Limecrete by Ian Pritchett

INTRODUCTION

I know that several people around the country have been using lime to make concrete for some time. Here at IJP we have been playing with limecrete for the last few years. As with all good experiments there has been an evolution in our thought process and trials. The first serious (well semi-serious) trials we did were as a result of an enquiry from a firm of Architects. They wanted to use limecrete for the floor of a large barn that would house an exhibition and asked us to carry out a series of trials leading to recommendations for a mix and methods of application (the floor slab was to contain un under-floor heating system). Extracts of our report are set out below:

After a visit to the site the following list of parameters was drawn up to consider:

1. Time taken to set
a) Dry areas and wet areas
b) The need for drainage

2. Acquisition of strength with time

3. The durability and compressive strength

4. The load bearing capability of the floor - a) Whether it can bridge gaps in the substrate b) Will it resist point loads from exhibition cases? c) How will it cope with chairs if required? d) Would any working areas have separate timber floors/platforms e) Will there be any floor coverings e.g. mats

5. The cost of the floor mix a) Its long-term maintenance b) The possibility of high traffic areas and the ability to repair if required c) Should the floor be laid in bays that could be replaced individually if required

6. The thickness of the floor

7. The colour and surface finish a) Will there be a top layer?

8. The potential for shrinkage and cracking a) Will expansion joints be required? b) One or two layer construction

9. The detail of the junction with the threshing floor

10. The permeability of the floor

11. The interaction with the heating system a) Insulation below floor b) Insulation to edge/break detail with service ducts c) The effect of the heating on curing

12. Moisture content of the required mix a) The need for compaction if a dry mix is used. b) The need for watering the floor during curing.

13. The requirements of the substrate and infill material

14. Information available from other sources and users of lime mortar floors

15. The ingredients of the mix
a) Aggregate size and type - local or otherwise
b) The type of lime required

c) The need for pozzolans d) The possibility of hot mix mortar.

The following points were subsequently confirmed:

The floor would be laid in sections with expansion joints between. These expansion joints would take the form of a service duct carrying cables, particularly down the centre of the barn.

There will 'be no insulation below the floor, but it would be wise to incorporate it around the edge.

The infill material to back-fill any excavations and make up levels following removal of concrete would be chalk.

There is a need to fix the heating elements in a uniform "blanket"

TEST PROCEDURE & MORTAR MIXES.

Test panels 500mm x 500mm x 100mm deep were made up using a wooden frame backed with ply. Each panel had a different mix put into it and they were observed over a period of time. The aggregates for the mortar mix were chosen to provide a well-graded matrix, but with a vernacular feel. The aggregates were:

1 part Redlands ballast from their Caversham Quarry.
1 part Redlands sharp sand from their Caversham Quarry.
1/2part Redlands soft sand as dug from their Eversley Quarry.

The combination of these aggregates produced a blend close to a traditional as dug, un-washed material. The blend of aggregates remained constant but the binder was varied. The following binders were used:

1. 1 part Jura-kalk.
2. 1 part St. Astier NHL 5.
3. 1 part St. Astier NHL 3.5.
4. 1 part Hydraulic Lias Limes HL2.
5. 1 part Hydraulic Lias Limes HL2 + 13% Metastar 501
6. 1 part Hydraulic Lias Limes HL2 lump lime
7. 1 part HL2 lump lime + 13% Metastar 501
8. 1 part Jura-kalk + 13% Metastar 501
9. 1 part St. Astier NHL 5 + 13% Metastar 501
10. 1 part St. Astier NHL 3.5 + 13% Metastar 501

Metastar 501 was chosen as a pozzolan due to its ease of availability, consistent performance and cost. The 13% gauging was equates to 2 litres of Metastar 501 added to a 15 litre bucket of hydraulic lime.

The two mixes using lump lime (6&7) were included because it was anticipated that shrinkage could be a problem. Contemporary 19th century documents talk of using hot lime concrete for under pinning because it expands. Hence we considered that using lump lime to make a hot mix would combat any shrinkage. The mixes did expand, but to an extent that they broke up rising up above their boxes like a cake in an oven. We considered that allowing them to mix longer could control this problem, but since none of the other mixes showed signs of shrinkage we decided to rule them out in order to reduce the risk of error on site.

RESULTS

All ten mixes were mixed wet in a small Belle concrete mixer. The results after 14 days show comparisons:

1. Very hard. br> 2. Can be marked with a fingernail.
3. Can be easily marked with a fingernail
4. Can be marked with a fingernail.
5. Hard.
6. Expanded and broken up.
7. Expanded and broken up.
8. Hard
9. Can be marked with a fingernail.
10. Can be easily marked with a fingernail

The results after 14 weeks showed that all of the mixes (except 6 & 7) were similar. They were all very hard but could be scratched using a steel nail. It is anticipated that the floor mix will continue to gain strength over the next year or two.

There were no shrinkage problems noted with any of the mixes, although the test panels were only 500mm square.

The same test was run again on the five most suitable mixes (1,2,4,5 &9) and similar results observed.

Since the Hydraulic Lias Limes HL2 was the only British hydraulic lime in the trial and that it is reasonably local to the project (30 to 40 miles) we decided to persevere with mix No5 despite the fact that its early performance was exceeded by mix No 1 and mix No 8.

A test panel approx 500mm x 2000mm x 100mm deep was constructed and mix No 5 was used to fill it. 25mm of mortar was laid out, the heating element put in place and then the remaining 75mm laid in. Again a cement mixer was used, this time a problem arose. The hydraulic lime and aggregate required enough water to be included to stop the mix forming dry balls, however it became clear that after mixing for a while the mix became too wet. Attempts to reduce the water content and prevent balling were unsuccessful and the wet mix was used to lay the panel. This subsequently cracked in three places and despite floating over, cracked again.

The same mix was then tried in a pan mixer (or paddle mixer). The superior mixing action allowed the right moisture content to be achieved (a dry mix that can be compressed into balls - similar to a modem cement based floor screed). This mix proved to be easy to compact into place and float over, although the large stones in the ballast made floating difficult. The mix showed absolutely no signs of shrinkage when set.

Following the trials we drew up a draft specification:

1. Following removal of the existing concrete floor and archaeological investigations, infill the excavations with crushed chalk/chalk rejects mechanically compacted in 150mm layers.
2. Also use the chalk to build up low areas and level the floor. Leave the chalk 100mm below the finished floor level.
3. Working one section at a time lay down 25mm of the moist mortar mix and compact by tamping with a board.
4. Lay out and connect, as required, the heating elements. Protect them with ply boards whist walking and working over them.
5. Lay the next 75mm of the moist mortar mix in the normal screeding manor, but taking care to compact well.

6. Work in the necessary sequence to avoid walking over the freshly laid floor. Avoid walking over the floor until hard. (at least 14 days).
7. Keep the doors closed to prevent premature drying. Protect the new floor from all extremes of weather during drying i.e. wind, rain, sun, frost etc. This can best be achieved by laying polythene sheet over the new floor to keep the moisture in.
8. When the floor is hard to the touch (but can still be marked with a finger nail) carefully sprinkle water over it each day and turn on the heating for one hour each day.
9. Lay hardboard or ply over the floor before walking over it during the first three months of curing.

THE MORTAR MIX INGREDIENTS AND METHODS.

The mortar mix:
30 litres Redlands sharp sand from their Caversham Quarry (or similar).
7.5 litres Redlands soft sand as dug from their Eversley Quarry (or similar).
15 litres of hydraulic lime (see below).
2 or 3 litres of Metastar 501. *

The hydraulic limes identified as being suitable were: - St. Astier NHL 5 - produced a good hard floor and would be very porous.
Hydraulic Lias Limes HL2 - produced a very good sample and is known to increase in strength with time due to its high free lime content. Also locally produced.

Although the Jura-kalk is definitely the hardest of all the mixes tried, it is probably the least porous and is thus ruled out. (The metastar would not be needed if using Jura-kalk since there is only 3% free lime for it to react with).

Further research has indicated that the amount of Metastar 501 can be increased to 3 litres if using the Hydraulic Lias Limes HL2. This will produce a faster set and a harder floor without significantly compromising the porosity.

Mixing. The mixing will have to be done with care to achieve the best results. The ingredients should be accurately measured with gauging boxes or buckets. The mixing must be done in a pan/paddle type mixer or a screed mixer in order to get it well mixed but not too wet. The mix should be just wet enough to form a cohesive ball when subjected to hand pressure. (will form a "snowball"). Mortar should be laid within two hours of mixing.

LIGHTWEIGHT INSULATING LIME CONCRETE.

This project left us wondering how we could achieve a porous lime based concrete that could be used with an under-floor heating system and insulation. Our next opportunity for experimentation came when we were developing a repair specification for a project in Henley. The building was a 17th century timber framed stable block known as The King's Arms Barn. Here amateur archeologists had dug up most of the original stable brick floor and so it was ideal for it to be re-laid over lime concrete and insulation. We had two further points to consider

1. The neighboring building (The Henley Police Station) had foundations that were at our floor level and in danger of slipping sideway. Consequently our limecrete had to have enough strength to satisfy the Engineer that it would resist any sideways thrust.
2. What type of insulation could we use that would still allow the floor to breath but would not decay?

We decided to look at the expanded clay insulation that is often used in chimney lining systems (Fibo-fill in our case). This comes as a series of balls of lightweight expanded clay. We wondered whether we would have to crush it up or mix it with sand to achieve a well-graded mix, and if so how it would affect the insulation values. We were extremely pleased to find that we could get the Fibo-fill in a range of different sizes ranging from about 1mm to 20mm diameter. Having obtained some bags of the material we set about making up a well-graded aggregate form it and then mixing it with hydraulic lime. Since we were looking for a high strength material we used St Astier NHL 5. The mix was

1 part 0 - 4mm Fibo fill
2 parts 2 - 4mm Fibo fill
2 parts 10mm Fibo fill
1 part 10 - 20mm Fibo fill
3 parts St Astier NHL 5

This was mixed fairly wet and put into a test cube mold. The test cubes were tested at Oxford Brookes University and the results were:

4.5N/mm2 (Av) at 28 days
4.9N/mm2 (Av) at 71 days

The test cubes produced were amazing, they were a very pale grey colour when dry and very light. The 100mm test cube weighed approx 1Kg. This is the same density as water rather than conventional, cement based, concrete. The cubes were placed on top of a storage heater to assist their drying. After several hours we noticed that although the bottom surface was hot the top was still cold.

We wanted to lay our limecrete directly onto the subsoil without any sort of dpm, but we were concerned about its capillarity (ability to draw moisture up). We set up a simple experiment with a tray of wet sand. We stood the limecrete test cube in the sand and did the same with a soft red handmade brick. Both drew up water at a similar rate and to the same height. We felt that the capillarity noted was on the borderline of being safe for our project. Consequently we decided to construct our floor using 100mm of the 20mm fibo-fill insulation without any lime binder (loose). Then a Terram geotextile layer (porous) followed by a 100mm layer of our limecrete. On top of this we laid 40mm thick brick pammets (tiles) on a 10mm hydraulic lime bedding mortar.

There was a period of around 8 to 10 weeks between laying the limecrete and putting the pammets down. During this time we had a chance to observe the performance of the limecrete. It was easy to lay and started to set quickly (3hrs). It hardened to a point where foot traffic didn't damaged it (we kept off it for 48 hrs). The rooms concerned felt noticeably warmer than they would have done with a cement based ordinary concrete slab.

The porous nature of the floor initially meant that it was damp around the edges where it was in contact with the damp walls of the barn (brick and flint). However over the course of around 9 months the walls and floor have both noticeably dried out to an acceptable level (now used as a Tourist Information Office).

As a result of giving a short presentation on this material last year at The BLF Gathering in Kent some students at Bradford University have been looking at the material in greater depth. The areas we highlighted for further research were:

- Using different limes NHL3.5, HL2 (Blue Lias). Jura-kalk.
- How lean can it be mixed and still perform? (Jura-kalk 1:6?)
- Different grading of aggregates
- Try using volcanic aggregates - Try adding metastar to increase performance
- The influence of temperature on speed of set, strength etc

- Methods of mixing.
- Is there any benefit in adding other aggregates
- silica sand etc?

Assess:
- Workability
- Setting time
- Strength (crushing)
- Modulus of elasticity
- Porosity
- Water vapour permeability
- Capillarity
- Density

Can any of these mixes be used without a finishing material?

Look at surface finishing e.g. tamping, floating, toweling, power floating etc.

Assess the impact of under floor heating when used with these materials.

Look at detailing particularly junctions with other materials (walls etc).

Look at problems and benefits of a lightweight material.

We await their published results.
I hope that some of you reading this will realize the enormous potential of being able to use a concrete slab in an old building without it pushing water up the walls and also getting the added benefits of insulation (150mm gives a U-value of 0.45 when used with cement concrete). I think this materials is an ideal partner to under-floor heating which in itself is often the most appropriate form for historic buildings.