A SMALL LIME KILN FOR BATCH AND CONTINUOUS FIRING

CONSTRUCTION DETAILS AND EVALUATION OF AN EXPERIMENTAL KILN

Introduction

In 1996 ITDG (now Practical Action) commissioned Paragon Ceramics Ltd to build an experimental lime kiln at Dedza in Malawi. Paragon designed the kiln in partnership with local lime burners. It works with a variety of fuels and can be operated as a batch or continuous production kiln. Where wood is the only fuel option, the kiln works well burning softwood which could be grown on a managed plantation. Good quality hydrated lime and lime putty have been produced for building. These notes are a practical guide on how to build the kiln, and explain its operation. Because it is experimental the Dedza kiln is small. Anyone who wishes to build a bigger kiln should seek further advice.

Figure 1: The construction of the experimental klin, Dedza, Malawi.
Photo credit: Practical Action/Kelvin Mason

Background

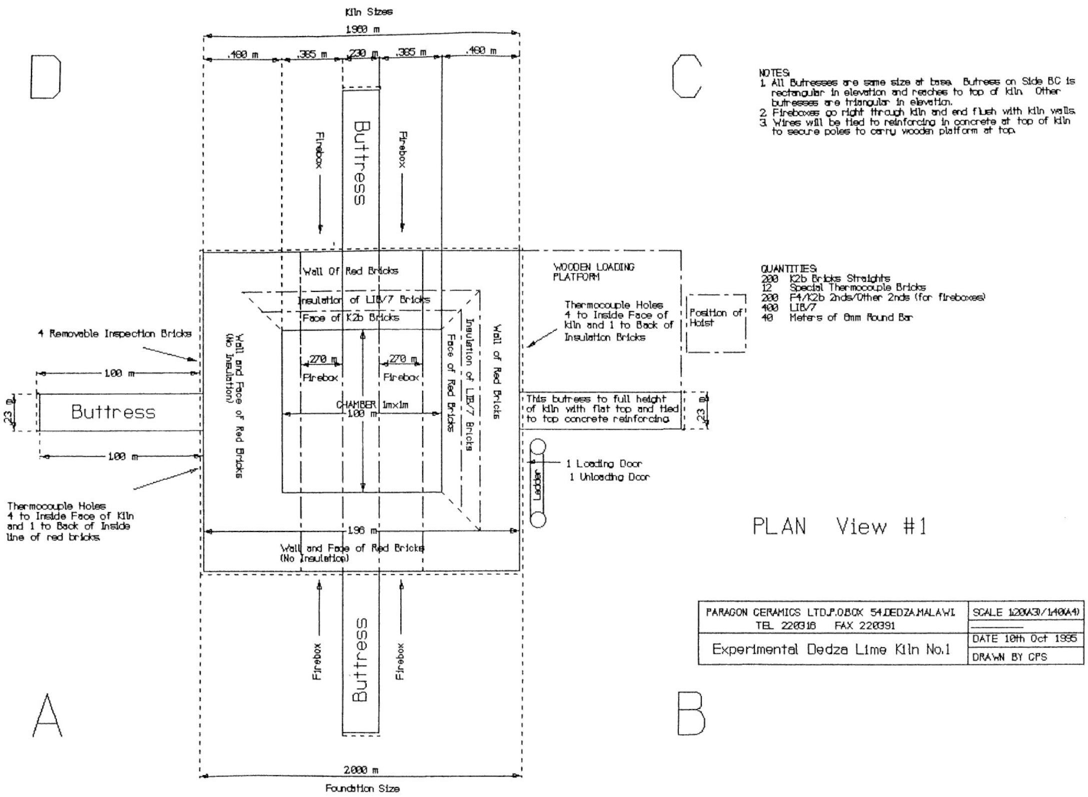
In Malawi lime burning is often a seasonal, dry weather, activity for small farmers who use traditional 'box' kilns. These are rectangular structures with walls of limestone boulders bonded with mud mortar. A typical box kiln would be about 4m long, 2.5m wide and 1.5m high. These kilns are charged with alternate layers of firewood (usually indigenous hardwood) and limestone to a level above the height of the walls. Traditional kilns use a lot of fuel, mainly because of their shape and a great deal of heat is lost through the top. Firewood is very scarce in lime burning areas in Malawi and deforestation is a major problem. Box kilns generally do not produce good quality lime because to do so would use a lot of firewood and cost too much.

Figure 2: Malawian box kiln
Photo credit: Practical Action/Kelvin Mason

Practical Action, The Schumacher Centre, Bourton on Dunsmore, Rugby, Warwickshire, CV23 9QZ, UK
T +44 (0)1926 634400 | **F** +44 (0)1926 634401 | **E** infoserv@practicalaction.org.uk | **W** www.practicalaction.org

Design

The Dedza kiln was designed to test a more efficient and environmentally benign option for small-scale lime burners. The kiln has been fired with softwood, charcoal, briquettes of waste material, and combinations of these fuels. The kiln is relatively low-cost and easy to operate. Because it can also be used as a continuous kiln, it has the potential for lime burners to expand their operations. It is an intermediate stage between traditional production and relatively capital intensive technology. Such a kiln could represent a step away from seasonal lime burning towards a more full-time approach which does not, however, need a big investment or major changes in operating practice.



The kiln is 'tall and slim' to reduce heat losses from the top. It is insulated to reduce heat losses from the sides. Although a kiln with a round section would be more energy efficient, this kiln is square because it is easier to build and to load when burning wood. Construction is simple and uses inexpensive local materials; built using mainly common bricks and as little cement as possible. Even though using these materials and this design, it does require a cash outlay, whereas a traditional kiln does not. Nevertheless, the design described was developed to minimise materials costs. An oil drum is used as a chimney to increase draught and take smoke away from the loading area.

Design Considerations

Construction materials

- **Foundation**

Well burned bricks laid in mortar, 3:1 (river sand: hydrated lime).

- **Fireboxes, firebars**

Refractory bricks (fire bricks) laid with fireclay mortar.

- **Outer skin, buttresses and inner skin**

Common bricks laid in mud mortar, 2:1 (dambo sand: river sand)

- **Reinforced ring beams and capping slab**

Reinforced concrete beams as shown on drawing. Capping slab 1 brick thick. Mortar for beams and slab, 4:2:1 (20 mm aggregate: sand: cement).

- **Insulation skin**

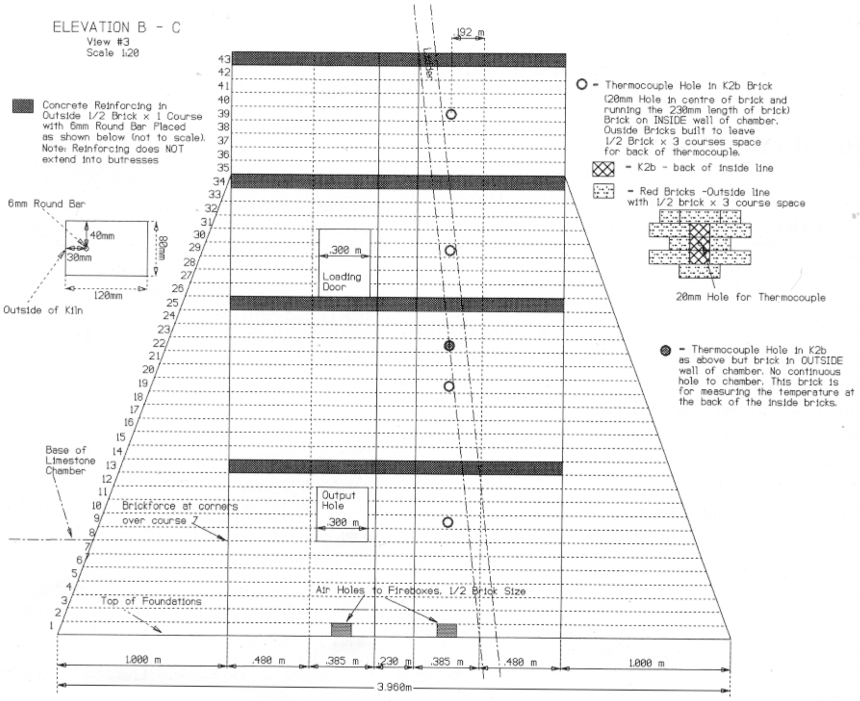
Hand-made insulation bricks in mud mortar, 2:1 (dambo sand: river sand).

- **Mortar**

External pointing and mortar for top five brick courses is 3:1 (river sand: hydrated lime)

- **Chimney**

The chimney is a 200 litre oil drum. The chimney is removable for loading the kiln. It has an angle-iron frame which rests on the capping slab. Draught could be increased by extending the chimney with a second drum. Alternatively a chimney could be fabricated from mild steel sheet or built in brick. If chimney height is increased, then more secure fixing will be required and a loading door will be needed in order to charge the kiln.



- **Kiln height**

The height of the kiln is similar to the gable of a single-storey house: a height builders will be comfortable working with. Being under 4 metres high means that no special foundations are needed on soil with good load-bearing characteristics.

- **Unloading**

Limestone burned at Dedza breaks up into powder as it changes to quicklime. Hence, unloading is achieved by raking quicklime via the output port and removing it from the fireboxes. Where quicklime remains in virtually stone size pieces, a larger output port with a steel door should be considered.

- **Fire brick spacing**

The spaces between fire bricks in the top of the fireboxes (which is also the firing chamber floor. See detail on elevation A–B, page 6) are determined by stone size and type and should be adjusted as experience is gained. At Dedza, using stone with a diameter of 45 to 60 mm which burns to a powder, the spaces are set at about 80 mm.

Construction Details

Construction details, given in the following drawings, are for the experimental Dedza kiln incorporating minor improvements.

- **Foundations**

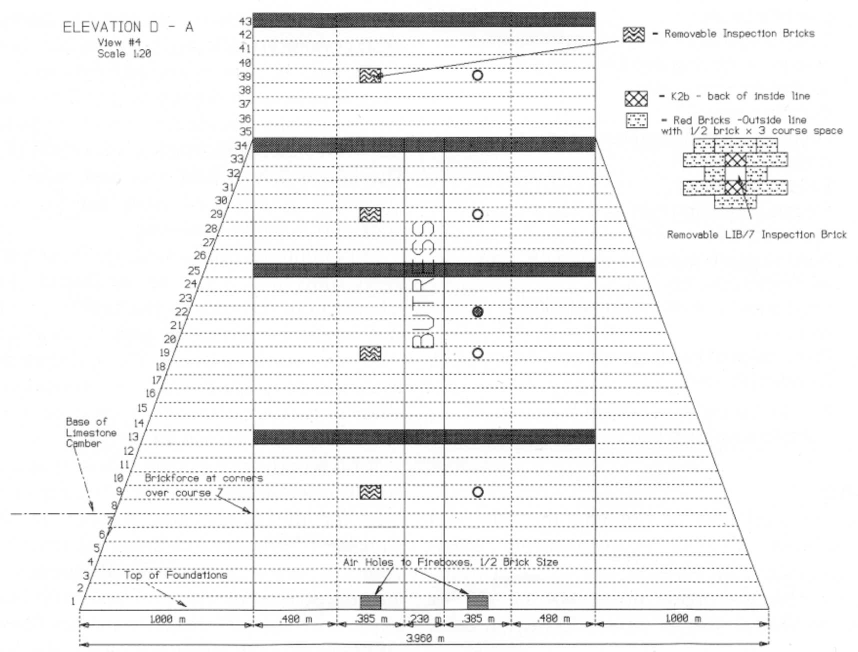
With a firm and rocky subsoil, as would be expected in lime producing areas, a foundation between 60 and 80 centimetres deep will be adequate. The foundation platform should cover the full square area of kiln and buttresses.

- **Loading ports**

The loading port shown midway up the kiln on elevation B-C is for the initial loading to reduce work in loading the first half. For a kiln built in a hillside with a ramp for loading or if an efficient hoist is used then it may not be very advantageous to use the top loading port.

- **Fireboxes**

Except where the fireboxes pass under the kiln walls, the bricks spanning the top of the fireboxes form part of the floor of the kiln chamber. These bricks are adjusted to give the maximum space for the fire to enter the chamber without allowing the unburned limestone to fall through the gaps. The fixing of these bricks is exactly the same as for the firebars to allow for easy replacement. There are 2 fireboxes and they run right through the kiln with the same cross section as shown in the drawing (Elevation A–B). The fireboxes are built with standard "heavy" firebricks.



- **Firebars**

Firebar spacing is approximately 100 millimetres. The "firebars" are standard firebricks which rest on the bottom pairs of protruding bricks in each firebox. The size of the gaps between the firebars can be adjusted depending on the fuel but for firewood we used gaps of about 25 cm. Small pieces of brick bedded in a very low clay content mortar are placed on the protruding bricks between the firebars to keep them in one place (See Elevation A–B). Gaps should be left at the ends of the firebars to allow for expansion and for easy replacement when the firebars break.

- **Insulation**

For insulation bricks, a few tests will show the maximum combustible material which can be added to clay while still producing a brick strong enough to handle. Sieved sawdust is an ideal combustible, but cereal husks or other chopped vegetable matter can also be used. Firing insulation bricks needs a long soak at top temperature with a clean – smokeless – flame.

- **Ring beams**

The Ring Beams are cast as the wall is being built. When the correct course is reached the outside 1⁄2 brick is left out all the way round and shuttering fixed level with the top of the course. A single 6mm round bar, bent to shape and hooked together at the ends, is used for reinforcement. It is placed in the middle of the brick vertically and approximately 1⁄4 way across the brick from the outside wall horizontally (See detail in Elevation B–C). Provided the concrete is kept damp for 10 days kiln building can continue 24 hours after placing the concrete.

- **Capping slabs**

The capping slab ties in the final brick courses and prevents bricks being dislodged when working at the top of the kiln.

Infrastructure and Accessories

- The buttress on side B-C is a constant rectangular section built to the full height of the kiln. It is used to hold the loading platform which is otherwise supported by timber poles. Depending on the site of a particular kiln, this structure may not be needed – for example where a kiln is built into a hillside.
- The loading platform has a safety handrail made from wooden poles.
- A hoist is used to lift limestone and fuel to the top of the kiln. At other sites a ramp may be a more suitable option.
- Access to the loading door and inspection holes is provided by a portable ladder. A second, strong ladder is used to gain access to the loading platform.

Construction programme

For planning purposes the following programme can be used as a guide. It assumes a team of 2 skilled builders, 4 assistants and 1 carpenter.

Day	Action
1	Site clearance, excavation of foundations, setting out.
2 – 3	Build foundations to about 150 mm above ground. Make ladders.
4 – 5	Build fireboxes.
6 – 8	Build outer, insulation and inner skin, plus buttresses to course 12.
9 – 10	Prepare shuttering and reinforcing. Cast first concrete beam.
11 – 12	Build to course 24. Prepare scaffolding.
13	Prepare shuttering and reinforcing. Cast second concrete beam.
14 – 15	Build to course 33.
16	Prepare shuttering and reinforcing. Cast third concrete beam.
17	Build to course 42.
18	Prepare shuttering and reinforcing. Cast fourth concrete beam.
19 – 20	Build stepped courses to course 48. Cast reinforced concrete cap.
21 – 23	Point outside of kiln. Erect poles for platform.
24 – 25	Point inside of kiln (mud mortar). Begin wooden platform.
26 -28	Prepare bricked area outside fireboxes. Complete wooden platform.

Costing

In 1996 the total cost of building the kiln was 18,355 Malawi Kwacha (approximately £730) excluding design, supervision and material transport costs. This was made up of MK 11 455 for materials and MK 6 900 for labour. Transport costs for materials may be a significant factor at some sites.

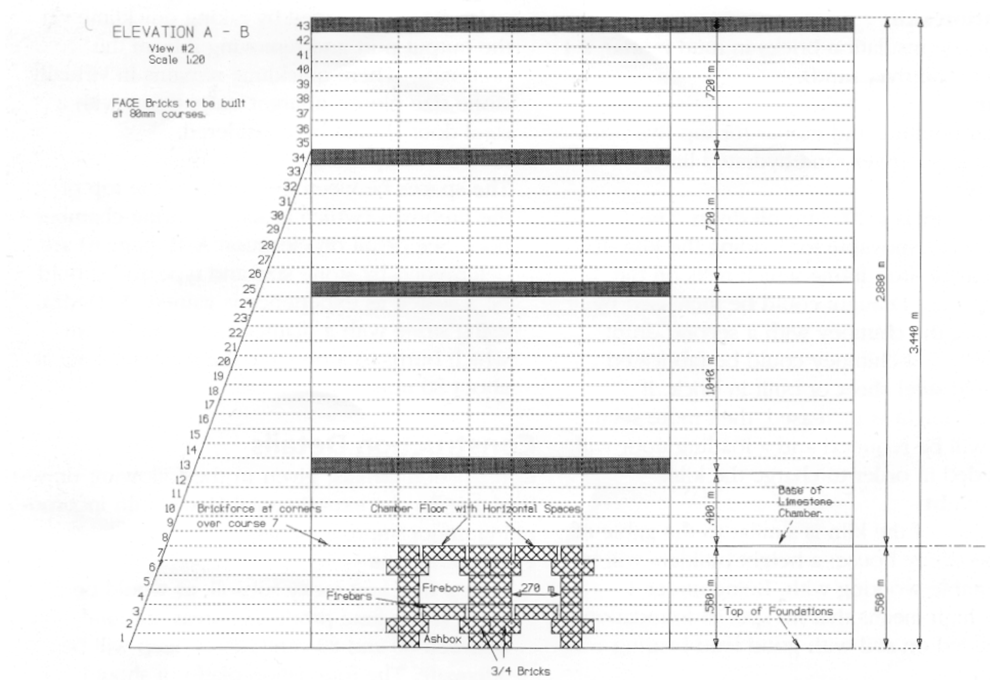
Table of costs

Item	Quantity/Size	Cost (MK)
Common (red) bricks	7 000	1 750.00
Locally made insulation bricks	1 000	2 000.00
Fire bricks (refractories)	250	3 750.00
Fireclay mortar	3 x 50 kg	450.00
Cement	4 x 50 kg	400.00
Hydrated lime	12 x 50 kg	960.00
Brickforce (2.5mm steel mesh wire)	1 roll	55.00
Dambo sand	5 m^3	250.00
River sand	5 m^3	250.00
Reinforcing bar	6mm round x 55m	220.00
200 litre oil drum (ends removed)	1	250.00
Angle iron 40mm x 40mm x 3mm x 6m (chimney frame)		240.00
Poles (platform, 20 x 5m x Ø120mm handrail & scaffold)		400.00
Timber 12 x 3m planks (scaffold & platform)		480.00
Total materials		11 455.00
Labour		6 900.00
Grand total		**18 355.00**

Operation

When used for batch burning, the kiln is loaded with alternate layers of firewood and limestone. The size of limestone should be determined by local conditions. Slightly larger stones can be used in the mid section of the kiln where it is hottest. Once limestone at the top of the kiln is red hot and the charge has subsided, it is possible to top up the kiln with small limestones to make use of this heat. The kiln is left to burn out and, when it is cool, quicklime is removed from the bottom loading door and from the fireboxes. In continuous production, quicklime is removed every thirty minutes or so. At Dedza quicklime is raked to fall through to the fireboxes. Mixed fuel and limestone is loaded into the top of the kiln every two or three hours. Though they are expensive, refractory bricks might be considered for the inner skin when the kiln is used continuously as they will last much longer.

If firewood or charcoal is chosen as a fuel, then lime burners must consider planting trees to provide for the future and counter environmental damage. Alternatives to firewood have been tried. Charcoal does work well. Briquettes of waste material soaked in waste oil burn well but produce unpleasant smoke before they catch fire. Waste oil 'dripped' into the inspection holes also produces a lot of smoke and doesn't work well. However, a system of spraying oil into the kiln at mid height could work. Blowing sawdust into the kiln is also possible, but this requires an electricity supply. Using coal would certainly work.



In both batch and continuous operation the loading port and output port are sealed with bricks and mud mortar during firing.

Capacity and output

A traditional box kiln would typically have a capacity of more than 15 cubic metres. The experimental Dedza kiln has a capacity of only 3 cubic metres. This could be increased to 12 cubic metres if the sides of the internal shaft were doubled in length to 2 metres. When used for batch burning the Dedza kiln would be suitable for rapid production of small quantities of good quality lime. Fully charged it holds 1620 kilograms of limestone and about 1400 kilograms of dry pine firewood. So the output should be 900 kg of quicklime, giving around 1 190 kg of hydrated lime.

Efficiency and fuel use

The efficiency of traditional box kilns varies, but results obtained in Malawi suggest it is typically less than 10%. As a batch kiln the experimental Dedza kiln has achieved 15% efficiency producing much higher quality lime. In continuous operation the experimental kiln has achieved similar efficiencies and product quality. Scaling up the design to 12 cubic metres would be expected to improve performance. Interestingly, this research indicates the way to further improve performance would be to develop small, continuous vertical shaft kilns (VSKs).

Reference and further reading

- How to Calculate the Energy Efficiency of Lime Burning, Practical Action Technical Brief.
- How to Build a Small Vertical Shaft Lime Kiln, Practical Action Technical Brief
- Lime Kiln Designs: *Small & Medium Scale Oil Fired Lime Kilns* Practical Action Technical Brief
- A Small Lime Kiln for Batch and Continuous Firing Practical Action Technical Brief
- The Small Scale Vertical Shaft Lime Kiln: A practical guide to design, construction and operation, Kelvin Mason, Practical Action Publishing, ISBN 9781853394652
- Small-scale Lime-burning: A Practical Introduction Michael Wingate, Practical Action Publishing, ISBN 9780946688012

This technical brief was originally produced for **basin**, Building Advisory Service and Information and was prepared by Chris Stevens of Paragon Ceramics Ltd. (PO Box 54, Dedza, Malawi) and Kelvin Mason, a consultant to ITDG (now Practical Action).

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Practical Action
The Schumacher Centre
Bourton-on-Dunsmore
Rugby, Warwickshire, CV23 9QZ
United Kingdom
Tel: +44 (0)1926 634400
Fax: +44 (0)1926 634401
E-mail: inforserv@practicalaction.org.uk
Website: http://practicalaction.org/practicalanswers/

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