Demonstration Lime Burning Event
Whitlingham Country Park, Norfolk - 10-12 September 2010

Project Report by Matt Muldoon
(The Natural Building Company)

Objectives

- To construct a small, functioning lime kiln which can be used for public demonstration events and which can be easily dismantled and reassembled for transport and storage.
- To produce quicklime in the kiln in two burns over the weekend of 10-12 September 2010.
- To demonstrate the slaking process and the uses of hydrated lime.

Kiln Design

The kiln design was based on one used by Andy Lawson of Limecraft. Matt Muldoon of the Natural Building Company built a kiln using an oil drum, with the top removed and a grate fixed to the bottom which could be removed from underneath. The drum sat on a plinth of unmortared concrete blocks, with a 300mm access hole left between the blocks on one side for lighting, ventilation, and to remove the contents of the kiln after burning. Inspection holes were drilled every 200mm up one side of the drum, these would align with the chalk layers when the kiln was charged so that the temperature in each layer could be judged. Each inspection hole had a projecting piece of steel pipe, supported with clay packed onto the side of the drum to the depth of the insulation layer. The insulation layer consisted of vermiculite, poured into a cavity between the drum and a retaining structure. The structure consisted of hessian tacked to staves fixed into a wooden ring surrounding the drum, with a minimum of 150mm of clearance between the drum and the structure. The original design used wattles instead of staves and hessian.

First Burn

The kiln was loaded with alternating 100mm layers of house coal and chalk. The chalk was donated by Anglia Lime and sourced from the Needham Chalk Quarry. As the kiln was loaded, the chalk lumps were broken down with a lump hammer into pieces roughly half the size of a fist. Smaller lumps of chalk were also included, down to the size of a walnut.
A fire was lit in the access hole between the blocks. This ignited the first layer of coal through the grate. After three hours, the fire had spread through the whole drum. The chalk layers were seen to be orange through the inspection holes, indicating a temperature of 1000-1200 degrees Celsius.

After three and a half hours, the vermiculite began to glow and quickly set fire to the retaining structure, which failed and released the glowing vermiculite. The retaining structure and the vermiculite were removed, and the burn continued without an insulation layer.

The fire continued to burn for a total of 13 hours. The kiln retained its high temperature for most of this time, judging by the colour of the chalk and coal seen through the inspection holes. The oil drum was also glowing red (nighttime conditions) for most of the burn. By the end of the burn, the drum was breached in some places, where the fire had been hottest and most sustained.

The kiln was cool enough to unload after a total of 15 hours.

Dirk Bouwens (EARTHA) and Matt Muldoon (right) watching the dry slaking process.

Results of First Burn

The grate was removed from under the drum and the contents were raked out through the access hole. It was easy to separate the burnt chalk from the ash by passing a rake through it.

Burnt chalk from the middle layers was slaked to see if it had converted to quicklime. Wet slaking (submerging the quicklime in water to produce lime putty) produced a very slow reaction which was not immediately apparent. But dry slaking (adding limited water to the quicklime to produce a dry hydrate) produced a noticeable reaction, with the lumps starting to break down into a powder after 20 seconds.

Some burnt chalk from the top layer produced no reaction, indicating that the conversion to calcium oxide had not taken place, but upwards of 80% of the chalk had become quicklime.

Some larger lumps which had been included (size of a fist and above), either produced no reaction or converted to a dry hydrate leaving a chalky core, indicating incomplete burning.

Second Burn

The breaches in the drum were patched with clay, and a burn went ahead with no insulation layer.

The kiln was loaded with alternating 100mm layers of house coal and chalk. Within each coal layer, a ring of chalk was placed against the wall of the drum in an effort to stop the steel degrading further. The chalk was not broken down, so lumps were present from the size of a walnut to the size of two fists. Some effort was made to place the larger lumps at the bottom of the kiln, so that the extra burn time would allow for them to convert to calcium oxide, but the effort was not particularly consistent.

Chalk supplies were limited, so the kiln was just over half full.

A fire was lit in the access hole between the blocks. This ignited the first layer of coal through the grate. After two hours, the fire had spread through the whole drum. The chalk layers were seen to be orange through the inspection holes, indicating a temperature of 1000-1200 degrees Celsius.

Patching up the damaged drum in preparation for the second burn.

The fire continued to burn for a total of 10 hours. The kiln retained its high temperature for most of this time, judging by the colour of the chalk and coal seen through the inspection holes. The oil drum was observed to

glow red after night fell, but much less so than in the previous burn.

The kiln was cool enough to unload after a total of 12 hours.

Results of Second Burn
The grate was removed from under the drum and the contents were raked out through the access hole.

Again, upwards of 80% of the chalk was converted to quicklime. Some burnt chalk from the top layer produced no reaction, indicating that the conversion to calcium oxide had not taken place, but upwards of 80% of the chalk had become quicklime.

Some larger lumps which had been included (size of a fist and above), either produced no reaction or converted to a dry hydrate leaving a chalky core, indicating incomplete burning.


Dry slaking: lumps of quicklime (Calcium Oxide) converting to slaked lime (Calcium Hydroxide) in the presence of water.

Guidelines for Future Kiln Designs
If a broadly similar design of kiln is to be used, the following is suggested:
- A non-combustible structure should be used to retain the vermiculite. Possibly sheet or corrugated steel.
- It would be helpful to have a means of controlling the ventilation of the fire, such as door built into the access hole. Clay slurry or mortar could be used to close the gaps between the blocks.

Instead of including a loose fill insulation layer, the oil drum could be surrounded with a cast covering of vermiculite and clay or lime. It could also be surrounded with clay, or it could be left with no covering. Quicklime was produced on the second burn without an insulation layer, which shows it would be possible to successfully operate a kiln which is nothing more than an oil drum on blocks.

The original kiln design has an inherent weakness in that the thin steel will not survive many burnings. Placing chalk around the coal layer in contact with the wall of the kiln helps, but if the kiln is to be used on more than a couple of occasions, then a more resistant kiln chamber should be used. A 24” concrete tube might last longer than an oil drum, though it is significantly less handleable. It could also be surrounded with an insulation material such as vermiculite.

The most resilient demonstration lime kiln would be made of masonry, but it would no longer be easy to dismantle and reassemble it.

Guidelines for Future Kiln Operation
The ratio of 1:1 chalk to house coal seems to produce enough heat to convert the chalk into quicklime. Wood, coke, or other types of coal could be used. Alternating 100mm layers also seems effective but other configurations should be trialled. To ensure complete burning with this set-up, lumps of chalk should be no bigger than half a fist. It is also helpful to place a ring of chalk in the coal layer, in contact with the wall of the kiln, to reduce the heating of the steel. A full kiln will burn for around 13 hours, and be cool enough to rake out about two hours afterwards.