SB & WRC project

Prototype 2 – Waste duvet insulation

Samples and making

This report was commissioned by University of Brighton as part of the SB&WRC project. The SB&WRC project is part of the Interreg VA France (Channel) England Programme and benefits from financial support from the ERDF. The ERDF is contributing €1.26 million towards the project (69% of the budget).The project was designed and led by Nomadéis, a consulting agency.

INTRODUCTION

Local Works Studio were commissioned in January 2018 to undertake the sampling and making elements of prototype 2 for the University of Brighton Interreg funded project – SB & WRC (Sustainable Bio & Waste Resources for Construction). The project focus for the University of Brighton was to locate waste materials from the city that could be re-purposed into building insulation.

Through discussions with Veolia (a project partner) it was highlighted that waste bedding was currently a huge problem in the industry, and there was no re-use or re-cycling activities with this material. Within one collection of waste bedding from a waste recycling centre near Brighton, we had enough material to start a prototyping and testing program. The bedding material from this collection was divided into roughly 70% polyester (hollow-fibre and micro-fibre) and 30% feather (unknown origin).

MINI_PROTOTYPES

The first stage of making in this project was to produce 8 mini-prototypes of raw materials, and material blends for ESITC Caen University in France to test for thermal performance. Included in the 8 samples were some smaller tiles that were to be fire-tested at UniLaSalle University in Rouen, France.

The list of mini-protypes is shown on the next page.

23/4/2018

Prototype 3: Mini-Prototypes delivered to ESTIC on 27th April 2018

Produced by Local Works Studio for University of Brighton

Number	Size	Purpose	Insulation material	Binder	Outer material	Binder	Top covering
1	300 x 300 x 100mm	General tests	Feather	No	Feather	Marseille soap foam	No
2	300 x 300 x 100mm	General tests	Feather	No	Feather	Jesmonite	Tyvek
3	300 x 300 x 100mm	General tests	Polyester	No	OSB timber board		Tyvek
4	300 x 300 x 100mm	General tests	Polyester	No	OSB timber board		Feather-board Render. Waste agg. in lime
5	260 x 70 x 12mm	Fire tests	Feather	Jesmonite	No	No	No
6	260 x 70 x 60mm	Fire tests	Feather	No	Feather	Marseille soap foam	No
7	220 50 x 50mm	Fire tets	Polyester	No	Tyvek	No	Tyvek
8	220 x 50 x50mm	Fire tests	Feather	No	Tyvek	No	Tyvek

University of Brighton

Local Works Studio

The mini-prototypes were tested by Caen for thermal conductivity:

MP2 (loose feathers in a duvet with Tyvek) = 0.053

MP3 (polyester duvet with Tyvek) = 0.056

MP4 (polyester duvet with featherboard and render) = 0.063

The smaller samples were tested by Rouen for fire performance:
Observations (Rouen):

MP5 does not ignite but is damaged on a height of 1 cm;
MP7 ignites directly when it comes into contact with the flame and continues to ignite after the flame has been removed, but extinguishes after a few seconds;

- *The inflammation of MP7 generates ignited droplets ;*
- *M-P 8 exhibits a similar behavior to M-P 7 with two differences that are a more rapid inflammation and a greater presence of droplets.*

Conclusions (Rouen) :

- *The outer component that would be more resistant to fire is the Jesmonite + duck feathers "M-P 5";*
- *The tyvek degrades as soon as it comes into contact with the flame;*
- *Polyester seems to be less risky than duck feathers, which faced to fire produce a larger amount of ignited debris.*

The results from Caen and Rouen informed our next design stage, and several changes were made:
- It was quickly concluded that waste materials should be kept separate, for ease of end-of life recycling. Therefore insulation material (duvets) should not be mixed with any binder and used in their raw state within a building cavity wall.
- The fire tests showed that polyester performed marginally better than the feathers, but further work was needed to ensure the polyester was encased in a fire-retardant material.
- The polyester duvets are by far the most common waste-stream, so they were chosen as the material to continue testing.
- The project brief for Brighton would now become to develop an insulation from polyester bedding and to separately develop a waste-based cladding that could be used on the exterior of a building.

MAIN PROTOTYPE

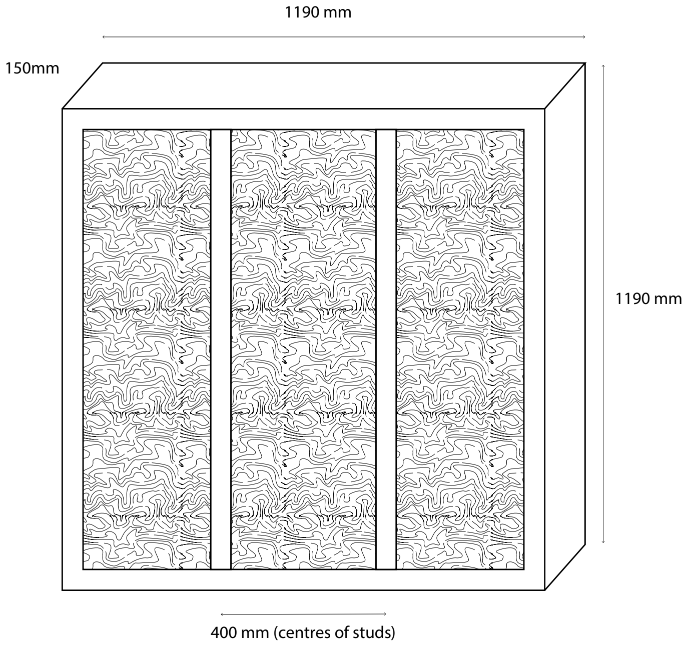
Local Works Studio were tasked with producing 2 versions of the main prototype. One would be installed and tested at The Waste House, within the campus of the University of Brighton, and the other would be made and sent to the University of Bath for further testing.

PROTOTYPE A

The Waste House is constructed as an experimental building that tests construction techniques with waste materials and different insulation materials within its timber frame. It has a large wall thickness with a 400mm cavity for internal insulation and there is 100mm of external insulation under the tile-hung exterior. A sample wall area of roughly 2 meters high by 1m wide was chosen on the North wall of the building, in order to reduce any large changes in external wall temperature for better test results. We opened up the wall internally and externally and removed the existing insulation materials and the polyester duvets were hung in the voids in vertical strips. The duvets were cut to fit the void dimensions, and stapled in place to prevent slumping. The internal insulation density was 21.4 kg/m3 and the external insulation density was 11.3 kg/m3.

PROTOTYPE B

This was a separate single box of duvet insulation that was sent to Bath University for further testing (image on next page).



SB&WRC Project

Prototype 2 (BETA)
University of Brighton

We would like to submit 2 models for testing as previously discussed. Both will be of dimensions: 1190 mm x 1190 mm x 150mm
The central void will match current building regulations with timber studs at 400mm centres.

BETA 1 will have waste duvets hung as vertical layers

BETA 2 will have waste duvets stuffed into the voids of the model

Both models will have Tyvek membrane covering the front and back faces.

EXTERNAL CLADDING

Exterior cladding was required to cover the panel of test duvets within the wall of the Waste House. Local Works Studio has a background in historic building materials and processes, which led us to consider using our own research into forming a lime mortar from sea shells rather than limestone to make the cladding tiles.

The technique of shell-based building lime is widespread across the globe in communities that don't have access to a source lime rock. Often it's island cultures on volcanic rock outcrops, or coastal communities with abundant shell material. It seemed slightly odd to be considering using shell lime in such a lime rich region of the country. The South Downs form a chalk ridge that runs through Sussex just to the North of Brighton, and has historically supplied all of the lime industries of the region. There was also an idea that chalk rock from foundation digging within large construction sites in the city could contribute the raw material for lime production, but it was decided that waste sea shell could potentially be a more interesting and thought provoking waste material to test.

We have previously worked with sea shells to create lime mortars, but hadn't considered the possibility of locating the waste stream solely from restaurants, rather than fisheries. Foods such as oysters, mussels, crabs and lobsters are mostly sent to the restaurants in the their protective shells and also presented to the customer in this primary state. This does not allow for ease of material collection for re-processing as compared to other shellfish, which are de-shelled by the fisheries at central locations. The shell waste in restaurants from the plates and bowls are usually binned with the rest of the rubbish and collected for landfill. We focussed this project on using oyster shells to make our lime binder. Lime can be made from other shells, but it was the most abundant of the foods and there are some excellent historic references to the use of oysters in lime production. This is a great quote about the architect, diarist, and the first curator of The Royal Society: Robert Hooke – 22nd April 1696

"Doctor Hooke sayd that as to Lime he had reason to believe that no substance whatever make so durable plaster as oyster shells and that instead of sand he thought nothing better than ground cinders which two would together make a much harder and more durable mortar than any other whatever"
Extract from a PhD thesis on Sir Christopher Wren and the Royal Society by James Campbell – University of Cambridge.

We set up a relationship with two fish restaurants in Brighton, collecting their oyster shells over the period of a month during the summer of 2018, which gave us a huge volume of material for this project.

Each restaurant gets through about 50,000 oysters per year, which can yield up to 3.75 tons of shell. The restaurants were happy with us collecting the waste, as they have to pay for its removal. The only slightly challenging aspect was that the waste shell had to be picked up every other day (during the summer period) due to the sizeable quantity produced and the issue of the smell of the rotting shellfish.

Through our initial research we also sourced a large quantity of demolition waste from construction sites throughout the city. This material was a mix of crushed historic buildings (pre-concrete), containing bricks and lime mortar, and crushed concrete from old foundations. These materials added to our palette of waste as aggregates for our shell lime mortar.

The waste aggregates contributed colour and the possibility of a weak pozzolanic reaction with the lime binder. This could help with quicker and possibly harder setting and curing.

We also used crushed oyster shell as an aggregate, but wanted to test various blends and the possibility that demolition waste could contribute vast quantities of material to future waste mortar applications. After an initial period testing some different oyster lime mixes, applications and finishes, it was decided that hung tiles made from lime mortar would be the best use of the waste material. Other lime-based finishes such as render and cast bricks were considered, but the flexibility of interchangeable tiles was perfect for this project.

OYSTER LIME HISTORY
Oysters have been linked with humans at every point of our history, due to the shells longevity, they exist as our historic detritus. The shells are used for DNA analysis and dating of human settlements across the world. The oyster was an easily available source of protein found in sheltered estuaries all around the UK. In Roman times when Colchester was the capital of Britain, all the Roman boats had to go via the river to get to Colchester. It is believed that the Romans enjoyed the oysters so much that they towed them in nets behind their boats all the way back to Rome. The native oyster to the UK is a bivalve with 2 flat shells (Ostrea edulis), and is only in season for harvesting between September – April. To bridge the gap during the summer, the Pacific Oyster (Crassostea gigas) was introduced here from Japan.

In the USA an oyster based lime mortar for buildings was produced in the South Eastern coastal states and named ‘Tabby’. The mortar was produced in large quantities and consolidated into timber shuttering, like rammed earth, to produce solid thick walls and buildings. It is dated from the late 1500’s to the 1850’s, and could have come from Spanish settlers and/or Arabic or African roots. In Arabic *tabbi* means a mixture of mortar and lime, and in Spanish *tapia* means a mud wall. The material was a mixture of calcined (burnt) oyster shell (the lime binder), ash (from the burning process) and sand. The ash from the burning of the shells added strength to the final mortar. Several experiments re-enacting the process of the oyster shell burning have successfully been undertaken in various parts of America in order to repair buildings or replicate historic techniques. One project in Virginia constructed a traditional oyster burning technique called an Oyster Rick, a large wood fuelled bonfire that fires the shells to turn them into quicklime (Calcium Oxide).

This link shows a video of the fire process:
www.youtube.com/watch?v=tDuDGyYA7pQ

Many historic Tabby buildings remain, with lack of maintenance seemed as the main culprit for decay, rather than direct failure of the material.

In Australia oyster lime was used for the early building around Sydney, due to a lack of limestone in the area.
"The lime procured at [Newcastle] is made from oyster shells. These shells lie close to the banks of the river, in beds of amazing size and depth. How they came there has been a matter of surprise and speculation to the colonists. Some, are of the opinion that they have been gradually deposited by the natives [aborigines] in those periodical feasts of shellfish, for the celebration of which they still assemble at stated seasons in large bodies…
… The process of making lime from them is extremely simple and expeditious. They are first dug up and sifted and then piled over large heaps of dried wood, which are set fire too, and speedily convert the superincumbent mass into excellent lime. When thus made it is shipped for Sydney and sold for 1 shilling per bushel."
Description of the Colony of New South Wales, London, Whittaker, 1819.

In the Spring of 2017 Local Works Studio visited the Faroe Islands in the North Atlantic to see the shell lime mortar of this limestone-free volcanic island group. The Faroes were settled 1000 years ago by Irish monks and then Viking-aged settlers in the 9th century. They found a barren group of islands with little raw materials beyond its hard, black basalt rock. There are stories of whole timber buildings being sailed over from Norway to be re-built in order to have some meaningful shelter, and to maintain a link to their past. The early masonry buildings are survived by the impressive cathedral ruin of St Magnus in the village of Kirkjubøur on the island of Streymoy. The building was started in 1300, and still stands today, roofless but semi-protected for on-going repair work since 1997. The hard basalt stones are mortared with a shell lime material made from shell sand that makes up some of the local beaches. The shell sand was burnt for quicklime and added to the beach deposit (aggregate) to make the bedding mortar for the large stones.

In the UK there is historic evidence of shell lime mortars in Scotland, where the geology proved challenging in some areas to use a lime rock for production:

'Scottish lime, particularly in the Western Isles, was also produced from sea shell. When burnt in a kiln, the shells are reduced to lime. The loose nature of the material allows it to burn easily and completely, so that the lime produced is not contaminated with lumps of un-burnt lime. This produced a very high quality and pure (or feebly hydraulic) lime that was particularly good for internal plaster work'
Clare Torney – Lime Mortars in Traditional Buildings – Historic Scotland

MATERIALS
The reason for using oyster shell for lime production in this project was in order to achieve a 100% waste-based material. There are many ecological benefits to using lime mortars: their lower firing temperature compared to cement production, their ability to absorb CO_2 for curing, their proven longevity, the ability to clean and re-use bricks and masonry that have been laid in lime mortar, etc. We had previously researched and tested using waste aggregates with lime and clay binders, in order to replicate vernacular techniques. These have been successful, and produced a material that was at least 75% waste-based. But it has always been a goal to find and use a waste-stream for the binder element of a mortar, in order to get a completely recycled (and recyclable) material.

The materials for this project came from 3 locations:
English's of Brighton – Fish Restaurant
Riddle and Finns, Brighton – Fish Restaurant
University of Brighton – Demolition waste
These 3 sites are within 1 km of each other in Brighton and all material processing was done at our workshops 15 kms to the North East of the city.

One main aim was to produce a finished architectural product that would be from the city, and be easily sourced, manufactured and installed. The lack of hi-tech machinery required, and simple making and installation techniques were really key to us choosing these materials and processes.

The waste oyster shell from restaurants, in this country, primarily enters the waste stream and is sent to land fill. It is important to note

that in the USA and other countries the waste shell is beginning to be diverted back into the sea as a false reef material that the young oysters can bind onto and grow. This is well documented to have huge beneficial results to the biodiversity and the water purity of an area.
This link is to a project in San Fransico: www.wildoysters.org/our-work
and in Chesapeake Bay, Virginia: www.cbf.org/about-cbf/

The aggregates within our waste-based mortar are a mix of crushed oyster shell and crushed demolition waste. These materials are all high in calcium, which can benefit the carbonation of the lime binder:

‘The use of calcitic aggregates such as crushed limestone and oyster shell has been shown to aid carbonation. These materials act as seeding agents in the mix providing nucleation sites for the precipitation of calcite crystals, promoting the carbonation process. The purity, crystallinity, particle size and quantity of seeding agents all impact their performance. Finely ground pure sources of calcium carbonate (substituted for aggregate) in concentrations above six per cent have been found to positively impact carbonation and strength development.’
Clare Torney - Lime mortars for high exposure levels. Cathedral Communications ltd

All our waste aggregates were sieved from 6mm to dust. We were keen not to take out the finest grain size particles (for reasons shown above), so all material was added to the mix. The maximum aggregate particle size is important and can be detrimental to masonry joints and cast objects if too big. We were keen to be able to see the particles within the mortar matrix, in order to add value and meaning to the material, so a balance was struck between the maximum size of the particles and the thickness of the tiles. We also found that the aggregate made from oyster shells is mostly thin and flat (like a mica mineral) when crushed. These shelly particles tended to align flat within the tile when the moulds were filled and tamped.

We have considered that the demolition waste could be mildly pozzolanic, and give a slightly faster curing and final strength to the mortar. Pozzolans are finely ground materials containing silica and alumina that have been heated (naturally or artificially) to become reactive. The brick dust in the demolition waste may be reactive, but it may also be too highly fired (in its production) and not be ground fine enough to have any effect on the lime binder, other than being a great porous aggregate. We have not tested the final mortars for strength in a controlled lab-based procedure, but have not noticed any differing strengths or curing times between the pure oyster blends and the oyster/rubble blends. Our initial mortar trials involved many different blends and proportions of materials, including adding various commercially available waste-based pozzolans, but after curing we found very little difference in the strength and performance of the mortars and so opted for no additions to our pure oyster and oyster/rubble mixes. We have heard that oyster shell lime can be feebly hydraulic in nature due to the chemical composition of the shell. We have not managed to find any further information or research on this.

METHOD

From the start of the testing into the oyster lime mortar we have been using the Hot-Lime method for mixing the materials. This involves blending the aggregates and oyster quicklime together during the slaking (adding water to quicklime), rather than slaking the quicklime prior to adding the aggregates. There are many reasons why we now prefer this historic technique, but the main advantage in this process was an early stiffness/set allowing the tile to be de-moulded within 4 hours rather than after 3 days (when cast in a cold mix lime mortar). The hot lime mix was added to the moulds whilst still warm, this meant that there is still an expansion occurring within the material as it slakes, this helps to separate the mould from the tile. This technique could have negative consequences with other cast shapes and applications.

The oyster shells were fired in a gas kiln to form the quicklime (Calcium Oxide) material. This gave us the certainty required that the shell had reached the correct temperature and was not under-fired (may not slake) or over-fired (leads to vitrified areas of the shell not being able to absorb water and slake).

The raw materials of oyster quicklime and aggregates were heaped on a flat bench in the correct proportion and quantity for one tile. Water was added to the quicklime and immediately covered with the aggregate. After the initial swelling and rapid boiling all the materials were mixed together to the correct consistency and added to the tile mould. We were able to de-mould the tiles after 4 hrs, and the mortar was allowed to slowly carbonate as we turned the tiles over the course of about 1 month.

Final finishing involved polishing the surface of the tile to reveal the aggregate. This was the first time we could really see the effect of the different material blends on the colour and texture of the tiles. We made blends from pure oyster to pure demolition aggregate (still with an oyster lime binder), and several in between. This gave a range of about 6 different colours in order to showcase the materials and possibilities within a limited palette of materials.

The finished tiles were displayed on a building within the campus of the University of Brighton called the Waste House. The building is a permanent research facility and design workshop for the University and was constructed in 2014 from unwanted construction materials and a huge variety of other waste, including carpet tile cladding on the exterior walls. The Waste House is being constantly monitored for its thermal performance, and the oyster tiles are attached on an exterior wall as an example of protective cladding.

CONCLUSIONS

It is possible to use oyster shells as a source material for lime production. They can make a beautiful mortar that is very pure and easy to work with. One benefit is their size as they don't need to be crushed or graded prior to calcining, this also allows for an even burn and little, if any un-slaked particles in the final mortar. These findings correspond with historic text that oyster lime is a very pure material, possibly saved just for the finest work such as internal plastering and decorative applications.

It has been a very rewarding process to produce a durable lime mortar made from 100% waste materials, and also to be able to limit these materials to 1 or 2 sources only.

We've also enjoyed highlighting these historic building techniques to a wider audience within the architecture and design disciplines and beyond. We feel there is much more potential for vernacular crafts to contribute to current and future practice and materials, especially concerning the use of waste and sustainable principles.

References

James Campbell. University of Cambridge. PhD thesis on Sir Christopher Wren and the Royal Society. 2000

www.blogs.sydneylivingmuseums.com.au/cook/oyster-shells/:
Description of the Colony of New South Wales, London, Whittaker, 1819.

Clare Torney. Lime Mortars in Traditional Buildings. Historic Scotland 2014

Clare Torney. Lime mortars for high exposure levels. Cathedral Communications ltd 2016