The removed material is immediately put back in place on top of the wall.


Work of the facing with a spade fork

In order to limit the overhang and to obtain a good surface condition when recutting, and therefore to avoid hollows or gaps, the facings are regularly beaten using the heel or the top of the foot. It can also be beaten with a stick, with the flat of a spade or large mallets or wooden bats.

Once the lifting height has been obtained, the wall is tightened with a pitchfork or bat before being recut after a short drying time.

The work of recutting the wall is the same as in France. However, the tools can vary a bit; There doesn't seem to be a specific paroir type tool. It is the hoe or the spade which are most regularly used. The stick is more frequently used than the stick.

## Control of the ratio height/width/plasticity of the mixture :

The plasticity of the mixture greatly conditions the height of elevation possible during implementation. The plasticity of the cob mixture depends on the granularity of the earth and mainly its clay content, the amount of water and the fibre content added during mixing. The lifting may be significant for a cob made with clay soil, very loaded with straw and quite firm (lifting of 1m or more). It will be much more limited with loamy soil, lightly loaded with fibre and softer (30 to 50cm in height). In the absence of standardized tests to assess this plasticity/elevation height ratio, it is up to the mason to assess the limit of this height before subsidence or collapse of the wall. This evaluation is made by feeling the subsidence, the widening during the laying of the forks, or in the case of the "English" cob under the weight of the mason walking on the mix.

As part of a study carried out in Germany (C. Ziegert 2003), the height/width ratio (slenderness) of lifts measured on existing buildings (Leipzig region) oscillates between E=1.3/1 and E=1 ,8/1. In contemporary construction, for a good mastery of the technique, a ratio greater than E=1.5/1 should be avoided (source: building with earth, Röhlen/Ziegert – Paris 2013 – p194).

## Traditional Variations

*"gazons, pâtons ou caillibotis"*

The soil mixe was prepared firmer than for the cob implemented with the fork and was compacted in the form of a ribbon of about ten centimeters thick.

Clay dough pieces are cut with a spade or with a sharpener to dimensions of around 20x30cm, 10x20cm in the contemporary version by Ghislain Maetz, depending on the geographical area and the thickness of the wall to be built.

The clay dough pieces are then flattened against the wall either in horizontal beds or in oblique beds (opus spicatum) by placing the clay dough pieces in staggered rows to avoid saber cuts.

Clay turf tests, training in experimental archeology – Lattes, 2009

As the clay dough pieces are firmer, the facings are built at their final plumb. Recutting the wall is normally not necessary.

Once the lift has been implemented, the facings are tightened with a stick.

*Cob on plant beds*

This rarer technique consists in implementing a plastic mixture of earth and water, often devoid of any plants, on a fairly low thickness of 6 to 8cm, alternating with a bed of plants, straw, heather or other, arranged longitudinally or perpendicular to the wall. This technique has been little studied and consequently the principles of implementation are unknown, in particular the possible size of the facings or use of formwork.

**Mechanized implementation using an excavator**

The principle is inspired by the traditional English mode of implementation.
The mixture is deposited using the bucket of a mechanical shovel. The mixture must be as compact and homogeneous as possible in the bucket as soon as it is loaded. This requires working the mixture with the bucket by pressure on the pile to tighten the cob, eliminate the maximum vacuum.
The mixture is deposited by inverting the bucket on top of the wall, taking care not to drop it or unbalance the lower layers. The flat of the bucket can then be used to lightly tamp the mixture on top of the wall or reposition it nicely in the center of the wall.
Once the bucket has been removed, the mixture is trampled on from above to bring the cob onto the exterior facings if necessary. Using the spade fork, the excess cob is removed and placed in hollow or missing areas before being trampled on again.
The work of cutting the facings is done in a traditional way as mentioned above.

Implementation with an excavator

**Implementation of shuttered cob**

In order to speed up implementation times and limit the number of stages in the construction of cob walls, several formwork tests have been carried out, in the past (cf, 1st transdisciplinary exchanges on raw earth constructions - 2003 - A Klein p 417-437), and more recently in Normandy in Brittany, England and Switzerland. The formwork allows without too much constraint and risk to implement by dumping and trampling the cob to obtain a good compactness. It allows you to control the overhang and avoids having to recut the facings.

But due to the plasticity of the mixture used, stripping proves to be the delicate point. The suction force exerted by cob on the formwork can lead to deformations of the wall during the removal of the formwork. Different masons have devised different strategies to circumvent these constraints:

- Conventional formwork, but with stabilization of the cob. To accelerate the hardening of the cob and allow rapid formwork removal, a stabilizer (lime or cement) is added to the basic mixe of earth, water and fibre during mixing. Once implemented in the formwork, it is necessary to wait until the next day to strip the formwork, then a few days before being able to reassemble a following formwork. This principle is similar to the poured earth tests currently being developed by companies and laboratories in different countries. It remains questionable with regard to the quantity of added cement penalizing the carbon balance of the wall and the modification of the properties of the earth and in particular of the clays by blocking all or part of their ability to regulate humidity.

Stabilized cob shuttered – single dwelling, Les Frères Bon

- DLow height formwork. The implementation by thin beds makes it possible to limit the deformation of the lifting lord of the stripping (a bit on the principle of the adobe moulds), and to have a drying in the heart of the lifting faster and thus to allow to implement the next lift faster

Low height formwork – cider cellar, Les frères Bon

- Mesh formwork to avoid the phenomenon of suction by providing a small contact surface between cob and the metal mesh. Forms can be removed if filled early, or on the contrary if the cob is too viscous, left in place so as to contain the mixture while allowing it to dry and harden. The spacing of the mesh determines the fineness of the facing. Once the formwork has been removed, the facing can be tightened with a stick or trowel.

Meshed formwork – Les frères Bon

Meshed formwork – Olivier Dargagnon

- Solid wood formwork, but working on the plasticity of the mixture. By reducing the water content of the cob, it adheres much less to the formwork, which can thus be removed without difficulty. Two variants of implementation have been identified. One consists in adapting the Britain “caillibottis” technique. It has been developed to facilitate the management of construction sites carried out on a participatory site, therefore with unskilled labour. The formwork serves as a guide for the safe installation of the cut cob blocks. The other hybrid rammed earth. The continuous formwork in height is filled with a firm cob which then requires compaction with a pneumatic rammer to drive out the voids, bind the clods to each other and homogenize the wall and its facing. The formwork immediately slides upwards to perform the next lift. Tests have also been made in England on cobs as firm as gratings and trampled in a solid wooden formwork.

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Solid wood formwork – Ghislain Maetz

Solid wood formwork – Les Frères Bon

## 2.2 Trials

The objective of cobbauge is to optimize the traditional technique. Several factors in the construction process can influence the implementation time, the number of people mobilized and the overall duration of the elevation of the wall, with also and consequently an influence on the cost of the cob wall.

Implementation time

In the traditional implementation, stacking the clods with the fork requires a fairly long implementation time. It is estimated that a team of three people will mount the facing including 7 linear meters per day for a lift of 50 cm wide by 50 cm high (3.5 m²/J). In the case of implementation with an excavator, the implementation time is almost halved (6.6m²/day). A team of three companions will implement approximately 20 linear meters finished in 1.5 days. In the case of the coffered compacted firm cob, the same team will produce a wall of approximately 3 linear meters by 2 meters in height (6m²/day).

The arduous nature of the work, closely linked to the implementation time

The implementation with the fork naturally solicits the body quite intensely, just like the work of facing, in particular during the use of the spade or the wall which solicits the back by obliging a shift of the bust in the void above. beyond the plumb of the wall. The work of pruning the hay cutter is just as difficult. In this sense, boxed solutions offer an interesting alternative. They make it possible to create the final facing during implementation, and to a lesser extent

save mixing. It is therefore a part of painful work avoided, even if there is still the installation of formwork. It should be noted however that in the compacted version, the use of the pneumatic rammer used for the rammed earth is quite trying.

From these observations, we have directed all of our tests towards cased solutions offering more optimization potential with a good time saving/difficulty ratio.

### 2.2.1 First test wall

Implementation

The first test was carried out during a cob training course organized by Amaco at Les Grands Ateliers de l'Ile d'Abeau. The first results of measurement of thermal and mechanical performance revealing the impossibility of having only one mixture responding to both mechanical resistance and thermal resistance, it was a question of testing the implementation of two different mixtures in the same formwork. The insulating part being planned to be outside in order to optimize the thermal mass of the load-bearing part, it required the completion of a coating in the long term. We therefore opted for a test with a mesh formwork. The mesh being loose (5x5cm), to prevent the light earth/hemp shives mixe from passing through the mesh, we first applied a glass screen with a tighter mesh (8x8 mm).

On the load-bearing cob side, we wanted to try a solid wooden formwork in order to obtain a facing as flat as possible to constitute the final facing.

The carrier mix was first applied to a thickness of about fifteen cm, against the wooden formwork and to a depth of 30 cm, leaving a reserve of about twenty cm for the insulating part. The clods of earth were pressed into the bottom of the formwork and trampled down to make the layer homogeneous and compact. This junction was worked by chamfering it so that the two facings are harped on the height of the formwork. The light mixture, here made with a slip of earth and hemp, was then placed in the reserve left between the carrier cob and the mesh formwork, lightly compacted using a manual rammer. Before making the next layer on the same principle, a hemp rope was placed in a zigzag pattern at the junction between the two facings to provide a mechanical connection.

Once the formwork was completely filled, the block was immediately removed from the mold. No problem removing the mesh formwork and the fine mesh weft. The relief is marked and will probably allow adhesion of a coating. The wooden formwork could also be removed without too much difficulty by sliding it parallel to the facing to avoid tearing it off. The deformation seems minimal, but it should be noted that the block was small (1m long, 80cm high, 50cm deep), which probably allowed for such easy stripping. With a larger contact surface, the suction force of the cob would probably have made the stain more difficult and deformations of the wall more likely.

Report

The installation of cob clods and their treading is quite easy. the filling of the lighter part as well. The installation phase of the connecting cord of the facings wastes time. It will be necessary to study its use.
Once the formwork has been removed, the relative irregularity of the load-bearing cob and lightened cob beds can be seen. The shaped reserve causes the thickness of the insulating part to vary between 15 and 25cm, thus making the thermal performance of the wall random.
After drying, the block presented a fairly significant deformation, the head of the wall seeming to have shifted laterally. The block, made on a pallet, having been moved fresh, it was difficult to establish whether the deformation was due to differential settlement between the load-bearing part and the insulating part, or whether it was due to the movement. On the other hand, no separation between the two facings was perceptible.

### 2.2.2 Second tests wall

Implementation

The second test was carried out in a context closer to that of a construction site. The land used corresponded to that studied by ESITC and UoP. FR3 was used for the lightened earth because of its very high clay content, and FR2 for the carrier cob. The fibre used was raw hemp straw cut into strands of 10 to 60cm in length for the carrier cob part. Hemp shives was used for the insulating part.

FR3 was soaked for 3 days in tanks filled with water, mixed once a day with an electric portable mixer to properly loosen the clays. The day before implementation, the earth slurry was coarsely sieved (8mm mesh) to eliminate undiluted conglomerates. The water content was then checked and adjusted to obtain a 12cm disc with 100ml of slip poured onto a flat surface. In order to see the limit between laboratory tests and site practice, 100ml of slurry was placed in an oven to determine the dry weight of soil and to assess the quantity in volume of hemp shavings to put in.

 

Clay slip and hemp shives were then mixed together in a small planetary mixer on site at the rate of 200l of hemp for 40l of slip. The mixture was left to soak overnight.

Cob was prepared with an excavator (see 1.2.3) the next day at the same time as the formwork was put in place. Regarding the latter, the mesh metal formwork was tested on both sides. The face receiving the insulating mixture has, as for the first test, been covered with a fibreglass frame. The side receiving cob was covered with a metal mesh deployed in order to test a finer mesh than the 5x5cm mesh used. The stitch here was 2x1.5cm.

The base of the wall was made of a thick plywood board 2m long by 70 thick.


The two mixes were implemented here on the same principle as the first test, with a load-bearing part on average 45cm thick and an insulating part 25cm thick. The wall was mounted 1.1m high. It was stripped the next day without any particular difficulty.

## Report

As for the first test, the implementation by shaping the reserve for the insulating part does not allow to have a good regularity of the two parts. The preparation of the slip with the clay soil is tedious because of the high clay content of the soil.
On the other hand, the mesh of the expanded metal mesh gives good results. The cob does not pass through and provides a flat but sufficiently rough surface to receive a finishing coat.

2.2.3 Third test wall

Implementation

The materials are exactly the same as in test 2. The test here was focused on improving the implementation process to achieve greater regularity in the carrier/insulation thicknesses. The expanded metal grid has been replaced here by a square grid with a 2x2cm mesh. Finally, to test an hypothesis emitted during the cob course of L'Isle d'Abeau and the construction of test wall 1, we sought to see if it was possible to optimize the drying of the wall at heart by creating vertical cavities allowing to circulate the air from the base.

Wooden formwork was made to place in the bottom of the formwork and create the reserve for the insulating part. These wooden forms also make it possible to adjust the thickness of the cob layer used. PVC tubes 5cm in diameter spaced 50cm apart are fixed vertically from holes made in the plywood base.

The implementation is always done on the same principle, the wooden reserve being removed once the cob is implemented. The slice of the cob is just summarily rebeaten to give a trapezoidal shape at the layer. The insulating mixture is then implemented. This wall was mounted on 75cm only. The PVC tubes were immediately removed, quite easily.

Report

Secondary formwork makes it possible to obtain regular facing thicknesses without impacting the implementation time. The two test walls 2 and 3 were each equipped with three probes to measure the humidity level at different depths, so as to assess the impact of the hollows made in wall 3. After 2 months of measurement, there was no there is no difference observed. Static or non-forced ventilation apparently has no impact on drying at the core of the wall.
On the other hand, the hollows seem to have caused the formation of cracks.

### 2.2.4 Fourth test wall

Implementation

This wall was made as part of the Clayfest. It was not purely intended to test the principle of implementation but to begin to approach the implementation in detail. The formwork used was a wooden formwork for the rammed earth, provided on one side with a mesh. The wall was mounted in L of 1m x 1m to be able to manage an angle, and on one of its ends a reserve to make a rebate in sight to install carpentry

The formwork was filled according to the previous principles of wall 3. In order to allow the attachment of the carpentry, a dovetail piece of wood was embedded in the cob. After about thirty centimeters of thickness, a wooden formwork was put in place on one of the branches of the L to create an opening. Arrived at the upper level of the formwork, a layer of cob was implemented about 5cm thick before drowning thick branches to create the frame of the lintel. The same was done at the level of the insulating filling.

 

The whole thing was stripped the same day quite easily. A slight subsidence occurred at the level of the lintel of the load-bearing bauge.

### Report

The principles of treatment of the details will have to be refined according to the junction with the insulating part so as to avoid thermal bridges. But the principles of implementation are sum all similar to the principles of traditional cob. Regarding the treatment of the lintel, additional tests will have to be carried out. The narrow opening here should have allowed a problem-free construction of a reinforced cob lintel. Here probably the use of simple green branches was not appropriate. Part of the insulating part collapsed above the lintel. But the wall having been built in a public site and having remained unsupervised for some time, the cause of this rupture cannot be precisely defined.

### 2.2.5 fifth test wall

Implementation

This wall was created as part of the science festival at ESITC Caen. The wall was mounted on a ½ scale so that it could be used in a climatic chamber once finished, i.e. 2m long and 30cm wide. In order to obtain the flattest surface possible, we tested on this wall traditional formwork for concrete, aluminum frame with film-coated plywood. Against the plywood, the expanded metal mesh has been placed in order to limit the contact surface between the cob and the formwork, and to be able to strip formwork more easily

The mixes were made with ESITC mixers (see 1.2.5). The light mixture was however made with crushed reed following the results measured by the ESITC and the UoP on thermal performance. The implementation was done as for tests 3 & 4. The only difference lies in the use of a small pneumatic rammer to compact the soil over a small width. This tool has been shown to be particularly useful in avoiding having to trample on the mixture, thus enabling safe working from scaffolding.

## Report

The formwork remained in place for 4 days before stripping. They were removed quite easily, and the screens were removed immediately. the cob had not particularly hardened which confirms the interest of mesh formwork to facilitate the drying of the cob before stripping.

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The wall suffered a subsidence just after the stripping and a start of tipping. After analysis, it is a problem of slenderness of the wall. Indeed the formwork was filled to the top, which in relation to the thickness corresponded to a wall 160 cm high, i.e. a slenderness E=h/e=5.33 if we only take into account the part carrier. However, the limit that we reached during previous experiments was E=5.45 in the case of the use of mesh formwork and implementation in hot and dry weather with stripping one day after implementation, and an E =5 in the case of the firm cob compacted with a pneumatic rammer in solid formwork, and an E=3 in the case of test wall 3. It was therefore quite probable that this wall wobbled with a cob that remained plastic.

## 3 – Conclusion – Proposal for an implementation process

These 5 experiments carried out on these 5 walls allow us to identify the various avenues for optimizing the implementation of the cob. The use of mesh formwork seems to be the most relevant to secure the implementation and allow the walls to be erected with a slenderness twice as large as in the traditional cob, and without work on the size of the facings.

The use of forms allows efficient loading of the formwork with a machine bucket (or mixer buckets). However, these formwork panels are only suitable for a coated finish, or require the surface to be reworked quickly after stripping. Unless you can adapt the skin of the formwork.

It is in this sense that the formwork project was worked with the company Maloisel. To allow greater adaptation of the CobBauge process to the know-how of conventional companies, the final formwork was worked from conventional concrete formwork. The aluminum frame has been retained and adapted to allow several different skins to be slid: film-coated plywood, simple plywood or expanded metal mounted on a light frame. The formwork can be assembled in a conventional manner to allow linear or overhead work, remaining in place to allow the cob to firm up before stripping. The formwork is also adapted to allow the time of this drying to embed an articulated structure there to cover the top of the lift carried out.

In the absence of a sector capable of producing hemp straw cut into short strands, it seems that flax is the most suitable fibre for the mixers tested. It will nevertheless be necessary on this aspect of the mixing to carry out additional tests in real situations to estimate the times of implementation in a more realistic way and thus validate the times of implementation and the gains compared to the traditional technique or the adaptations already tempted.

The use of an interior intermediate formwork is essential to ensure the proper regularity of the layers and thicknesses of each facing. On the other hand, additional tests will be necessary to determine if over the long term and for complete drying, the two facings remain joined and if there is no differential settlement between the two wall facings. These tests will also be necessary to evaluate this same behavior during the loading of the walls (installation of a beam or a floor for example). This will make it possible to assess whether the use of ropes interposed between the layers of cob is interesting or if other devices are to be imagined.