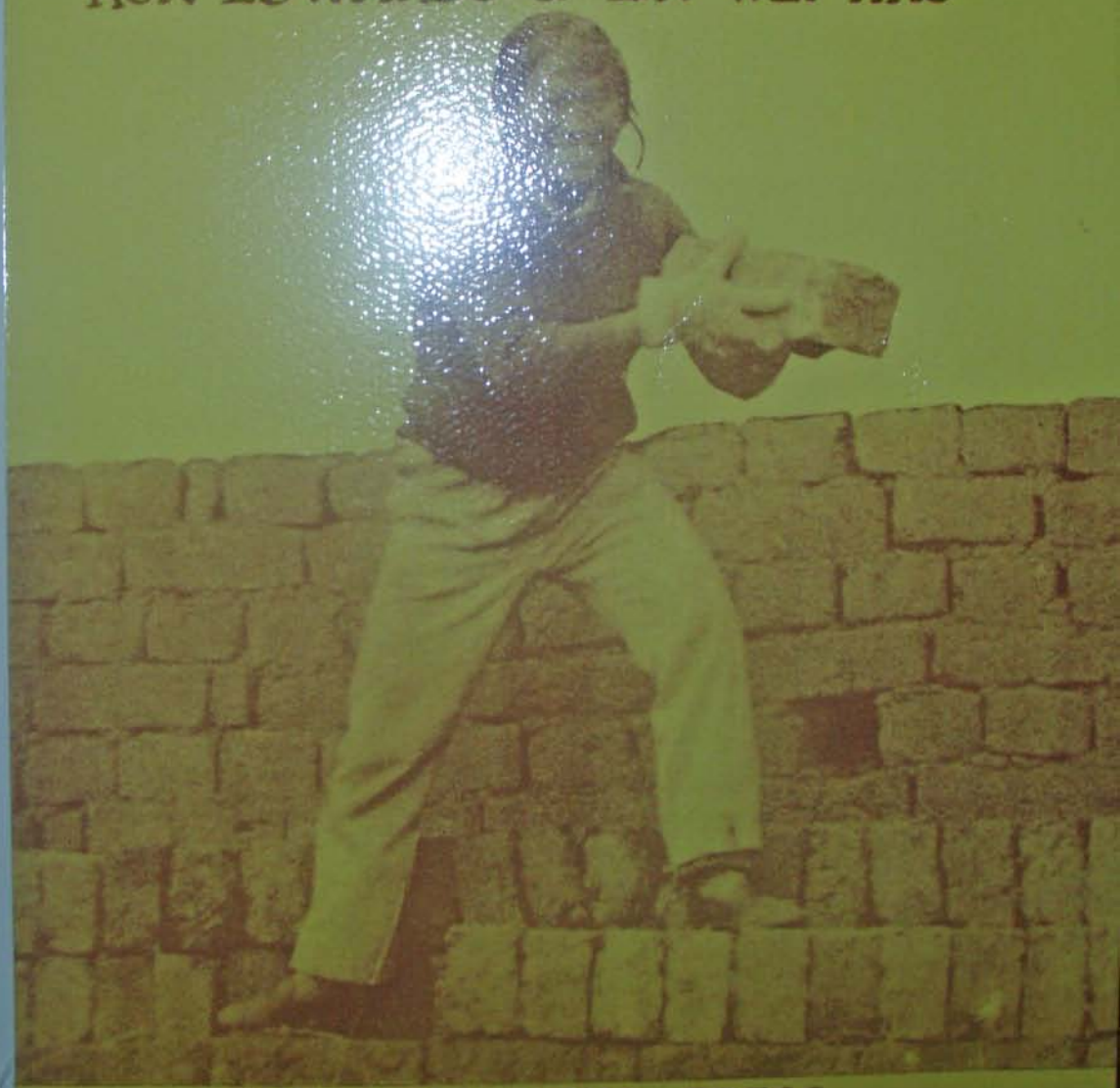
Mud Brick and Earth Building the Chinese Way

RON EDWARDS & LIN WEI-HAO



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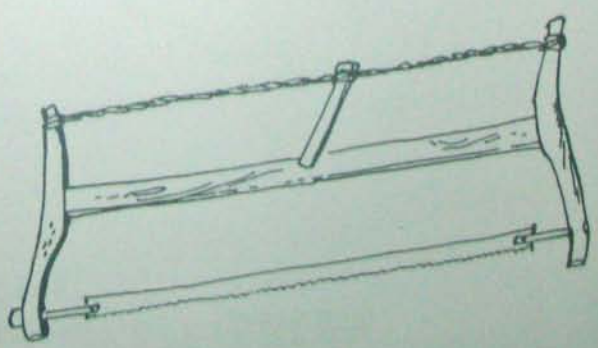

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Dedicated to the farmers who made this book possible

Mud Brick & Earth Building

the Chinese way

RON EDWARDS & LIN WEI-HAO

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ACKNOWLEDGMENTS

Thanks are due to my co-author Lin Wei-hao for all the work he put in to make this book a success.

Thanks are also due to the many Chinese people in the countryside who offered me information and hospitality, even though they could not understand why a foreigner should be interested in earth buildings.

Thank also to the many Chinese officials who helped me, especially my interpreter Wu Zhong-ning and Driver Zhuang of Kunming.

My sixth visit to China would not have been possible without the financial support of the Australia-China Council. This body was set up by the Federal Government in 1979 to promote understanding between Australia and China. It finances projects, visits and exchanges in a wide variety of sports, cultural and educational fields, science and community activities.
I also appreciate the help given to me by Laurie Brooks of the Australia-China Council in organizing that trip.

Thanks also to the Director of the Council, Dr Jocelyn Chey who came up with some valuable information on cave homes in north-west China.

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An old mud brick building in Kunming

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A BRIEF EXPLANATION OF TECHNIQUES

MUD BRICKS. Mud bricks are made by placing mud, with or without straw, into a wooden mould without a bottom, lifting off the mould and allowing the brick to dry. The same sort of mud is used as a mortar when building a wall with the bricks.

RAMMED EARTH. A wooden form is placed where the wall is to be built and moist earth placed in this and rammed firm. When the form has been filled the form is moved one step on and the process repeated.

POLE-MOULD WALLS. A rammed earth technique in which long poles are used instead of a wooden form. The method is fast but has some disadvantages.

RAMMED BRICKS. An interesting technique for low rainfall areas in which the earth is removed from the ground and put directly into a brick mould and rammed firmly.

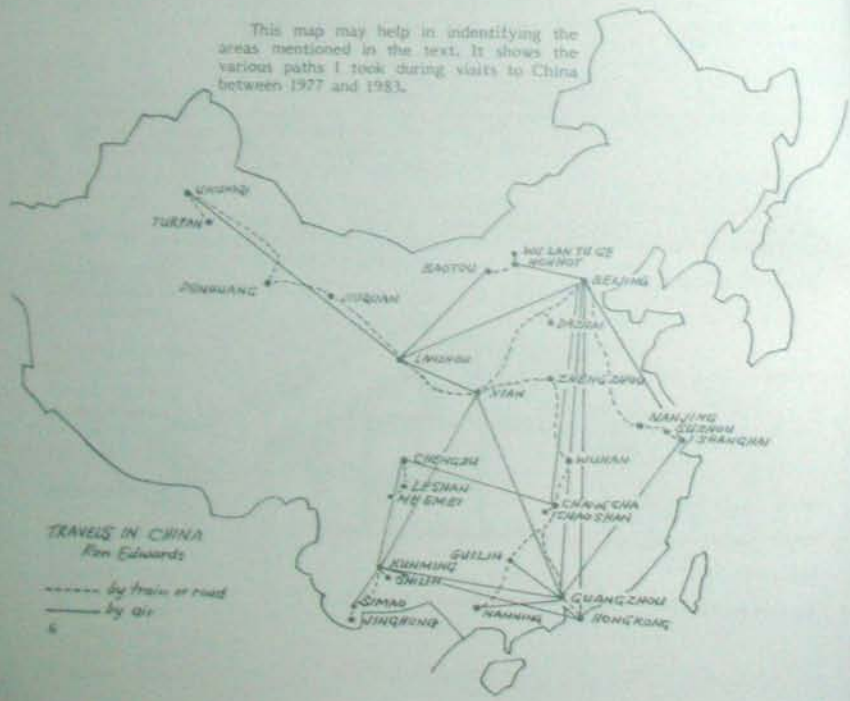
WATTLE AND DAUB. The wall area is filled with a network of sticks and mud is plastered over it. Practical only if a ready supply of straight sticks is available.

COB. I only came across one example of a cob wall in the process of being built, and this was in Inner Mongolia. A stock-proof fence was being erected. The technique is very simple and uses no forms at all.

Mud containing a lot of straw is placed by hand on the wall . Further layers are added as the first dries sufficiently to take the weight.

The resulting wall is usually rather lumpy and uneven, but is easy to build. The technique is not used for good quality walls.

This map may help in indentifying the areas mentioned in the text. It shows the various paths I took during visits to China between 1977 and 1983.



Introduction

I first met Lin Wei-hao in the Chinese city of Kunming on a mild autumn evening in September 1979.

I had set off in search of a shop selling drawing paper and was approached in the street by a young Chinese couple who asked, in English, if they could help me.

At that time it was very rare to find anyone who could speak English, and I was delighted to have their help. I was also surprised to learn that they had taught themselves English.

Our meeting was quite a coincidence, for I was collecting information on earth building during my travels in China, and he was a translator at the Yunnan Institute of Architectural Science.

We became friends, and after a time I suggested that he should become my partner in writing this book.

From that time on he wrote to me regularly, sending very clear notes and drawings.

His drawings will be readily recognized throughout the book as coming from someone with an architectural background.

His notes have been incorporated into the general text unless otherwise stated. Wherever the first person is used I am referring to my own observations in China.

I made six trips to China in the course of writing this book, and the last was the most important, being sponsored by the Australia-China Council.

Being a guest of the Chinese Government was a great advantage as I was allowed to move around the countryside at will, stopping wherever I saw any building going on.

I had with me an interpreter Wu Zhong-ning who had such an excellent grasp of English that I was able to have conversations with Chinese people in the fields just as easily as if we all spoke the one language.

Because of this I was able to help build a wall in Kunming, make rammed earth bricks in Xian, and clay tiles in Xi Shuang Banna. This was a great help in fully understanding the various techniques.

My interest in earth building began in 1950 when I bought a block of land at Eltham, Victoria, and began building a mud brick home.

The project was never completed as I moved to Ferntree Gully to found the Rams Skull Press in 1951, but it left me with a lifelong interest in earth wall construction.

Helping friends with both mud brick and rammed earth buildings over the years I learned one very obvious lesson, and that was that earth construction in Australia was very hard, tiring work.

The forms used for rammed earth were tremendously heavy and awkward to move, and the mud bricks were very big and very heavy. Everyone seemed to pride themselves in demonstrating that earth construction was real man's work.

On my first visit to China in 1977 I was amazed to see both the extent of earth building and the ease with which it was accomplished.

The walls built in China were thicker, and therefore stronger, than those common in Australia, and yet their construction was far less physically demanding.

Over the centuries techniques had been developed that allowed the whole family to join in every part of construction.

Many Westerners think of the Chinese farmer as someone slaving in the fields until he is exhausted, but this is far from the case.

The Chinese farmer flows through his work, he works steadily but without strain, and at the end of the day he is pleasantly tired but content.

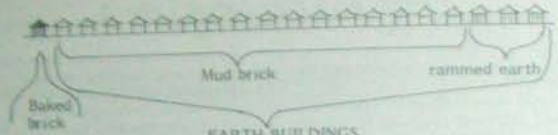
This was brought home to me on many occasions when I have been quietly sketching in some country lane at dusk and noticed how many workers leaving the fields for home would be singing or whistling.

The farmer builds his home in the same spirit, neither exhausting himself nor slackening in his steady pace. Because of his lifelong familiarity with earth building he can begin building a house as casually as we would set about planting a vegetable garden.

He knows just how simple the techniques are, and he also knows the few basic rules that will ensure that what he builds will last for his lifetime.

Many people in the West would like to build in earth but feel unsure about the techniques involved and the lasting properties of the finished product.

I hope this book will prove that all the various systems are both simple and sound.



EARTH BUILDINGS

Building materials used in the rural areas near Kunming, south-west China.

The Chinese have been building in earth for thousands of years and show no signs of abandoning the practise.

Lin Wei-hai did a survey of building techniques in the countryside around Kunming and the diagram shows the results.

93% of the buildings are of earth construction, and only 7% of baked brick.

The earth buildings are divided into 85% of mud brick and 15% of rammed earth. These figures confirm the Chinese preference for building in mud brick rather than rammed earth when constructing their homes.

No one knows exactly how many earth buildings there are in China, but a rough estimate can be made by using these figures and adjusting for various factors such as the preference for fired bricks in flood-prone areas, and the fact that many communes are moving members from earth homes to apartment blocks.

Allowing for all this it could be estimated that there are at least ninety million earth homes in China at present!

Nearly all these homes are in the country. In the cities rising population is causing the demolition of the old earth walled homes and their replacement with cement apartment blocks.

Earth homes have a nice feel about them, by their very nature they harmonize with the landscape, and their sheer weight seems to suggest security.

My wife and I live in the mountains above Cairns, and even on winter nights when the house is hidden in thick fog the mud brick walls of the bedroom keep the room warm and dry, while in the heat of summer the room is much cooler than outside.

WHICH TECHNIQUE IS BEST?

This is an important question and one that is asked by all people who are about to experiment with earth building.

As Lin Wei-hao has shown the country people around Kunming prefer mud bricks for their homes rather than rammed earth, and this attitude holds good for most of China.

There seems to be two main reasons. Although mud bricks require more handling they are less physically demanding than working in rammed earth. Mud bricks also allow a much more flexible plan to be adopted.

Where long walls are to be built rammed earth is often chosen, and so farm buildings such as barns are frequently of rammed earth.

The drawing on the next page shows an example of mixed techniques.

I sketched this huge barn near Simao, south-west China. It had been built in 1937. The bottom floor was used as a stable for buffalo and the top was a storage area for fodder.

The foundations are of large squared rocks with only mud used as mortar, and rocks are also set into the earth walls on the corners and in places where damage is likely to occur through rubbing.

The walls are 500mm thick. The lower floor is constructed of rammed earth. Above this height the technique becomes cumbersome, so the upper floor is of mud brick with timber along the sides. The roof is of tile.

There is no whitewash or plaster on this building and it does not seem to have been renovated since it was built, even though this is an area which receives the full force of the monsoons.

It was interesting to notice that the mud bricks showed less signs of age than the rammed earth.

UNEXPECTED PROBLEMS

Earth is an organic building material and because of this some unexpected problems can arise.

It is worth noting that the Chinese always keep the base of their outside walls clear of vegetation as well as making sure that water cannot sit near them.

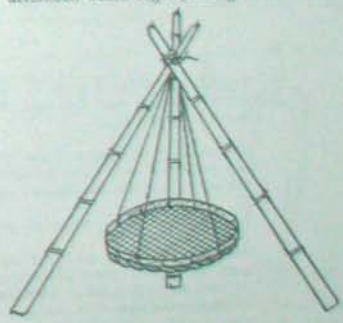
Hose sprinklers can be a problem if you forget that your walls are of earth. We have had surface erosion by forgetfully placing a sprinkler near a wall. Serious damage is unlikely, but it means extra plastering.

Horses like earth walls. I built the dividing walls in the stables of earth. These go to shoulder height, but the problem is that the horses love to rub themselves on the bricks, and I have already had to replace bricks which they have dislodged from the top course.

Hens also seem to like earth bricks, and recently while drying some narrow rammed earth bricks I found that the hens would insist on sitting on the stacks and quite often knock some bricks over.

The most unusual problem that we have had with the bricks was when some abraded areas began appearing at the base of our walls. It took several days to discover the cause, but not the remedy.

It seems that when I had made the bricks the grass hay that was included was in full seed. In time my pigeons discovered this source of snacks, and when released in the afternoon would begin pecking at the wall.



A sieve suspended from a bamboo tripod. This type of sieve is often used when prepating the soil for wall plaster.

The tripod supports the weight of the soil while the worker is shaking the sieve.

A pair of mud brick shops in Xiao Ban Chao (Small Long-Stone Bridge Village) near Kunming. The roofs are of thatch with a porch of tiles.

The shop on the right is the 'Two Friends Shoe Repair Shop', and colourful New Year pictures are pasted on the doors. On the left a hen sits in a basket hanging from the wall.

The footings are a mixture of old fired bricks and tiles.

The locals gathered to watch me sketching, but as I was sitting with my back to the wall they could not look over my shoulder, so they stood in front, chewing sunflower seeds and generally obscuring the view.

It seemed that nothing much happened in Small Long-Stone Bridge Village, and watching me helped pass the time, until a lady began an argument at the top of her voice further up the street, and the crowd drifted off to watch her.

Mud Bricks

HOW TO MAKE MUD BRICKS IN ONE PARAGRAPH

For the Chinese farmer the art of making mud bricks is as easy as riding a bicycle. He takes four pieces of whatever timber is available and nails them together to make a small box without top or bottom. This is done by eye and there are no standard measurements. This mould is then wet and some mud, usually mixed with straw, is place in it. The mould is then lifted and the brick left to dry.

SOME FURTHER OBSERVATIONS ABOUT MUD BRICKS.

In the West mud brick making is surrounded by clouds of mystique but to the Chinese nothing could be more simple.

Having read the first paragraph you can now confidently set about making mud bricks. The rest of this section is really only about making the job as easy and efficient as possible.

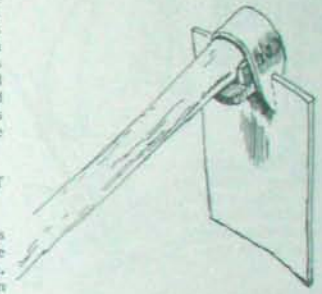
TOOLS NEEDED

One of the attractions of mud brick making is the simplicity of the equipment needed. Only two items are really needed, a mould and some sort of digging tool.

The basic Chinese digging tool is the hoe. They are made by village blacksmiths and so many variations may be found from place to place.

The sketches show two typical examples, one broad and the other narrow. Both have a slight curve from side to side.

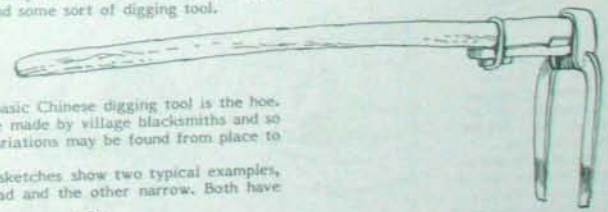
The handles are held in place by wooden wedges.

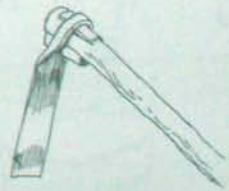


DIGGING RAKE

This is not a rake at all, but as we do not use this type of tool in the West we do not have an exact term for it. It is an ideal tool for excavating earth for mud bricks as it breaks up the lumps as it is used.

However not all households have these digging rakes, and the hoe is the most common tool used.





This sketch was done near Xian and shows a two-toothed rake.

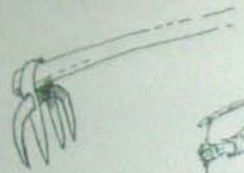
This tool has been used in China for centuries, the next sketch shows a four pronged version well over a thousand years old in the Beijing Museum. Note how it has been made from only two pieces of metal, one piece fitting through slots in the other, without the need for any welding.

SHOVELS AND SPADES

Shovels and spades are used not so much for digging as for moving earth that has already been broken up by the hoe.

OTHER TOOLS

If the soil is very lumpy a wooden club or mallet may be used to break it up.

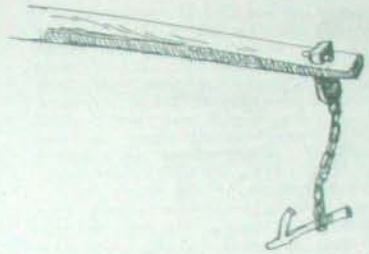


The sketch shows a worker carrying water in metal containers, but wooden pails are more common, and are beautiful craft objects in themselves.

This pair, with carrying pole and ladle, were sketched at Shilin, Yunnan Province. The buckets are held together with heavy wire. Wire is also used to attach chains to the shoulder pole.

Sickles are used to cut straw in the field and any sort of chopper or knife can be used to cut it into short lengths to add to the mud.

A pair of pails and a carrying pole are used to bring water to the site, and baskets are also used with the carrying pole to transport earth.



In some parts of China the carrying poles are of bamboo, in other places solid timber is used.

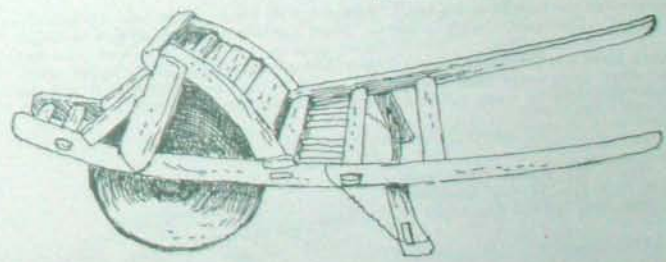
There are many ways of suspending the load from the pole. In this sketch a small block of wood goes through a hole in the pole and is kept in place with a piece of dowel.

A small length of chain hangs from the block of wood and a natural wooden hook is attached to the chain.

Bamboo poles are sometimes made from solid lengths of bamboo, sometimes from slit lengths. The split length is more comfortable as it has a wider cross section and so does not cut into the shoulder.

This sketch was done in Suzhou. The basket is of bamboo as are the pieces that connect it to the pole.

The bottom drawing shows how the end of the pole is shaped. This type of pole is very common in the south where bamboo is plentiful.



WHEELBARROW

A wheelbarrow made entirely of wood, including the wheels, used to carry mud bricks and other materials to the building site.Chengdu, Sichuan Province.

HAND CARTS

If soil or bricks are to be moved any distance the Chinese make use of their excellent hand carts.

These sturdy vehicles have a pair of wheels rather like motor bike wheels and are used to move a thousand and one items around China.

Here in Australia I have made one using motor bike wheels and find it to be of tremendous use around the place, and much more versatile than the wheelbarrow.

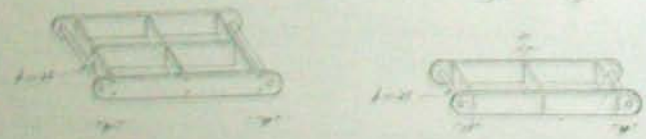
The courtyard on the farm of Li Fu-wen, Dragon Springs Commune, north of Kunming.

The sketch shows a heap of mud, wooden buckets for water, some newly made bricks and the hand cart used to move the mud from the area where it had been excavated.

When I returned to the farm a fortnight later another room of the same size had been added to the left of the upper room. The walls had all been completed and the roof frame was almost finished.

MOULDS FOR MUD BRICKS

The moulds are always made from timber, and here Lin Wei-hao illustrates moulds to make one, two and four bricks at a time.



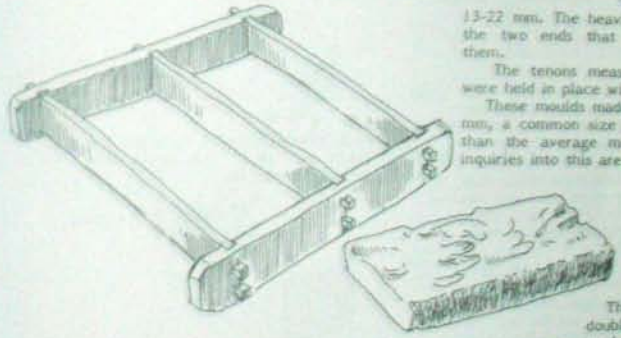
The amount of work put into making a mould depends on the individual. The next sketch shows moulds in their most simple form. I sketched them in Kunming, Feb 1983. They were very light, being made from pine boards 80 mm wide and 20 mm thick. They were simply nailed together and had rough grooves chiselled in to provide a grip for the fingers. Their inside measurements were 300 x 170 x 80 mm.

This simple pair of moulds would have only taken a few minutes to make and yet they had been used to make 20,000 bricks!

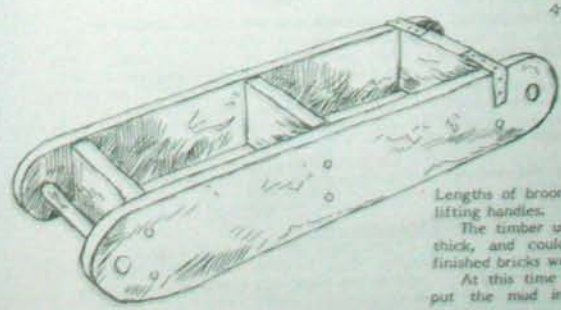
A double mould can also be made with the bricks side by side lengthways. I did this sketch in Lanzhou, March 1983. More work had gone into the making of the mould than in the previous example, but typically the builder used whatever timber was at hand, and the timber used varied in width from 13-22 mm. The heavier timber was used for the two ends that had the holes cut in them.

The tenons measured 13 x 13 mm and were held in place with small nails.

These moulds made bricks 325 x 165 x 60 mm, a common size in this area but thinner than the average mud brick in China. My inquiries into this are given later.



This is a sketch of a double mould that I made using the design drawn by Lin Wei-hao. I used a smooth grained hardwood so that it would not be affected by the constant soaking in water.



This added extra weight and was unnecessary as the Chinese successfully use softwood for the job.

Lengths of broom handle were used for the lifting handles.

The timber used for the job was 25 mm thick, and could have been thinner. The finished bricks were 340 x 210 x 140.

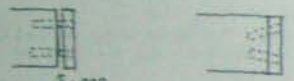
At this time we were using a shovel to put the mud into the mould instead of

following the Chinese custom of using hands, and so the mould took quite a beating. Even though it was strongly built I had to add straps of hoop iron at some joints to stop it coming apart.

The use of thick hardwood rather than thinner softwood made this mould much more tiring to use than a Chinese one, and after watching the Chinese at work I concluded that it was quicker and easier to use a light mould and no shovel.

In Lin's drawing of the moulds you will notice that they are held together with a series of mortice and tenon joints. I simplified this by fastening the mould together with dowels.

To make sure that the dowels did not work loose and leave a gap they were put in at an angle to each other.



To the layman the use of dowels may sound complicated, but they are simple to use. The holes can be drilled by eye, a spot of glue put in and then a short length of dowel hammered home and sawn off flush.

Dowelling is a very useful technique and one that we should pay more attention to. In Bali I have watched a large fishing boat being constructed entirely from planks held together with wooden dowels.

Some were used vertically to hold each plank to its neighbour while others went in horizontally and held the planks to the ribs.

The thousands of dowels used for this job were made on the spot by splitting scraps of timber with a small axe and then shaping them with a knife.

An old trick among European tradesmen was to have a piece of heavy steel plate with a hole drilled in it. Scraps of timber would be split down to nearly the right size and then hammered through this hole, changing their cross-section from a square to a circle.

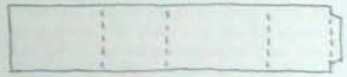
We have experimented with this method and found that it has two advantages. First you can use scraps of the same timber as you are working with. This looks better when making furniture as commercial dowelling is usually cream coloured.

Secondly the dowel becomes slightly compressed when being forced through the hole in the steel plate. Because of this it tends to grip better when hammered into timber as there is less chance of shrinkage.

On the other hand it is certainly much easier to buy ready made dowelling.

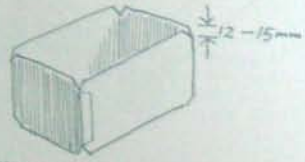
A SHEETMETAL MOULD

This is a simple mould to make as long as you can solder. It can even be made without soldering by simply crimping the seam.

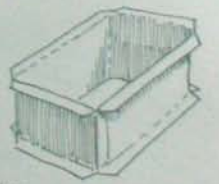


The metal should be cut as shown. The vertical measurement should be 30 mm more than the required height of the finished brick.

The metal is folded into a rectangle and soldered down the seam. This is the only soldering needed on the job.



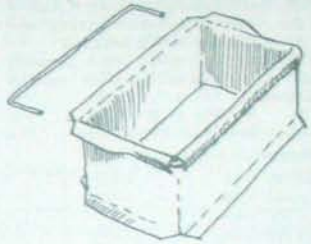
The corners are now cut as shown, to a depth of 15 mm.

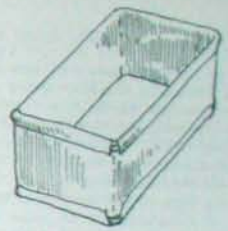


The edges are now bent over at right angles. This is done by holding the job against the edge of a bench and hammering it.

Four lengths of fencing wire are cut and bent. A wire is placed under one of the long edges and the metal hammered over it. The sides are then treated in the same way.

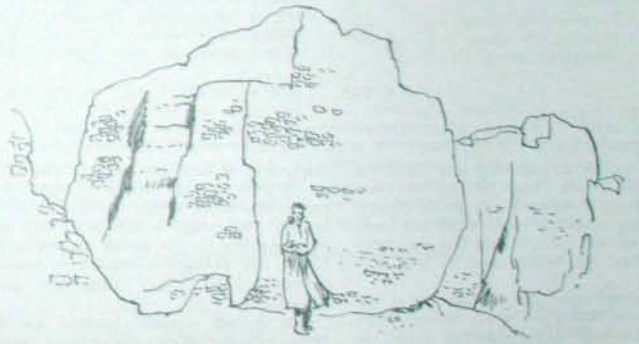
In the sketch below the left wire is ready to go in place and the other has been pinned in place. When all four wires have been put in place the mould is ready for use.





If desired handles could be soldered to this mould.

I have made several hundred bricks using a mould like this and found it light and easy to use. It needs to be dipped in water between each use the same as a wooden mould.



An ancient eroded section of the Great Wall out in the desert , beyond the last great fortress gate of Jiayuguan. The temperature was below freezing at the time of my visit.

The outer faces of the wall have been built with mud bricks and the inside then completed with rammed earth.

Below is an ancient fort far out in the desert, along what was once the famed Silk Road.

Built only from earth the walls are still an imposing landmark, though the buildings inside have been reduced to dust.

The lasting properties of earth as a building material can be appreciated after seeing examples such as this, exposed to the weather and without any maintainance for centuries.

DIMENSIONS FOR MUD BRICKS

There are no standard measurements for mud bricks in China. An infinite variety of dimensions are used and these have evolved from a combination of factors including the ease of handling small bricks compared with the speed of working with large bricks, plus a respect for the material being used.

The following figures give an idea of the great variety of dimensions to be found in mud bricks. The smaller class of brick is often found in the north of China and in areas of high rainfall.

Smaller bricks are made in order to speed up the drying time in view of uncertain weather conditions or short hours of sunlight.

Although this means more work it has a bonus in that fewer sub-standard bricks are produced when a small size is adopted.

The following table gives some common brick sizes that I have noted in various parts of China:

	Dimensions in mm.	Volume
Dunhuang (on the Silk Road)	320 x 160 x 60	.0030
Dunhuang	300 x 160 x 50	.0024
Anxi (near Dunhuang)	270 x 160 x 60	.0025
Yumen (Western end of the Great Wall)	300 x 140 x 60	.0025
Yumen	270 x 130 x 100	.0035
Lanzhou (NW China)	325 x 165 x 60	.0032
Kunming (SW China)	300 x 170 x 80	.0040
Changsha (Central China)	320 x 200 x 130	.0078
AVERAGE SIZE	300 x 160 x 75	.0036

As a matter of interest I also measured bricks used in the thousand year old ruins of Gaochang, a vanished city in the deserts of Xinjiang in the far north-west, and found them to be 440 x 220 x 125. This was much larger than the bricks used in this area today.

Consider again the average brick size given above, 300 x 160 x 75, volume .0036. By contrast the late Australian expert on mud brick building, G. F. Middleton in his book Build Your House of Earth, first published in 1953, gives a preferred brick size of 375 x 250 x 125, volume .0117.

This brick is estimated to weigh 22 kg, and is more than three times the volume of the average for the Chinese bricks given above.

The reason for the Western preference for a larger brick is because the Australian custom is to build walls with a single course of bricks laid lengthways.

The Chinese use smaller bricks but lay them in such a way as to make much thicker walls.

I have always considered that the one major reason for the limited use of mud bricks in Australia is connected with the discomfort of handling heavy bricks.

A brick of the average Chinese size as given here would weigh one third the weight of the Australian brick. Men and women share equally in the laying of mud bricks in China, but strength is needed to handle the Australian brick when made to the old dimensions.

The obvious answer is that we should revise both our brick dimensions and our methods of laying them.

The following table was prepared by Lin Wei-hao and shows a number of common dimensions for mud bricks made with straw. Note that wall thicknesses go up to a massive 600mm!

You may notice that his average brick size is greater than mine. One reason for this is that he lives in Kunming, in the south-west while the majority of my figures were collected in the north-west where, as noted earlier, the bricks are generally smaller.

In addition the lower part of his scale shows wall thicknesses suitable for the lower parts of two story buildings where it may be convenient to use larger bricks.

Wall thickness in mm.	Dimensions in mm.	Volume
350	350 x 170 x 100-120	.0065
380	380 x 185 x 120-140	.009
400	400 x 200 x 150-200	.014
420	420 x 210 x 150-180	.0145
450	450 x 220 x 120-160	.0138
480	320 x 150 x 120	.0057
500	330 x 160 x 120-140	.0068
530	360 x 175 x 140	.0088
570	380 x 180 x 120-140	.0088
600	400 x 195 x 130-140	.0105
Average:	379 x 184 x 137	.0096

DIMENSIONS OF BRICKS WITHOUT STRAW

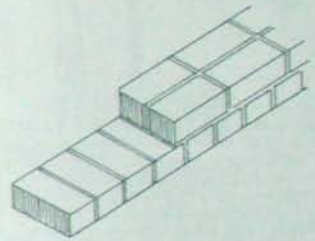
Lin notes that bricks made without straw are generally smaller than those in the above table . Length varies from 260-280 mm, width 150-200 mm, thickness 80-100 mm.

This gives an average of 270 x 175 x 90, volume .0042. This is not far from my average brick size noted earlier, and these bricks may have contained little or no straw for the most part.

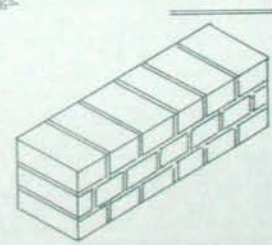
The addition of straw can only be seen by breaking the brick open, and the bricks that I measured were usually set into buildings.

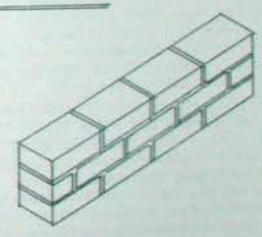
Note that the thinnest wall in Lin's table is 350 mm. This would be thicker than many walls being built in Australia today. It confirms the Chinese belief that a well made house should have good solid walls.

As stated earlier a thick wall has greater stability, better sound-proofing and insulation properties and is less likely to be damaged by the weather.



Although there is no single standard measurements for mud brick there is one point to remember. There are a number of different ways of building the bricks into a wall, and some of these call for the brick to have a width just a little less than half its length. The sketch explains why.





A COMPARISON

The sketch on the left shows a wall made with bricks laid so that their length goes through the wall. The sketch on the right shows a wall with a thickness of the width of a brick.

A wall 5 metres long and 2.5 metres high built with bricks 320 x 240 x 100 mm will require 4 cubic metres (521 bricks) if built as in the left sketch, and 3 cubic metres (391 bricks) if laid as shown on the right.

So the thicker wall uses 25% more bricks, but the increase in strength and stability of the thicker wall is far greater than 25%, and this certainly justifies the extra work and material involved.

TO SUMMARIZE

A brick measuring 335 x 210 x 145 will weigh 17 kg and have a volume of .0102.

Unless you are interested in body building this really represents the upper limit for convenient handling, especially at heights.

If the whole family is going to help lay the wall a brick of this size may be a little too heavy.

When smaller sizes are adopted there are fewer substandard bricks, there is less cracking and they dry faster.

On the other hand more bricks must be laid to build the wall – but the work is much easier.

IF YOU WANT IT, DO IT

Once a convenient brick size has been decided on anyone can make bricks. In February 1983 I was travelling down a country lane in Yunnan Province looking out for earth building in progress.

Motor vehicles did not use this track as we discovered when we came to a ditch that someone had casually dug across the road to take water from the irrigation channel to his fields.

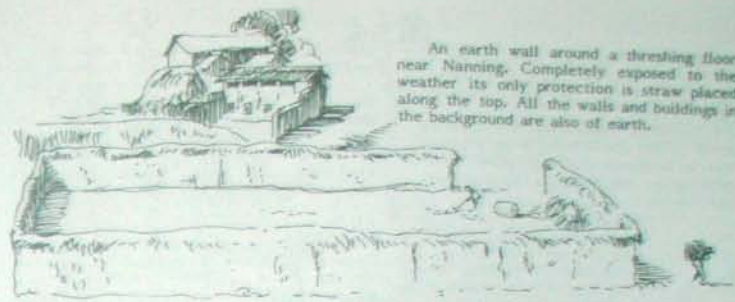
While the driver pondered on the problem I walked over to watch a couple of young ladies at work stacking mud bricks.

Although they looked like sisters I discovered that they were mother and daughter. They had decided that it would be nice to have an extra room on the house, and as the menfolk were busy in the fields they were doing all the work themselves.

They set up their worksite on the edge of the track, taking the mud directly from the irrigation channel. The fact that they widened the channel considerably as well as blocking up half the track with their bricks did not upset anyone, the Chinese are very understanding in these matters.

The bricks measured 300 x 150 x 100 mm, volume .0045, and they had made 2,000 of them. Soon their new room would be a reality.

At this point my driver solved the problem of the ditch by driving at it at high speed , coming down with a resounding crash on the other side. Chinese cars may not look much but they are very strong!



An earth wall around a threshing floor near Nanning. Completely exposed to the weather its only protection is straw placed along the top. All the walls and buildings in the background are also of earth.

CLAY

Potential earth builders in Australia should not become discouraged if their soil appears to be pure clay, as so often seems the case.

Despite appearances it is unlikely to be pure clay, and will often be found to contain a fair proportion of grit or sand and be quite suitable.

Before condemning any soil first make up a test brick. Any available container can be used as a mould, a plastic icecream container with the bottom cut out is quite suitable.

In Cairns I once made an incinerator with bricks made in such a mould.

When the brick has dried place it back in the mould in order to see how much it has shrunk. Pure clay will shrink to a marked extent, and cracks may appear on the brick.

The presence of a few small cracks is no problem, but if they are bad enough to affect the quality of the brick then some sand must be added to the clay mixture.

When coarse or medium sand is added to the clay the rate of shrinkage is reduced, and as a result cracks will not appear.

The addition of sand does not seriously affect the strength of the brick, but on the other hand the more clay the brick contains the stronger it is and the more impervious to water.

In Kuranda when working with heavy red clay I find it necessary to add some sandy soil to the mix. This is not done to any set proportions, but by having a look at the previous batch of bricks to see how they have dried.

Both coarse and fine sands are suitable, and also sandy loam, whatever is readily available.

SAND

Common sense must prevail in brick making. Pure sand cannot be used to make mud bricks, otherwise we could all go to the beach to make them.

But sandy soils can be used if sufficient clay is present, otherwise clay can be added to the mix. As before test bricks should be made using various proportions of available material.

In Kuranda we had to clean out a dam in a creek bed. The material was sandy silt and appeared to be quite unsuitable for brickmaking. But as it had to be moved in either the wet or dry state we decided to experiment and made 250 bricks on the spot.

These were easier to carry out when dry than the wet silt would have been, and to my surprise they were quite usable bricks. The material obviously contained a lot more clay than was apparent. This again proves that all soils should be given at least a test before being condemned. Far too many people cry "My soil is just pure clay" and abandon the idea of making bricks without even trying one test brick.

Furnace slag with a grain size of 5 - 20 mm is sometimes used in brickmaking if sand is not readily available. The slag is moistened before it is mixed with the clay.

This is an example of making use of whatever materials are readily available.

USE OF STRAW

Mud bricks are strengthened by the addition of some form of vegetable fibre, usually in the form of wheat or rice straw.

If this is not available any type of dry grass can be used, also flax, bast (fibrous bark), pine needles or hemp (cannabis sativa).

(For those Australians who may be surprised at the use of hemp in brickmaking it must be explained that large quantities of cannabis sativa are grown in China for use in rope making.

An interesting aspect of this plant is revealed in China Pictorial 5/1981 - though it has nothing to do with mud bricks.

In an article dealing with the long lives enjoyed by a group of mountain people in southern China it mentions that their staple diet consists of various types of pumpkin and squash, corn, pumpkin vine tips, wild greens and the seeds of cannabis sativa used as a flavouring agent.)

The bonding action of straw can be observed by breaking open a brick that has been made with straw and one that has not. The brick without straw will break cleanly while the one with straw will tend to hold together because of the fibres contained in it.

The amount of straw to be added to a mud mix is judged by eye, but a good average proportion is 5 kg of straw to each cubic metre of earth. The amount is really not critical, and the addition of any straw, even a small amount, will help in brickmaking.

Rotting straw is of no use, the material must be sound. It is roughly chopped into lengths of around 100 mm, or longer lengths may be used if desired, again there is no fixed rule.

BRICKS WITHOUT STRAW

In the arid regions of China where straw is not always available bricks are frequently made without it. As noted earlier these bricks are usually made a little smaller than those with straw.

Once laid in a wall the bricks without straw perform just as well as bricks with straw, except that they will erode faster if subject to direct wetting.

The sand content for a brick made without straw should range between 25% - 40%.

Longevity Pavilion, an old building near Kunming. The lower floor is of massive earth construction, and the surrounding wall is also of earth, set on a rock foundation.

SOIL QUALITY FOR MUD BRICKS

Clean sandy clay is the best material for making mud bricks, but in practise almost every type of soil is used. Some writers on earth building have tried to make the subject unnecessarily confusing by introducing scientific analysis of various soil types, but a glance at the millions of people who successfully build in earth using nothing but their own common sense shows that such an approach is unnecessary.

In China the convenience of supply is the major factor, and scientific analysis does not enter into it. The proof of this practical approach can be seen in ancient farmhouses which have been home to many generations and are still as strong as the day they were completed.

TOPSOIL

It makes sense not to use such a valuable resource as good, rich topsoil for bricks. This will be obvious to any gardener, and the topsoil should be removed before brickmaking begins.

An interesting exception to this rule can sometimes be observed in China. In the rice growing areas the fields are regularly fertilized with manure and with silt drawn from the canals.

In time this constant application raises the level of the fields to the point where they can no longer be irrigated by gravity.

When this happens the whole surface of the field is lowered by digging up the top layer and using it to make bricks. The bricks are made on the spot, and it is an astonishing sight to come upon a large field covered with thousands of newly made bricks.

Locked up in a brick the goodness of the earth is held in storage, not lost forever. I have seen an abandoned home with three of the walls knocked down and broken up, and cabbages thriving in what had once been the main room!

ADDING LIME TO BRICKS

For all practical purposes ordinary mud bricks are more than adequate for home building. The proof of this may be seen in the hundreds of thousands of village homes built of earth in southern China, in an area lashed by the annual monsoon rains.

Providing that the foundations are above ground level and the roof is adequate these buildings keep out the driving rain year after year.

However it sometimes happens that more water resistant bricks are needed for certain purposes, and in these cases lime is added to the earth.

The addition of lime improves the water resistant properties of the brick, but does not make them waterproof.

If the lime is not in powder form it must first be crushed . Straw is not used in the brick. Slaked lime is added to the earth in the proportions of 1 part of lime to 3-6 parts of earth.

The mixture is then allowed to cure for two days before the bricks are made. The bricks are also allowed to dry for a longer period than normal before being stacked.

PREPARING THE SITE

Half an hour preparing the site for brick making can save ten hours later unnecessarily moving bricks, trimming off uneven bases and so on.

First make the area as level as possible. A newly made brick will take on the shape of the ground on which it has been made, and if this is lumpy then the finished brick will be lumpy.

There is always a certain amount of excitement when beginning brick making and an urge to begin, but it is worth holding back until this levelling has been done.

There is nothing fundamentally wrong with a lumpy brick, but an even one is easier to stack and lay.

With certain types of soil a problem can arise when the wet brick glues itself to the ground. This is a double nuisance, for the brick lifts lumps of soil with it when it is moved, and these must be then scraped off, and in addition the ground is made uneven and not suitable for future brick making.

A thin layer of sand or powdered dry earth will solve this problem, the ground needs to be dusted before each batch is made.

The mud heap should be as close to the level area as possible, and the work should be planned so that you will not have to be stepping over newly made bricks.

Make sure that the area is not likely to flood with a sudden shower. The bricks will have to sit there for three days before they can be stacked, and while they can withstand a short shower they will collapse if sitting in a pool of water. Also try and pick an area that gets the full benefit of

An earth building in a village near Kunming. The unusual roof style is common to many old buildings in this area.

the sun. While it is pleasant to work in the shade the bricks will take much longer to dry.

While a slow drying time does not affect the bricks it slows up production, and the longer time increases the risk of rain damage.

It is possible to make bricks under shelter during wet weather, we have made them during the height of the monsoon season, but they take a long time to dry. A hundred bricks do not take up much space in a wall, but they occupy a surprisingly large area when laid out to dry.

Do not be discouraged if you have only a small working area. If the earth is kept moist and ready for use then a small number of bricks may be made at a time.

One of the great advantages of working with mud is the simplicity of the system. It is quite possible to make ten or more bricks to fill up your small area then cover up the mud heap, wash your hands and turn to some other work.

PREPARING THE MUD

The earth should be broken up as finely as possible, and while this is being done the straw can be added to it. As mentioned earlier 5 kg to a cubic metre of earth is a good proportion, though in practise it is always done by eye.

Water is then added until the mixture becomes plastic. The amount of water is judged by eye.

The mixing can be made easy or it can be very hard and tiring work. If you are going to enjoy making bricks then it is important to adopt the easiest possible mixing system.

In China buffaloes are often used. They walk around the pit in circles until the whole mixture is of the right consistency. I tried to imitate this idea by driving the tractor through the heap. This produced a good mix in the centre but the outer part was never properly mixed.

The great problem then was getting the good mud out from the centre, and this proved to be a lot of work so we abandoned this idea.

It is also possible to make the mixture by getting into the heap and stamping it with the feet. This works well but is also hard work.

The easiest system was first shown to me here in Australia by John Paice and I later saw the same method being used in China. The idea is to use what we call a crater pit.

The sketches are of John at work in Kuranda.

As with other methods the secret is to first have the soil well broken up and free from lumps.

A circular shallow bowl is then created. This can either be done by digging one out or by forming the sides up with already dug earth.

Two metres diameter is a convenient working size.

Water is poured into the depression and the earth added at the same time. The mixture is frequently stirred with the shovel to make sure there are no dry spots.

A handful of straw is shaken over the mixture at frequent intervals if it has not been already added to the dry earth. This is easier than trying to add all the straw at one time.

In this way a good workable mix is prepared without the need to have to stamp around in the mud.

The mud is then shovelled into a barrow and taken to the place where the bricks are being made.

After a few batches of mud have been made the pit develops its crate like shape and the edge becomes wide enough to walk around on while working.

MATURING THE MUD

For best results the mixture should be left to mature for 24 hours. This allows the earth to become thoroughly soaked right through, and is said to increase the plasticity of the material.

However in actual practise a lot of bricks are made as soon as the mud has been prepared.

MAKING THE BRICK

The mould is first dipped in water and then placed on the ground. Mud is placed in the mould until it is flush with the top. The mould is removed and the brick left to dry.

As mentioned in the section on moulds the best method of putting the mud into the mould is by hand. The top is also smoothed off by hand, no tool is needed.

If a shovel is used then the mould tends to get damaged and must be made much heavier.

At this point the smaller size mould is also an advantage, because a good operator can pick up enough clay in two hands to fill the mould in one operation.

Anyone who has made sandcastles as a child can make mud bricks. The following extract from my field notes may explain a little more about the process.

Kunming, February 21 1983

My interpreter and I set off from the city early in the morning and were soon in the country. Our road wound around a hill and I found that I could look directly down onto the farms below, and see what was happening inside the high walls of the farm compounds.

One compound was almost hidden in a carpet of newly made mud bricks, and we walked down a steep track to investigate.

As we reached the gate we had to jump to one side as a small horse and cart hurtled past. Just prior to this the horse had been straining to pull the load of briquettes, but now on the steep track paved with smooth stones it had no traction and was being pushed by the load! The driver and a helper swung from the back trying to act as brakes.

There was a moment of panic as horse and cart rocketed through the open gates of the compound heading for the newly made bricks, but the horse just managed to pull

Looking down onto the farm with the bricks laid out to dry. The heap of mud is in the centre and the handcart used to move it. To the right is the mat on which the mud is placed.

up a hoove's length from the first row.

There were several thousand bricks laid out to dry and a new batch was being made. This was the farm of Li Fu-wen and it was part of Dragon Springs Commune.

The bricks were for a new farmhouse, 20,000 would be needed for a two story building large enough to house one family.

The open space, 30 metres square, had originally been the threshing ground for the farm. It had been cemented and so was an excellent place to make bricks.

In the past few years many of the communes have installed threshing machines and the threshing grounds, once a distinctive feature of every village, are falling into disuse, the great stone rollers being pushed against the compound walls and abandoned.

The earth for the bricks was being prepared somewhere out in the fields and then brought in by handcart and dumped in the centre of the compound. It was then moistened again and worked up with hoes to the right consistency.

From this central point the mud was moved by handcart closer to where it was needed and tipped onto straw mats.

The use of mats saved having to constantly clean the mud off the cement, and the mat could be slid across the ground to make way for more bricks as work progressed.

The bricks were 300 x 170 x 80 mm. A pair of the moulds being used are illustrated in the section on moulds. They were of light construction and made from softwood planks 80 x 25 mm, nailed together.

The long sides extended a little beyond the ends to avoid splitting and the ends had small finger holds chiselled into them. There were half a dozen moulds laying around and all had been well cleaned after use.

Before making each brick the worker totally immersed the mould in a bucket of water. This again shows the advantage of the small moulds, for the wetting process can be quite time consuming when using large moulds, especially double ones.

The wet mould was placed on the ground and the worker scooped up a double handful of mud and pushed it in, kneading it well to remove air pockets.

Such was his skill that he would often pick up the exact amount of mud for one brick and there would be nothing left over when he had smoothed off the top. When there was a small surplus it would be placed on the spot where the next brick was to be made.

The mould was lifted to reveal the newly made brick.

I aked whether they were worried a out rain with so many thousands of bricks laying out and no way to cover them. They said that the frequent light showers that we were experiencing had no effect on the bricks and only heavy rain would damage them.

The bricks were left to dry for three days and were then stood on edge. After another four days they would be stacked into heaps. Straw would be placed on the heaps as a weather protection. They would be dry and ready to use in three weeks or less, depending on the weather.

DRYING BRICKS

After the bricks have been made they are left to dry and then stacked. The drying time is dictated by the weather.

In very hot dry conditions the bricks may be ready to stack in three or four days, but generally they take a week.

As soon as the bricks are dry enough to handle they are stood up to allow the base to dry out.

In some areas the custom is to tip them onto their long edges after two days and then stand them on end after another two days.

A partly dry brick can be tipped over onto its long edge while it is still too wet to be stood on end.

In other places they are left for three days and then stood on end.

The first system is the best in areas where unexpected rain is likely to be a problem, the sooner the base of the brick can be moved from the ground the faster it will dry. In areas where there is little chance of rain the bricks can be safely left for longer on the ground and only moved once before being stacked.

When tipping up the bricks the workers often carry some sort of cutting or scraping tool to clean off any loose dirt that may be sticking to the brick. There is no special tool for this work, they use whatever comes to hand

Bricks drying on the edge of a field near Nanning. The bricks are in the process of being stood up on end in order to speed up the process.

A DIFFERENCE OF OPINION

Lanzhou, north-west China, March 1983

It had been snowing in the morning, and I was taken to visit a family in a newly built home in Liu Jiaping Village.

The owner and builder, Song Zong-feng, invited us in out of the cold and poured tea.

The interior walls of the room were very smooth and white, and I was surprised to learn that they were of mud brick. My host showed me the mould and some of the bricks left over (illustrated in the section on moulds) and it was interesting to see that the bricks were fairly rough, with irregular surfaces showing deep finger and hand prints.

These uneven surfaces were completely hidden once the bricks had been built into the wall and plastered over. These bricks were not typical as most bricks are made very neatly, but they served to show that even a rough brick can be used to make a well finished building.

The roughness may have been a result of the speed of production as I was told that one person would make 500 bricks a day using this double mould.

When building a wall these bricks are most frequently laid standing on edge, as is also the custom with rammed bricks.

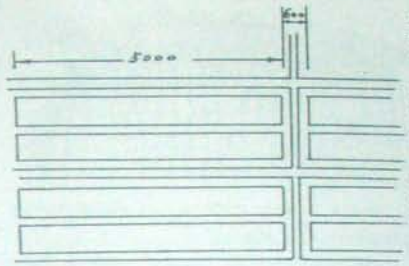
The bricks were only 60 mm thick, and I had noticed that all the bricks in the village were equally as small.

Our discussion about mud bricks had brought in the neighbours and there were now half a dozen men in the room. I asked them why such thin bricks were used in this area, much thinner than any bricks I had noticed in other parts of China.

At once a heated argument in Chinese broke out among those present. There was a great deal of shouting and it went on for some time. Was it because they dried quicker? Was it something to do with the soil? Or because they were easy to handle?

Finally the din subsided and my friend Wu translated the conclusion.

"They are made that size because that is the size they have always been made in this village."



This is a plan of a brick stacking area. Each rammed earth base holds two stacks of bricks and there is a gap between each base to allow for drainage.

The stacks are 5 metres long and there is a 600 mm walkway between them.

It is a good idea to scratch on one of the end bricks the date that the stack was completed and the number of bricks in the stack.

In normal weather conditions the bricks will be ready to use after 21 days in the stack. In very hot, dry weather they may be ready to use 21 days after being made.

In addition thick bricks take much longer to dry than thin ones.

RAIN PROBLEMS WHEN DRYING BRICKS

Cynics say that making mud bricks is a sure way to attract the rain, and certainly in the Cairns area we always get some rain at some time during the weeks involved in making and drying a batch.

No matter how fine the weather appears to be you should always have some material at hand to cover the stacks. The stacks should also be compact and laid out in such a way that they can be covered with the minimum of fuss.

The most critical time for bricks is the first 24 hours, because they are still saturated with water and laying flat on the ground. This is why it is important to get them up on one edge as soon as possible.

Once on edge they will take a certain amount of rain, just so long as the ground on which they are standing does not become soaked.

If they do get wet it is best not to touch them until they have dried again.

The sketch shows bricks at various stages of drying. The newly made brick on the left will soon break up if the ground becomes soaked, while the two centre ones will stand a much better chance of surviving.

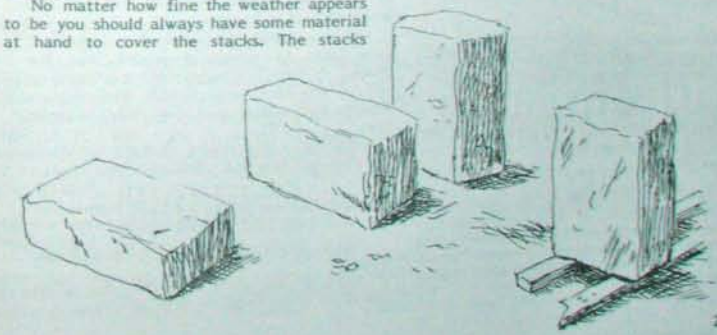
If rain appears certain the best idea is to get the bricks onto a pair of sticks as shown on the right. Once clear of the ground they will withstand quite heavy rain even if left uncovered.

At the time of writing we had a sudden storm that dumped down 15 mm of rain in 15 minutes. A strong wind came with the rain making it impossible to get the bricks covered.

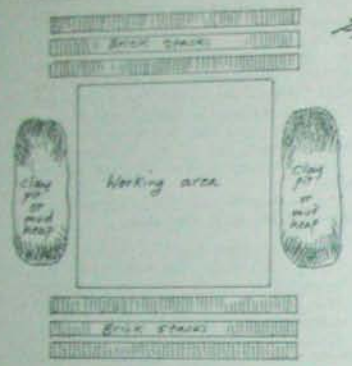
Luckily we had been expecting rain and had stood most of the part dry bricks on sticks.

The rain pitted the top of the bricks and moistened them to a depth of 40 mm. However after a few hours of sunlight they dried out and were as sound as before.

By contrast some bricks that had been left flat on the ground were ruined.



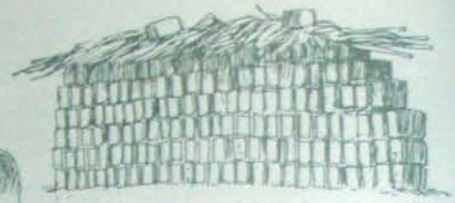
PLANNING THE WORKING AREA



The working area should be planned before work begins. Here is one common plan. The use of two mud heaps and two stacking areas lessens the distances that materials have to be carried.

This plan was noted in an area where the mud was being drawn from an irrigation channel.

A typical brick noted on the edge of the road near Changsha. It was raining heavily at the time and the bricks were being protected from the weather by straw thrown on the top and held in place with broken bricks.



Stack in drying protected with maize stalks

STACKING THE BRICKS

Bricks take three weeks to dry, and as they are stacked out of doors they must be protected against the elements. There is a lot of work involved in making bricks but this can all be lost through poor stacking.

The most important point is to make sure that water cannot gather around the base of the stacks as this will cause waterlogging and certain collapse.

To avoid this the base of the stack must be above ground level. This can be easily done by putting down a layer of earth about 150 mm thick and ramming it down firmly. A base of baked clay bricks can also be used.

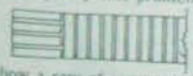
If there is any doubt a gutter can also be dug around the stack to take away water.

The bricks can be stacked up to six tiers high, but for a beginner four tiers is probably safer and more convenient.

The main thing in stacking bricks is common sense. A few bricks laid at an angle to the rest will help lock the heap together, but apart from that the only rule is to leave a small gap between each brick to allow the air to circulate. The gap can be as wide as a finger.

Narrow bricks are stacked on edge, and care must be taken to ensure that the ground is flat. If a narrow brick is stood on uneven ground it may tumble and cause a domino effect that will bring down a whole row.

Placing a few bricks at right angles to the rest will help stop this problem.



This is how a row of narrow bricks should begin.

If there is any chance of rain the stacks should be given some form of covering.

PROTECTING THE STACKS

Once the bricks are in stacks they are much easier to protect. In China they are commonly covered with straw. Sometimes broken tiles are also used.

Straw has a number of advantages, and there should be plenty of it around the brick making area. It is spread on the top of the stacks and weighed down with stones or broken bricks.

If the straw is thick enough it will act as a thatch and keep the bricks quite dry, and even a thin layer of straw will protect bricks from erosion by heavy, driving rain, even though the straw and the top of the bricks will become wet.

Straw does not blow away as readily as corrugated iron or plastic, even if only a few bricks are holding it down.

If straw is not available then other materials must be used. If plastic sheeting is chosen there are a couple of points to remember.

If plastic is spread over more than one stack without any timber supports between the stacks then the water will cause the plastic to slump between the stacks as it gathers in the depression.

The weight of water can tear the plastic or pull it off the stack.

Once the rain has passed the plastic should be removed as it causes the bricks to sweat and slows down the drying process.

On the other hand straw can be left on the stacks.

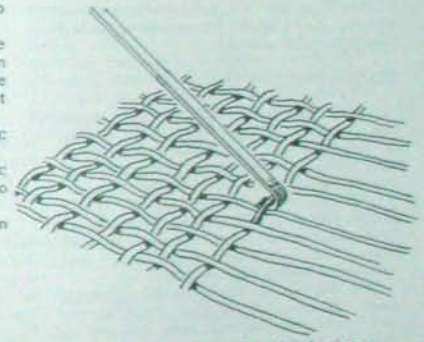
The use of straw in mud with a high clay content may be of some value, though cracking in mortar is not common.

The mortar is made in the same way as the mud for the bricks, except that more care is taken to screen out any stones and lumps.

If stones are present the mortar cannot be spread thinly enough. The Chinese use sieves of heavy wire for screening the soil. The sieve is suspended below a wooden tripod so that the worker does not have to take its weight. (See page 4)

The sieves are often bought ready made but they can also be made entirely by hand.

Returning from a wedding in Jinghong one night I was caught in a sudden storm and took shelter in a partly finished house. Inside two young men were busy making up a sieve from fencing wire.



They were weaving it all by hand using a simple tool made from a piece of bent steel. They hit the tool with a hammer in order to force the wire into position.

A traditional sand and earth sieve in Australia was made by simply standing an old wire frame bedstead up at an angle.

The Chinese also use a rectangular sieve stood up at an angle and throw the soil against it to remove the stones.

MORTAR FOR MUD BRICKS

People not used to working with mud bricks often ask why cement mortar is not used when laying mud bricks.

The answer is that far from adding to the strength of the wall it would actually weaken it by creating a structure composed of two elements which do not bond tightly to each other.

Mud mortar is used to lay mud bricks, and this means that the finished wall is a single unit, a solid mass of dried earth.

The mortar is usually made from the same mud that has been used to make the bricks. In some areas chopped straw is added, in others only plain mud is used.

The thickness of the mortar will be judged by eye, and is usually about one eighth the thickness of a normal brick. In practise this is generally 15-20 mm of mortar, or about the thickness of a finger.

LAYING THE BRICKS

The laying up of mud brick walls will be found to be faster and easier that the building of cement brick walls. The mud mortar can be readily washed off surfaces, hands and clothing, and does not have the same corrosive effect on the hands that cement causes.

Special tools are not needed to spread the mud mortar, it can be placed quite readily by hand. Some workers prefer to use a trowel as this leaves their hands clean to handle the bricks, while others like to use their hands.

One great advantage of using mud mortar is that work can be stopped at any time. The mortar can be covered with wet bags or straw mats and will remain ready for use as required.

The mud should feel smooth and plastic, not stiff and gritty, and this is why a high clay content is considered desirable.

It is advisable not to take a wall up too high in one session. 1.5 metres is usually high enough for one day.

TESTING MUD MORTAR

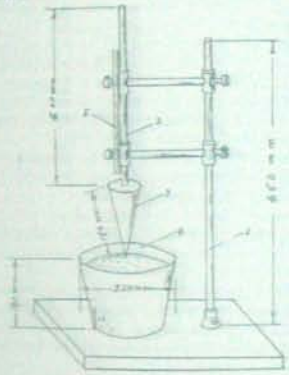
The mortar must be of the correct consistency. Mud that is too sloppy is easy to recognize as it is almost impossible to work with. Mud that is too dry can lead to weak bonding between the bricks.

For ordinary home building the mud is always judged by eye and feel. However in China large public offices are often built of mud bricks in the countryside, and sometimes testing may be carried out.

Lin Wei-hun has illustrated the apparatus used. A container of mud is put on the bench and the standard cone adjusted so that the point of the cone is just making contact with the surface of the mud.

The screws on the left are then gently loosened so that the cone sinks into the mud. There is a calibrated scale above the cone, and the depth to which the cone sinks can be read off this.

The cone is 130 mm deep and weighs 300 g. If the mud is of the correct consistency then the cone will sink to a depth of 60 - 80 mm.



1. Bench and support. 2. Sliding bar. 3. Standard cone, 130 m m deep x 75 m m diameter, weighing 300g. 4. Container of mud. 5. Scale.

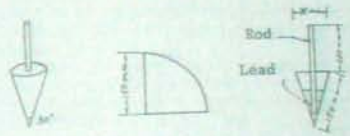
Farm buildings near Leshan, Sichuan Province, including some with unusual curved roofing. The mud brick building on the left is protected by a thatched roof with wide eaves, but the mud brick surrounding wall has no protection other than a little straw thrown over it at one end. A metre and a half of rain falls here annually .

The mud brick wall has been built on the badly eroded remains of an old rammed earth wall. Mud bricks are often used in the repair of rammed earth walls.

FIELD TESTING

The testing apparatus shown above would generally be found in a soil testing laboratory. For on-site testing a much simpler device is used.

This is simply a cone of the same dimensions as above , but with a handle. It looks rather like a spinning top.



It is made from sheetmetal, and the sketch shows the shape before it is formed into a cone.

The completed cone has a depth of 130 mm and a diameter of 75 mm. It is filled with lead until the whole thing weighs 300 g.

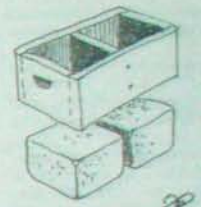
The cone is used in the same way as before. The operator holds the cone with the tip just touching the mud and then releases it. It is then removed from the mud and the depth to which it has sunk is measured.

If the measurement is between 60-80mm then the mortar is of the correct consistency.

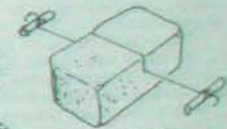
CUTTING AND TRIMMING BRICKS

In a well planned building there will be little need to cut bricks as the builder will have anticipated the need for half bricks or bricks of unusual dimensions, and will have either made up a special mould to make them or will have slipped a partition into his ordinary mould.

Any scrap of wood can be temporarily nailed into the mould, and in this way two half bricks can be made at a time.



Thin wire can also be used to cut bricks when they are partly dry and about the consistency of cheese.



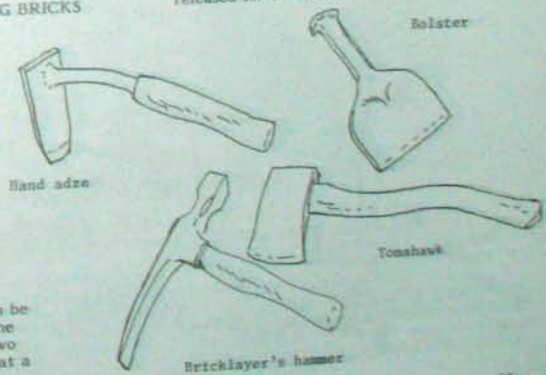
Once fully dry cutting becomes a time consuming business, and the Chinese will often lay bricks at an angle in order to avoid having to cut them.

If cutting does become necessary various tools can be used. The illustration shows some of the tools that we have used.

HAND ADZE. This is our most used trimming tool, used to remove lumps from the walls, shape bricks and cut grooves.

It was home made using a 130 x 60 mm section of heavy car spring, some bent pipe and a broken hammer handle.

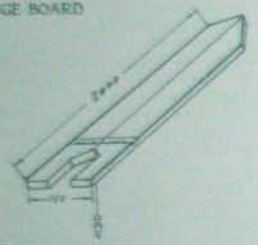
At the time of writing an inquiry to the Cyclone Company confirms that hand adzes are actually made in Australia, but only for export to the islands of the South Pacific. Let us hope that they will one day be released for sale here.



BRICKLAYER'S HAMMER. This can be used like a hand adze, but it has a smaller working face.
TOMAHAWK. Can be used for both cutting and trimming bricks.
BOLSTER. This is a bricklayer's tool, used for cutting fired bricks, but it can also be used for mud bricks.
CROSSCUT SAW. Discarded crosscut saws can be used to cut bricks if an exact size is needed. However they are slow and soon become blunt.

Whatever tool is used there is a knack in cutting mud bricks as they will often break in an irregular manner or shatter. A number of light blows all around gives the best results.

GAUGE BOARD



This is a simple but ingenious Chinese tool which takes the place of a spirit level. It is used to check that walls are being built truly vertical.

This is one aspect of earth building which cannot be taken lightly. There are enormous weights involved in earth walls and they must always sit on firm footings and be vertical.

The gauge is readily constructed from a length of timber, some string and a small weight, such as a metal nut. In Lin Wes-hao's drawing he shows a proper plumb-bob being used as the weight.

His board is also marked with a scale, and this can be used if a tapered wall is being built.

Following his instructions I built one of these boards and found that it took only half an hour to construct, a big saving when compared to the price of a bricklayer's spirit level.

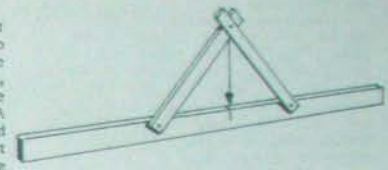
Typical mud brick farm buildings, Shaoshan, Hunan Province.

The dimensions of the board are not important, just so long as it is straight. Two metres is a good length or it can be made to the full height of the wall being built, and in this way the whole wall can be checked for level at the one time. A string is attached to the top of the board and hangs like a pendulum with a weight at the bottom. A piece is cut out of the bottom of the board with an inverted V cut marking the half way point across the board.

When the gauge is held against the wall the string should come to rest in line with the centre of the V, showing that the wall is vertical.

The gauge is also useful for showing up any lumps or hollows in the wall.

HORIZONTAL LEVEL



This simple device was used by both Australian and Chinese miners in Australia's gold mining days, when constructing channels, sometimes for a few kilometres, to bring water to their claims.

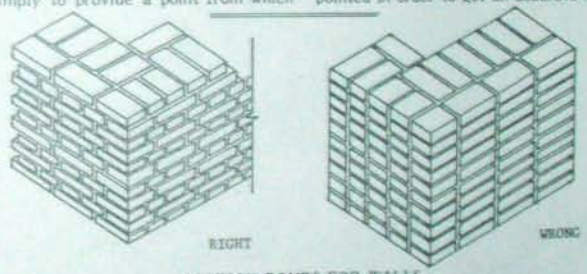
It can be put together in a few minutes using scrap timber. The triangle does not have to be of any particular dimensions, its job is simply to provide a point from which to hang a plumb bob.

The bottom board should be straight and 1.5 to 2 metres long.

Having suspended the plumb bob the level is then placed on a horizontal surface and a mark is made on the long timber to show where the plumb bob hangs when the level is horizontal.

Finding a truly horizontal surface from which to callibrate the level was sometimes a problem to the old miners. One solution was to stand some rocks in a pool of water so that they were just level with the surface. The level was then placed on these and the mark made.

If a proper plumb bob is not available it is possible to make one from a scrap of wood. Using a nut or a nail is not satisfactory, the bob needs to have weight, symmetry and be pointed in order to get an accurate reading.



COMMON BONDS FOR WALLS

Bond is the term used for the various ways that bricks can be laid so as to lock together.

To make a wall form an interlocking unit the alternate courses of bricks must be staggered. As a general rule the joints in one row should be no closer to the joints in the row below than one third of the breadth of the brick being used.

The sketch on the left shows a correctly built wall, the sketch on the right shows a wall with each brick directly above the one below. This wall would be in danger of cracking along the joins.

The following drawings show only a small sample of the various bonds used in China. They have been described by the names used by Western bricklayers, the Chinese do not

use these terms.

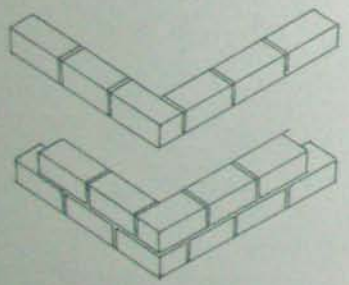
When I was in Lanzhou in March 1983 one of my travelling companions was Mr Wang, a very pleasant fellow who was a leading member of the Lanzhou Architects Association. I asked him what terms the Chinese used for the various bonds and he said that they were simply described literally, that is to say " 2 across & 2 lengthways" and so on.

I also noted that country people are very casual about their use of bonds. When another person comes to work on a job he will often use his own favourite bond irrespective of what has gone on before. As a result walls often show a variety of patterns.

The Chinese builder is only interested in building a wall of the maximum strength and stability, and as all the bonds work to this end he feels no need to stick to one particular bond.

In the following drawings the the upper course of bricks is shown floating in the air above the others in order to show how each course has been laid.

STRETCHER BOND



Stretcher Bond

The most common bond throughout the world. Walls made by this bond can be erected faster than by any other bond. It is simple and uses fewer bricks than any other bond.

On the negative side it is weaker than other bonds, due to the wall being only as thick as the width of a single brick.

It is used for interior walls, or to fill in sections of exterior walls where the roof is being supported by beams or pillars.

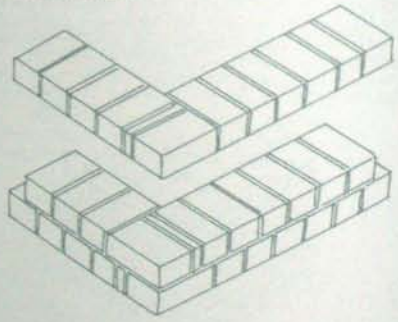
It is not reccomended for exterior load bearing walls unles the bricks are made wider than what is the average in China.

As noted earlier, bricks in Australia are customarily wider and heavier than in China, and this bond is the one most commonly used.

The Chinese would regard most of our mud brick load bearing walls as rather thin, and therefore not as strong as they should be.

The term 'Stretcher' refers to the fact that the bricks are 'stretched' lengthways along the wall.

HEADER BOND



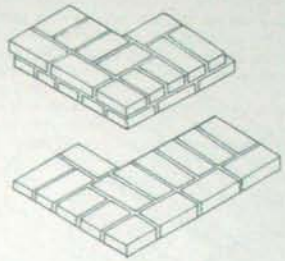
Header Bond

A useful bond, very common in China, producing a solid wall the length of a brick in thickness.

Notice at the corners a thin brick has been used so as to get the spacing right and create the correct bond pattern along the rest of the wall.

The term 'Header' comes from the fact that only the heads of the bricks show in the finished wall.

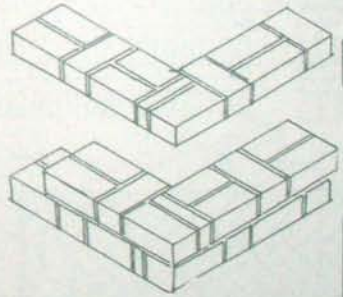
HEADER AND STRETCHER BOND



This produces an extremely strong, well bonded wall, especially suitable for load bearing such as the lower floor of a two story building.

It also uses up a large number of bricks. For instance a 5 x 2.5 metre section of wall would require 7 cubic metres of bricks if built in this bond, but only 3 cubic metres in Stretcher Bond.

FLEMISH BOND

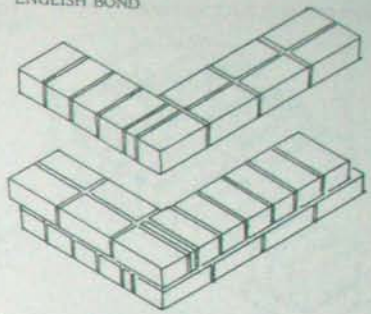


Flemish Bond

Both Flemish and English Bonds are used in China, but not under these names.

They bind a wall together well, but can only be built with bricks that have been made half as wide as they are long.

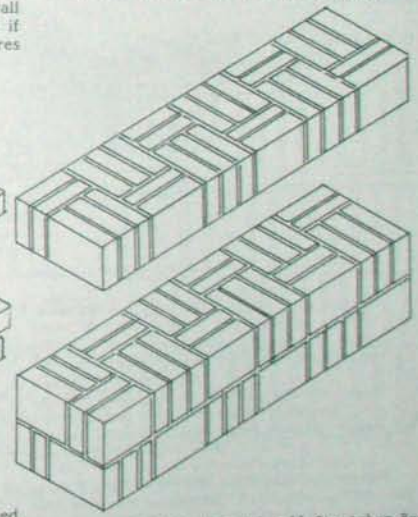
ENGLISH BOND



English Bond

Same remarks as for Flemish Bond.

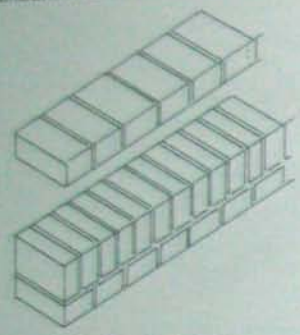
BULL HEADER & BULL STRETCHER BOND



Bull Header and Bull Stretcher Bond

This produces a very thick wall suitable for the lower floors of two story houses. A 'Bull' is a brick stood on edge.

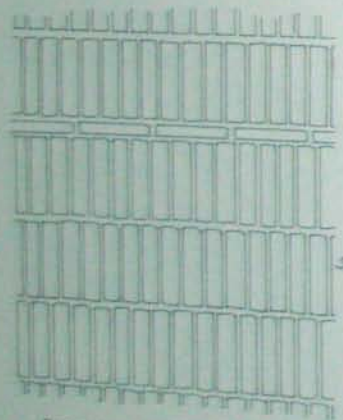
HEADERS AND BULL HEADERS



Headers and Bull Headers

When this bond is used there is no need to have a special half brick to start every second row.

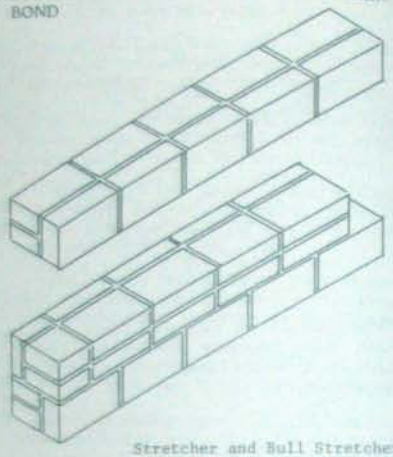
BOND FOR NARROW BRICKS



Rammed earth bricks, described later in this book, are made thinner than mud bricks, and as a result have a tendency to break when being laid flat down.

For this reason they are often laid as shown below, with an occasional course being laid flat to help bind the wall.

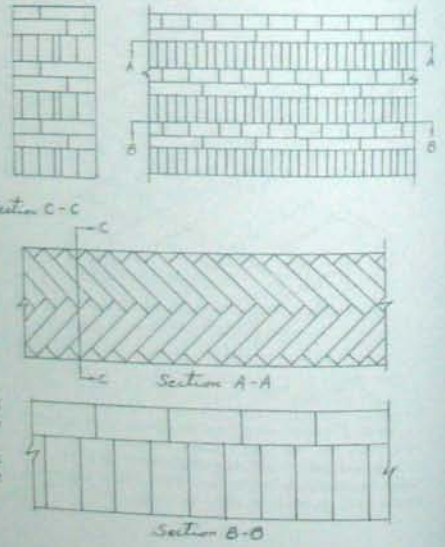
STRETCHER AND BULL STRETCHER BOND



Stretcher and Bull Stretcher Bond

Suitable for interior walls using comparatively thin bricks.

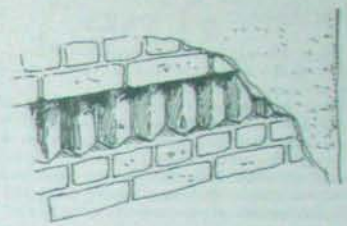
INCLUSION OF HERRINGBONE

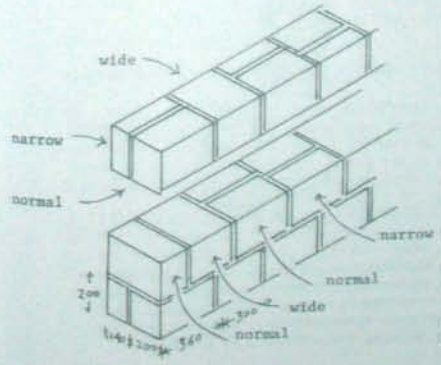


This unusual bond consists of two courses of Header and Stretcher Bond, then a course laid in herringbone pattern.
This causes an irregular surface on the wall, which is later covered by the plaster.

The only advantage of this method seems to be that the irregular surface provides a good key for the plaster.

When a wall of this type is plastered the first coat of mud contains a more than average quantity of chopped straw. This prevents the plaster from cracking.





A SHAOSHAN BOND

I came across this building on a hillside near the village of Shaoshan in central China. The foundations were of rocks carefully placed and without even mud mortar between them.

The roof was of thatch, and the poles sticking out of the walls supported the ceiling inside. Some spare bricks were stacked against the wall.

The wall on the right utilised an unusual bond, and one that demonstrates the flexibility of mud brick. The wall was 360 mm thick and used bricks of three different dimensions.

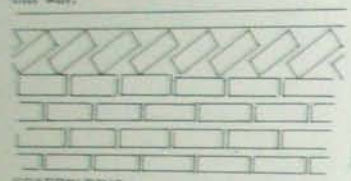
The bricks were all of the same length and height, 360 x 200 mm, but in width were 140mm, 200mm and 300mm.

OTHER BONDS

These drawings in no way cover the wide variety of bonds that are used in China, but they do cover the basic ones.

Bonds are sometimes created for specific needs, for instance to fill odd shaped spaces or, as in this example, when the space left below a window ledge cannot be conveniently filled using the bricks at hand.

Rather than mess around cutting bricks to fit, the builder will place a row of bricks at an angle and so quickly fill the space in this way.



SCAFFOLDING

Even the most simple form of scaffold is a great aid when building a wall.Using a single ladder and carrying bricks up one at a time is both tiring and time wasting.

The Chinese make a great use of scaffolding, and on large jobs will use ramps joining one level of scaffolding to another so that wheelbarrows full of materials may be pushed from ground level to the very top of the building. This is very useful in a country where cranes are not yet common on building sites.

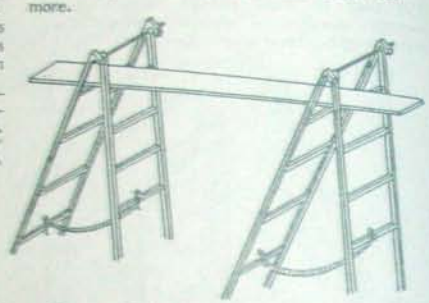
FIXED SCAFFOLD

Holes are left in the wall to take the horizontal poles. These holes are later plastered over. Planks are laid on this framework.

MOVEABLE SCAFFOLDING

Lin Wei-hao has illustrated the typical Chinese tops to the trestles.

This scaffolding must be made strong enough to take not only the weight of the workers but also the weight of a good number of bricks, so that the builders are not having to continually climb down for more.



This concludes the chapter on mud brick, but as there is still some space I will put in a small item about another subject.

A WEEDING TOOL

While collecting material for this book in China I often came across other examples of country crafts and skills.

Wherever I stopped to do a drawing a crowd would gather, and Hueko Village outside Xian was no exception.

While I was sketching a small girl stopped to watch. She had been working in the fields and carried a home made weeding tool, fashioned by heating up a scrap of steel rod and beating the end into a small blade.

Rammed Earth

The Chinese term for this technique is hang-tu-qiang which translates as rammed-earth-wall, so I shall use this term rather than the French 'pise.'

Rammed earth is used all over China but is not as popular as mud brick. This is probably because it is a more physically demanding technique , and also because it is less flexible than mud brick in the shapes that can be constructed. Mud brick walls can be used for the smallest of rooms, but rammed earth is best on long straight runs.

ADVANTAGES OF RAMMED EARTH

1. SOIL NEEDS LITTLE OR NO PREPARATION. At 200mm below the surface the soil frequently contains enough moisture to be used for rammed walls. It is dug on the site and thrown directly into the form.

2 LESS HANDLING. Mud bricks are handled a number of times before they are ready to be used, but the soil for rammed earth goes directly from the ground to the wall.

3 A FASTER METHOD. The above factors make this a faster method of building.

4 A MORE COMPACT MATERIAL. Rammed earth is more compact than mud bricks. This does not matter in a house where the walls are protected by the eaves but is important in courtyard walls.

DISADVANTAGES OF RAMMED EARTH

1. NOT CONVENIENT FOR COMPLEX STRUCTURES. Even a small home home can have a complex plan, with a number of rooms of different dimensions. These can be a problem when using rammed earth forms.

2. PROBLEMS WORKING AT HEIGHTS. Moving the form and getting earth up to it can be a problem when the wall gets high. For this reason some builders will take a rammed wall up so far then continue with mud bricks (this method is not common but is quite practical). (See sketch, page 8.)

3. PROBLEMS ABOVE DOORS AND WINDOWS. Lintels above doors and windows have to be extremely strong to take the force of ramming above them. A typical cement lintel in Kunming was 600mm wide and 125mm thick and reinforced with steel rods. Strong timbers are also frequently used.

4. PHYSICALLY DEMANDING. Rammed earth requires more stamina than mud brick. Woman play an equal part in making and building with mud brick but seldom attempt rammed earth.

5. THE FORM. The form required for rammed earth takes time to build, but a mud brick mould can be put together very quickly.

For all these reasons rammed earth is favoured for courtyard walls and farm buildings while most homes are built with mud bricks.

TYPES OF FORM.

All the forms described here follow the same general plan. They have two sides, one end and a movable saddle.

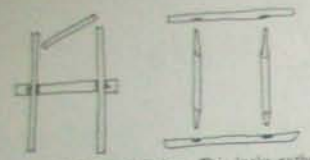
They are made to whatever width the builder desires, I have encountered forms from 400mm to 650mm wide.

This means that the end is a rectangle 400-650mm wide and 300mm high. Two crosspieces are nailed to this, usually of 50mm thick timber. These extend 200mm or more on either side and fit through holes in the long sides, where they are pinned in place.

The length and height of the sides also varies, but generally the sides are 2 metres long x 300 mm high and made of stout planks 50mm thick.

The sides have handles on them, and my sketches show the use of metal, leather and wood for this job.
Good handles make for the easier lifting of the forms when moving them along.

The open end of the form is held in place by the saddle. I have noted two different types of saddle. One holds the end in place by a gripping action on the previously made



section of the wall below. This looks rather like the letter H.

The other type of saddle consists of four pieces of timber that lock together into a rectangle.

The gripping saddle makes for more accurate placing of each section on the one below it but is more difficult to construct.

Unless very strongly made it also has a tendency to spread under use, and for this reason I would suggest the rectangular type of saddle as the better one for the beginner.

One point to note about the rectangular saddle is that it leaves a number of holes in the finished wall. The gripping saddle also leaves holes but these are not so noticeable.

These holes can be filled with some of the same earth, but as they do not affect the wall they are frequently left as they are.

Because the form has to be as strong as possible it tends to be quite heavy, but this cannot be avoided as the use of thinner timbers would cause the sides to bow out under the pressure of the ramming.

TAMPERS

Tampers vary so much in both length and weight that no standard measurements can be given. Their length can vary from 1100mm to 2200mm as will be seen in the sketch.

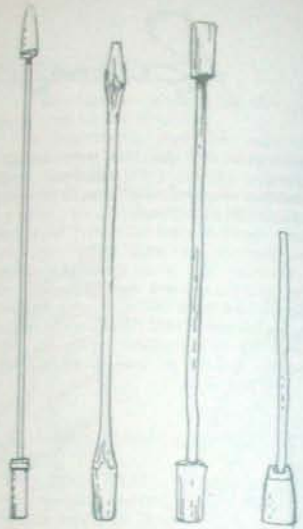
The one on the left has a handle of steel water pipe, and the wooden heads are bound with an iron hoop at the bottom and wire at the top. The top head has been made smaller to get into corners.

The second one has been carved from a single length of wood, while the third has a wooden handle and two lengths of log for heads.

These three were all noted in Kunming.

The smallest was sketched in the Nanning area. It had only a single square section head, while the others were all round with the exception of the heads on the upper part of the left hand pair, which were roughly rectangular.

The heads are usually held in place with small wooden wedges and twists of rag.



The head of the small tamper was 250mm deep and the square face measured 150 x 150mm.

Lin Wei-hao has noted that tampers with stone heads are very common in the Kunming area.

SPEED OF RAMMED WALLS

Speed of building depends on the distance the earth has to be carted, and the work also gets slower as the walls get higher.

Taking this into account one builder said that he would average 13 metres of wall 300mm high in a day working by himself.

A pair of builders working together said that they would average 26 metres, 300mm high in a day, which is the same output per man.

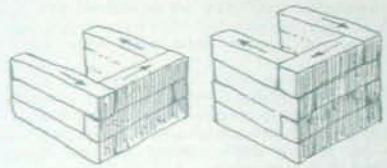
CRACKING AT CORNERS

Due to the fact that corner forms are not used there is a join at each corner and cracking will usually appear at this point.

If the forms are placed the same way for each course then all these cracks will be in line and so the cracking can be serious, as shown in the sketch on the previous page.

However most buildings show an alternating line of cracks creating a dovetail effect at the corners. This locks the corners together and so makes a strong building.

To achieve this effect one course will be laid from right to left and the next in the opposite direction. The small sketch shows the idea.



REINFORCING THE WALL

Rammed earth walls are strong along the face but will damage easily at the corners when knocked. This does not happen so much with mud bricks which tend to be quite tough in this respect.

To avoid this problem fired bricks are often incorporated into the corners and along areas where there is heavy traffic.

The bricks are not built into pillars to make a continuous edge but are placed at random intervals, often 300mm apart.

The Chinese regard this as a practical measure, but in Japan I have seen these inserts used as a form of decoration. One of the outer garden walls of the Daitokuji Temple in Kyoto has been decorated by inserting different sorts of roof tiles to form an interesting pattern. My sketch shows a small section.

Only once in China have I seen inserts that may have been intended as decoration. This was at Simao in Yunnan Province.

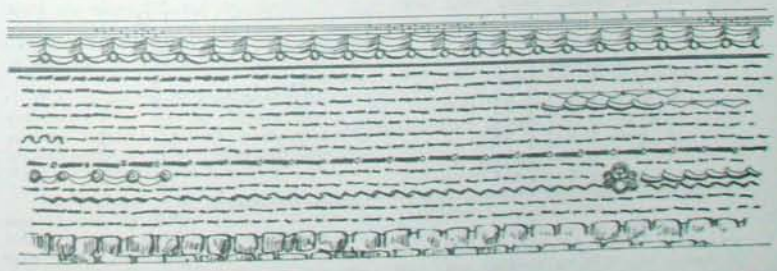
Towards sunset I walked out of the town and across the fields to a tiny village. Groups of swallows were clinging to the rough earth walls to enjoy the last warm rays of the setting sun, and showed no fear as I passed within an arm's length.

Inside the village I sat on a large log to do a sketch (next page). The gateway opens onto the courtyard of the home whose roof can be seen above the wall. The courtyard was larger than most, and through the open gates could be seen an attractive garden.

There was a large family woodheap to the right of the gate, an uncommon sight in China where firewood is generally scarce. Here in the mountains there was no shortage.

One section of the wall, partly concealed by the woodheap, had rows of fired bricks imbedded in it. The purpose of this was not clear, as no other wall in the area had been treated in this way.

Perhaps it was considered to be decorative, or perhaps the family just had some bricks left over from another job and wanted to use them up.



Decorated wall at Daitokuji Temple

WORKING METHODS

(The following field notes describe the use of both types of saddle when building a wall.)

Kunming, Feb 20 1983.

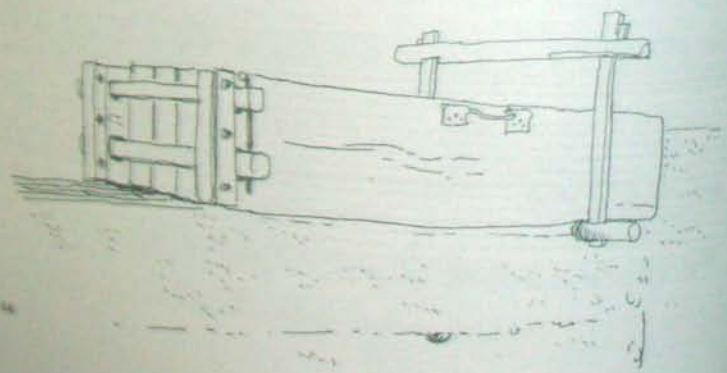
We had been looking at village buildings in the stony mountains to the north of Kunming. We looped our way back to the plains and at the foot of the range my interpreter, the keen-eyed Wu Zhongning, caught a glimpse of the tip of a tamper behind a high wall.

He hammered on the stout wooden gate and when it was opened we could see that his deduction had been correct and a rammed earth wall was in the process of being built inside the courtyard.

The head of the family, Yang Wen Yu, invited us in to see the construction. He and his son were at work building a pigsty, a project that was costing them nothing but their own labour. The result would be a building with walls half a metre thick that would last for decades.

It was noticeable in this area that mud brick was favoured for most homes while rammed earth was used for farm buildings and the more humble homes.

The reason for this may lay in the structure of the soil in this area which has a fairly high clay content, the result of which is that walls sometimes crack through shrinkage. This can often be seen near the corners.



The form being used was simple but very robust. Basically it consisted of two stout planks 2000x300x50 mm. There was one closed end. This had two crosspieces which passed through holes in the long planks and were held in place by a steel rod bent over at the top.

The saddle was as illustrated, the top horizontal piece held in place with wedges. This was not as efficient as the form I saw the following day, which is described next.

Lengths of split bamboo or long lengths of thin bamboo were laid along each course before a new course was laid. These acted as reinforcing and helped prevent cracking.

The handles on the sides were homemade and constructed from flat iron and steel rod. They were used when moving the form along.

I was told that it takes about half an hour to fully ram one form, and I probably slowed the work up by offering to help.

The father dug the earth from what would be the inside of the pigsty, thus lowering the floor level as the walls went up. He put the earth into a shallow basket and then walked up an inclined plank to where the form rested on the top of the wall. The earth was tipped into the form while the son and I stood inside the form using the tampers.

The tampers were the two shown on the left in an earlier sketch. The lower ends were cylindrical and 100mm in diameter.

The opposite end was roughly shaped to a rectangle (which had been worn to an oval) 100x45 mm. This end was used to ram along the edges and into the corners.

Particular attention was paid to the use of this smaller end, for the surface quality of the finished wall depended on firm edges.

The tampers were well balanced and not too heavy. The aim in making one is to produce a tool which is light enough to use all day without undue fatigue and yet heavy enough to properly ram the earth.

The workers use a combination of feel and hearing to judge when a section is properly rammed. When the earth has been consolidated the tamper will bounce from the surface and give off a distinctive sound quite different from that heard when ramming commences.

Father & son at work.

Kunming, Feb 21 1983.

My interpreter and I travelled through the countryside at will, taking small village tracks and stopping whenever we saw a home being built, or anything else that looked interesting.

The country was dotted with villages only a kilometre or two apart which could often only be reached by a narrow dirt road raised above the fields.

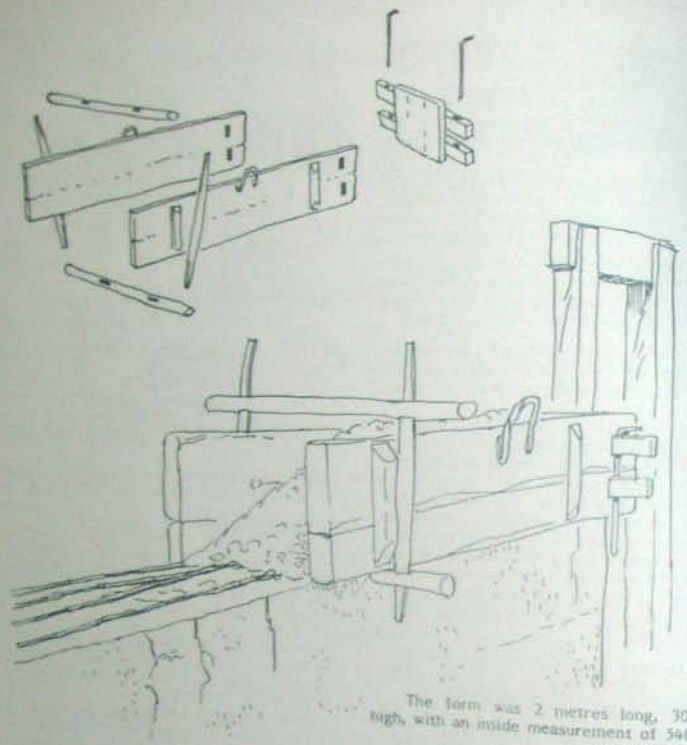
Sometimes the village homes were clustered together so tightly that the road stopped outside the village, and all progress was then along narrow footpaths that separated the houses.

In one such area we came upon the family of Sun Zi-ying who were having a high wall built around their courtyard.

They were a poor family but most hospitable and the lady of the house invited us in for tea.

The wall was being constructed by a professional builder and his form was similar to that previously described except that the saddle was fixed in a better way.

Instead of the top horizontal bar being held in place with wedges the two uprights had been tapered so that the crosspiece wedged itself firmly into place when bumped down.



The form was 2 metres long, 300mm high, with an inside measurement of 540mm.

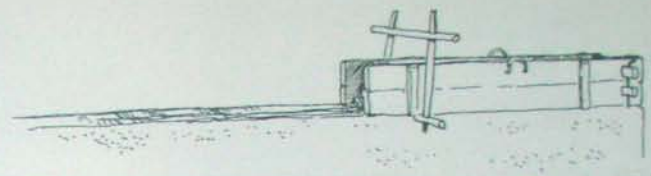
The sides had leather handles, formed by twisting a strip of greenhide into a tube.

In the sketch you will notice the strips of split bamboo laid on the previous course to provide reinforcing. These were called 'qiang jin', the tendons of the wall.

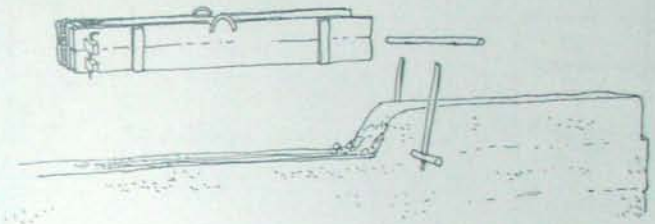
To the right of the form is the framework of a door. This had been placed in position after the first two courses had been rammed. It would be tied in as described elsewhere, using steel straps or blocks of timber.

The footings were of large rocks with mud plastered between them. They extended 1.2 metres into the ground and stood 500 mm above ground, and were the same width as the wall (540mm).

Each new course is begun with the closed end of the form at the end of the wall. The form is then filled with earth, a little at a time, and rammed until it is full.



The top bar of the saddle is removed and the form lifted up and turned around so that the closed end is now on the left. The bottom of the saddle remains embedded in the wall.

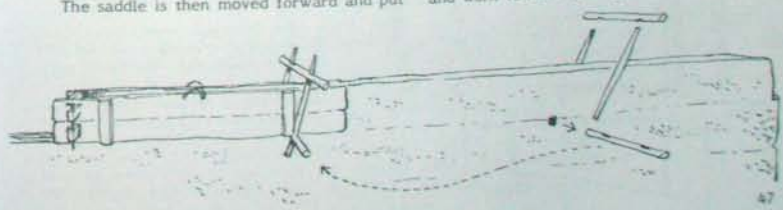


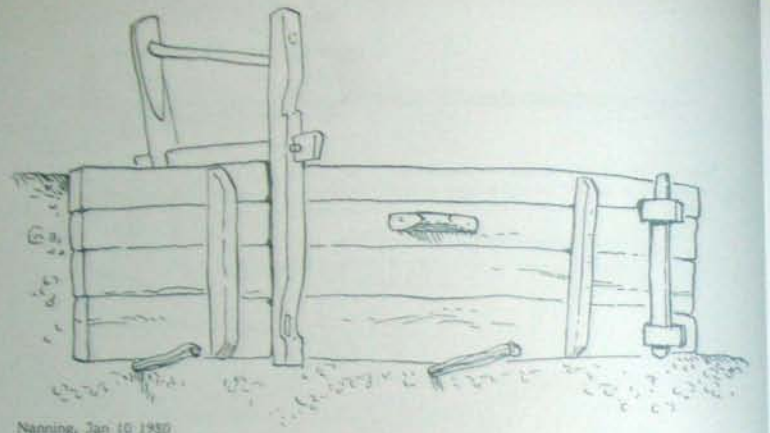
With the saddle still in the same place the sides are placed on it and the crossbar put back. Once again the form is filled and rammed.

When the ramming is completed the form is moved forward and the saddle is removed, leaving a hole in the wall (which can be filled with earth if desired).

The saddle is then moved forward and put together again. The rest of the wall continues in this same way, with the form being continually moved along.

The next course will begin at the left end and work towards the right.





Nanning, Jan 10 1980

Our party was taken 30 kilometres south of the city to visit some famous caves. We passed a number of small villages on the way, and I noticed that a lot of the buildings were of rammed earth rather than mud brick.

As we approached the caves we passed through a small cluster of homes called Yiling Village and I noticed some people at work on a rammed earth wall.

Arriving at the caves I said that I had a fear of holes in the ground and headed back through the fields towards the village, skirting around a small mountain along a track lined with healthy green cabbages.

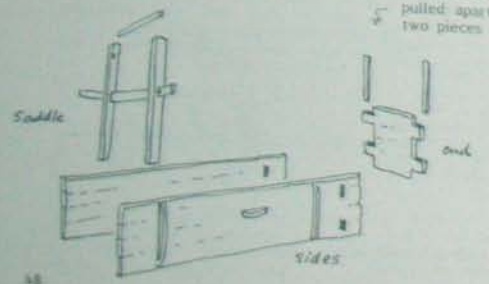
The villagers showed some surprise, I suppose I was the first Westerner to have ever visited their village, but they made me welcome and I spent the afternoon watching the builders at work and making sketches.

They were working on a small farm building 5x5 metres square, and I could see that it would only take a few days to bring the walls to roof height.

The first sketch shows the form when seen from the ground. The sides and end are made in the same way as the previous forms, but it has a different type of saddle.

The saddle will be seen to have all sorts of notches cut into it, but these have no bearing on the job, the builder simply used up an old piece of timber from some other construction.

This is how the form would look when pulled apart. The end is held in place with two pieces of timber which drop into holes.



The forms described earlier used steel rod for this purpose.

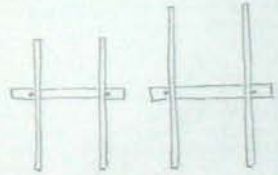
The form was roughly the same length and height as the previous ones described (2000 x 300 mm) but had an inside measurement of only 400 mm. The sides were of timber 50 mm thick and the ends were 30 mm thick.

This sketch shows the form from another angle. Notice the small plumb bob hanging by a string on the end. This was enough to ensure that the wall remained vertical. The horizontal level was judged by eye.

THE SADDLE

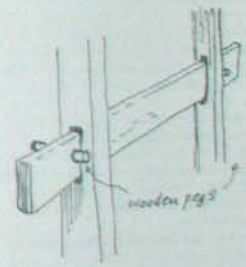
The saddle is in the form of an H and made of timber 75 x 50mm for the vertical pieces and 75 x 25mm for the crosspiece.

In this case the crosspiece was positioned just above half way as shown in the sketch on the left.



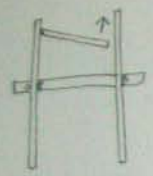
Later I saw another saddle which looked like the one on the right, with the crosspiece below the half way mark. This had the advantage of giving more leverage when putting the saddle in position.

The crosspiece is held in position with wooden pegs. I have made up one of these saddles for my own use and find that the pegs must be of solid hardwood. I found that anything less broke within a few moments of starting work. The pressure exerted against the pins is much greater than one would imagine. Steel rod would be better.



The gripping action of the saddle is caused by wedging a piece of timber in at the top of the saddle. This is simply a length of round timber cut to make a tight fit.

In the first sketch of the form you will notice that this piece did not even get pulled fully horizontal but was wedged in at a slight angle.



There is usually a socket carved into one of the vertical pieces of the saddle, but not the other. This is so that one end of the wedging piece will remain in a fixed position while the other is being pulled up into position.

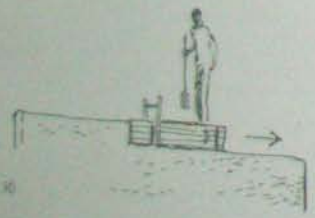
In this case the builder of the form had decided that the vertical piece was too thin to take a socket without weakening it, and so he had tacked on an extra scrap of timber with a hole in it.

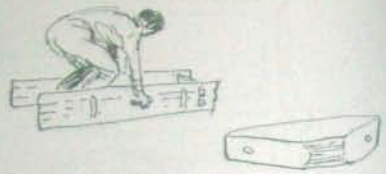
WORKING METHOD

The worker used a short tamper with a square face. It is the one on the right in my sketch of various types. It was not very heavy, and most of the time he used only one hand to wield it.

Other builders that I have watched rammed down about 100mm of earth at a time, but this one filled the form to a little over half, rammed this down and then filled it up to the top, heaping it up as high as possible. When this was rammed down the section was complete.

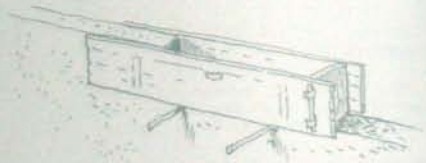
The form was now moved in the direction of the arrow.



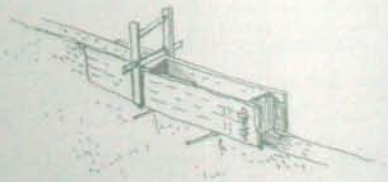


The form had wooden handles.

First two sticks were laid on the wall. They were nothing special, having been broken off a nearby tree, and were as thick as a man's thumb.



The form was then placed on these sticks, with one third of its length hugging the previously made section of wall.



The saddle was now dropped over the form at the point where it came in contact with the previously rammed section of wall.

The top cross piece was then wedged into place and the form was ready to be used.

When the form was next moved the sticks on which it had rested were left imbedded in the wall. Being greeen and smooth they were easily pulled out to be used again.

This building was being erected on a sloping piece of land, and the earth for the walls was being dug directly from what would eventually become the floor of the building. It was not moistened in any way but went straight from the ground into the form.

No reinforcing was used between courses, and no foundations had been dug. Many farm buildings are erected like this, directly onto the ground, but homes are usually built on a foundation of rock.

The lack of foundation and reinforcing very often leads to bad cracks appearing in the wall.

THE FLATTENER

A newly formed section of rammed earth is not as rigid as one might imagine. At one stage the man wielding the tamper noticed that a previous section had quite a bulge in it. He gave it a few hefty blows with the side of his tamper and soon had it straight.

It was interesting to see how flexible the wall was at this stage, and yet it would be tremendously strong and rigid when dry.

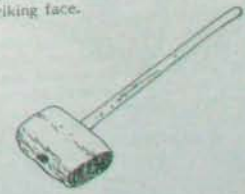
It seems that walls often need this attention in the course of building. This worker could use his tamper for the job because it had a flat side, but others had a special tool for the job.

At the previously described site the worker used a flattener made from one piece of timber, with the handle offset to one side for some reason.

The sketch shows him working on the courtyard wall, straightening a newly rammed section.

The walls of the home behind him show the characteristic holes made by the saddle, and also the interlocking pattern at the corners.

At the first site visited in Kunming the flattener had a heavy wooden head and a thin flexible handle. The broad side was the striking face.



A typical rammed earth farm building in Yiling Village, close to where the previously described wall was being built.

Both building and courtyard walls form a continuous whole. The exposed top of the wall is protected from the rain by a thatch of straw.

The walls are set upon a foundation of untrimmed local rock laid with mud mortar.

I was surprised to see Australian gum trees in the streets of this remote village, but they do well in this climate.

There are two huge specimens in one of the temples in Kunming and I wondered how such ancient looking trees had managed to find their way there.

A farm building in Five Trees Village, Yunnan Province, near the Stone Forest.

Built on a foundation of rocks laid in mud mortar.

Again the rammed earth walls show the holes characteristic of this method.

Pole Mould Walls

This is an amazingly fast technique compared to other methods of building with earth and requires only simple form work.

It is found in some farm buildings, but is mainly used for free standing walls. In northern China many of the old villages are still surrounded by high walls of earth construction.

In the past they were intended as a form of security, but their function today is not clear, except as a barrier against the bitter winds of winter. In addition to the village walls all the older homes also have walled courtyards, and so there is a great deal of exterior wall to be found in any village.

The pole mould system is ideal when there is a lot of wall to be built and the final finish is not of major importance. Some workers that I spoke to claimed that it was four to five times faster than building a rammed earth wall using conventional moulds.

However I think that part of this speed can be attributed to the fact that more workers can join in. I sketched the formwork at Hueko Village, east of Xian, and noticed that the whole family, including young boys and girls, were involved. At any one time there were two people ramming, two digging earth from the ground and four shovelling it up into the mould, while another two were taking a rest, a total of ten.

It sounds like a large work force but was only the family group, ranging from grandfather down to the children.

The completed wall was 2.6metres high and 700mm thick at the base tapering up to 400mm at the top. It was built in sections 2.5 metres long.

The workers said that they usually completed 3 sections a day, which made a total length of 12.5 metres of finished wall, a most impressive length!

They expected this type of wall to last thirty or fourty years at least, and pointed out some old village walls that were known to be a century old.

In the usual form of rammed earth construction the whole length of the wall is constructed in a continuous length and goes up layer by layer.

In the pole mould system the wall is built in sections and each section is taken to its full height and completed before the next section is joined to it.

This method of building has one very obvious disadvantage which can be seen in any old village wall that has not been maintained. No matter how well the ramming is done there is always a weak point where each section joins the next.

Heavy rain erodes the earth at these joins, and this type of construction can be readily recognised by the vertical cracks every two and a half metres. In time the join will erode until it is wide enough for an animal to pass through, and the wall is then of no further use and will be demolished and replaced with a complete new wall.

To prevent erosion the cracks are sometimes plastered with mud, but this has to be replaced regularly as it is softer than the rammed earth and soon washes out.

A better repair is done by filling the cracks with rammed earth bricks and mud mortar, and this seems to last reasonably well.

These repair measures seem to be only taken in home courtyard walls or walls that adjoin a house. The walls in the fields marking the village boundary do not seem to be given the same amount of attention, but stand out in the weather for thirty or forty years until they need replacing. (The Xian area, where these notes were made, is in the 500-1000 mm rainfall belt.)

Even though this method is so fast the village people that I spoke to all preferred to use conventional form work when using rammed earth walls for a home. The exception was when a home was built against an existing courtyard wall.

This was probably because the pole mould system is better suited to long straight runs, and because the finished job has an uneven surface caused by the roundness of the poles.

The erosion at the joins would also be a problem if the method was used for homes. The traditional home in the Xian area can be seen in some of my sketches. The eaves on the high side are of tiles extending out for only about 200mm, so driving rain strikes directly against the wall. (previous page)

In a traditional Australian farm house design with verandahs all round this problem would not occur, and this could be the ideal method for an earth builder in a hurry.

The wall could be given a good mud render to fill the grooves and would then look like any other earth wall except for the slight taper. Or it could be left unrendered to show the rows of horizontal grooves that are a characteristic of the method.

Village walls often appear to have been built directly on top of the ground, but this is not really the case. If they were built on top of the ground then serious erosion would occur at ground level during heavy rain and the walls could be undermined and topple over.

To avoid this problem a foundation ditch is first dug. Is is the width of the proposed wall and 500 – 1000 mm deep according to the type of soil. If the soil is very dense then 500mm is deep enough.

Having dug the ditch the same earth is then put back into it and rammed just as firmly as the rest of the wall. This provides a suitable foundation on which to build the wall. This method is only suitable in dry well drained areas. Where the ground is likely to remain moist for long periods the foundations are of rock with earth mortar. The mortar, which is simply mud, does not bind the rocks together but simply fills in the gaps.

The basic principle behind pole mould walls is that a random number of poles are placed horizontally between four upright poles so as to form a mould.

Earth is then thrown into this mould and rammed firm. When the new wall reaches the top horizontal pole the bottom ones are removed and leap-frogged up to the top.

My sketches show the form being used at Hueko Village. As in all other methods of earth construction each area has its own variations of the basic principle.

In other areas I have noticed that the horizontal poles go inside the four uprights, in this case they go inside one pair and outside the other. The villagers thought that this provided for a quicker release of the poles.

The four upright poles are of strong timber sunk 500mm into the ground. They are put in position while the foundation is being prepared. Each pair taper towards each other, and in this case the pair on the left are tied at the top with rope, though often a crosspiece of timber will be fixed here instead.

The right hand pair of poles have crosspieces and bracing nailed to them, and a stout log set into the ground to counter the force of the ramming.

This end also has to be closed off so that the dirt will not fall through it. Usually a few upright poles or planks do the job but in this case the end was one of the 'planks' used by builders when they have to get wheelbarrows across muddy ground or over gutters. These planks are made of split bamboo on edge bolted together .

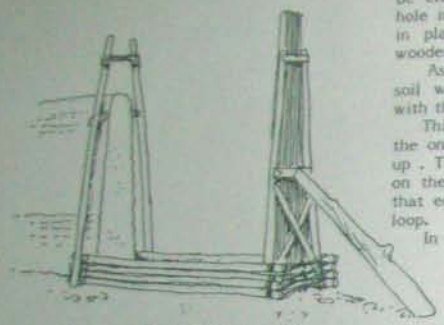
This end does not have to be tied to the upright poles, the wall being built will keep it in place.

A broken brick hanging by a string from the top crosspiece provides a quickly made plumb line to ensure that the wall is vertical.

The small sketch shows how work begins. Any number of horizontal poles can be used, in this case there were four.

On the left end they go inside the poles. They do not go tight against the poles but are wedged in place with a brick.

Whenever the pole is moved, the brick is



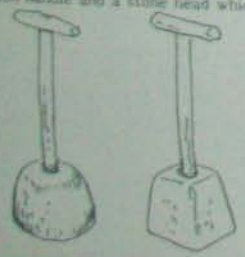
knocked out and the pole is then free.

On the right each pair of poles are held against the uprights by means of a loop of stout rope. A short piece of stick is put into this loop and twisted in order to pull the poles as tightly together as possible. The sticks are left in place.

The earth for the wall is dug directly from the ground, and as close to the site as convenient. In this case it was being dug close enough for the workers to be able to throw it directly to the base of the wall.

The earth was not dug until it was needed, and it was then used straight away. 200mm below the surface most soils hold enough moisture to make this type of building possible without having to add extra water, and it must be noted that in this case the work was being done during a dry time of the year when the ground surface appeared to be bone dry and raised a dust when disturbed, yet below it was moist.

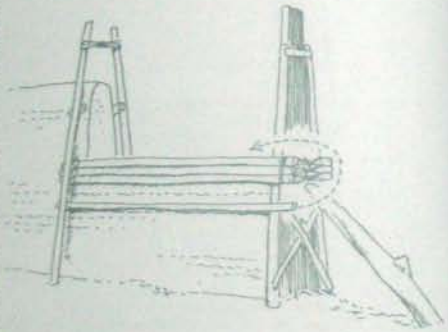
Dirt was shovelled into the formwork to a depth of about 100mm and two men began ramming it down. The tampers usually have a wooden handle and a stone head which can be either round or square. The stone has a hole in it to take the handle and this is held in place with a twist of rag and rough wooden wedges.



As each layer was rammed down more soil was added until the wall came flush with the top horizontal pole.

This pole was left in place but some of the ones below it were removed and moved up . Two people removed the poles, the one on the left knocked out the brick to free that end while the other untwisted the rope loop.

In the second small sketch two poles have already been moved up, as can be seen by the gap, and the third one is about to be lifted.



Notice on the left side at the top that a couple of bricks go between the poles and wall to maintain the gap.

The top of the wall is finished off to a curve so as to shed the rain.
Sometimes straw is also laid along the top, as can be seen in the sketch at the start of this section. In windy parts stones are laid on the straw.

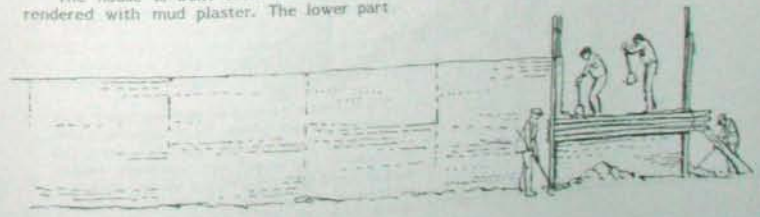
Although pole mould walls are most commonly found in the north I have also seen a barn made by this method near Nanning, in a higher southern rainfall area (1500-2000mm a year).

These walls were protected by wide eaves and so not affected by the frequent rain. Not far away was an abandoned farm building. This had the roof removed and as a result the erosion was very severe.

I did this sketch near Xian in a village on the Horse Banner Commune. The house shows the typical roof profile found in this part of China. I have noticed this architectural style all the way to Lanzhou, where it changed to flat roofs.

The house is built from mud brick and rendered with mud plaster. The lower part of the outer wall of the house incorporates part of the courtyard wall.

The wall had been built by the pole mould method and shows the usual erosion cracks at each section. Where the walls form part of the house these cracks have been repaired with mud plaster.



This wall was completed in one day by the family. It was 12.3 metres long, 2.6 metres high and 700 mm thick at the base. Hueko Village, near Xian.

The most simple form of all

The fort at Jiayuguan.

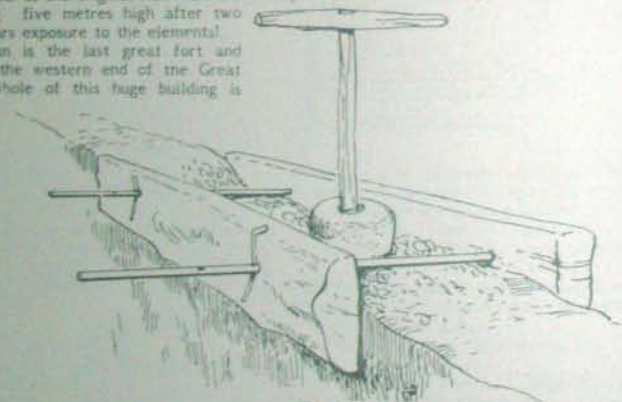
Most visitors to China see the Great Wall near Beijing, and at this point it is constructed from stone and brick. But the Great Wall is also one of the world's greatest examples of the lasting power of earth as a building material.

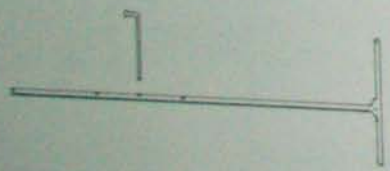
Many Australian Building inspectors are still of the opinion that an earth construction will collapse after the first shower of rain, yet in north-west China eroded sections of the original Han Wall are still standing five metres high after two thousand years exposure to the elements!

Jiayuguan is the last great fort and gateway at the western end of the Great Wall. The whole of this huge building is constructed from earth, as is the Wall itself at this end.

In ancient days the fort was occupied by the military. Outside the walls of the fort was a civilian town, long since vanished, and this in turn was surrounded by another earth wall.

This outer wall was in the process of being repaired when I visited there in June 1982, and the workers were using the most simple forms that I have yet encountered.





The forms consisted of nothing more than a pair of heavy planks held together with steel rods. The planks were of no fixed dimensions, obviously any available timber was utilized. In length they varied from 2-3 metres, in thickness from 50-75mm and in depth from 200-300 mm. As can be seen in my sketch some of the planks were very rough and irregular.

The planks were held together by a pair of steel rods. A 200-300 mm long T piece had been welded onto one end of the rods.

This gave a good broad grip on the plank and helped prevent splitting under the pressure of ramming.

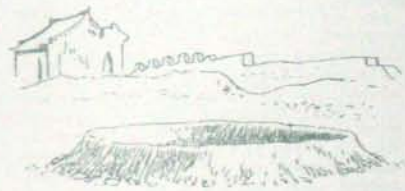
A number of holes were drilled through the rods, and a steel pin fitted into the holes. this allowed the planks to be set at different distances apart for different wall widths.

I noticed that the pins had nearly all bent due to stress during ramming, but this could have been lessened by using large steel washers between the pin and the plank.

This type of form is easy to make, assemble and use.

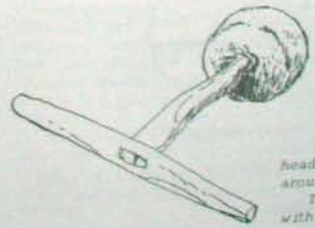
The forms did not have ends in them, but when one is working on the Great Wall ends are not going to be used very often!

If an end was needed a short piece of plank would be placed on the inside against one of the rods.



At this point the wall is out in the stony desert. The earth for the work was being brought from some distance, and because of the arid climate it was not moist enough to use as it was.

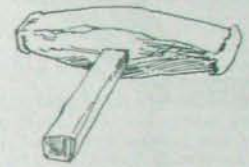
It was heaped into crater like shapes on a flat piece of ground, making a circle of 4-5 metres in diameter, and water was poured into the centre. The earth was then mixed to the right consistency.



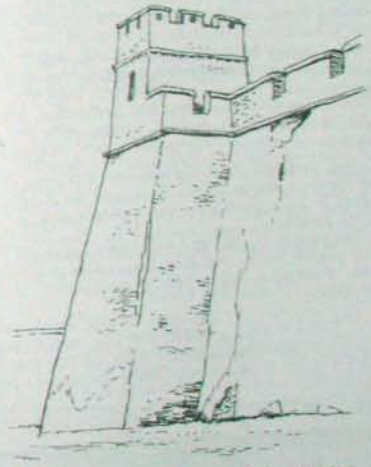
Another view of the tamper. The stone head is held in place by a scrap of rag around the handle.

The cross piece of the handle is fastened with wooden wedges.

The tampers had rough wooden handles and stone heads of cylindrical shape. Short handled wooden mallets with handles 300 mm long and heads of the same length are used to hammer down edges where the tamper could not get, and also to help release the forms when a section is finished.



When a form has been filled and rammed the pins are knocked out of the rods and then the rods pulled out of the newly made section of wall, leaving a small hole.



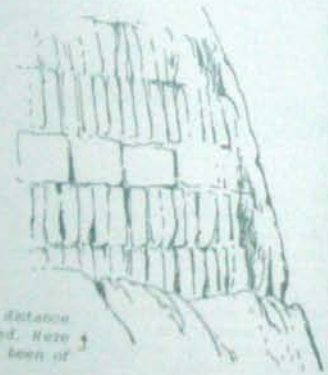
Part of the massive walls of the fort built entirely from earth.

The sketch shows a section of the wall being repaired. The darker patches are the new sections.

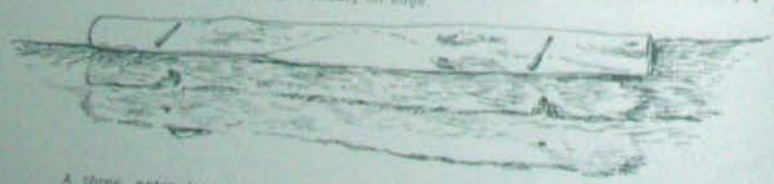
Any number of forms can be used at one time, and the forms can also be placed at any desired angle.

This sketch is from the opposite side to the previous sketch of the form, and the T pieces of the rods can be seen at either end of the planks.

This section of the wall had once had a mud plaster finish and even now, centuries later, traces can still be seen at the base of the wall.



A section of the wall a short distance away from the area being restored. Here the original face of the wall has been of mud brick, mostly standing on edge.



A three metre long form showing the natural shape of the tree on the outer side. It has just been moved up and below it can be seen the holes left by the rods being withdrawn to move the form up from the previous position.

Rammed Bricks

The most common method of producing earth bricks is to first turn the earth into mud then place the mud in a mould. The mould is removed and the brick left to dry until it can be handled.

With rammed bricks the earth is not moistened but is used directly from the ground, being placed into a strong mould and rammed hard. It can then be taken directly to the stack.

This technique is new to the West, but has been popular in northern China for countless generations. Travelling by train to the north-west from Xian you will pass thousands of homes built with rammed bricks, even in the desert areas beyond the end of the Great Wall.

ADVANTAGES OF RAMMED BRICKS.

MINIMUM SOIL PREPARATION. The earth is usually dug directly from the site and placed into the moulds without having to be moistened or treated in any way (though straw can be added if desired).

MINIMUM HANDLING. The rammed brick goes directly from the mould to the stacking area , unlike the ordinary mud brick which has to be individually handled and dried before it can be stacked.

A GOOD SPARE TIME TECHNIQUE. Because the soil does not need to be prepared this is a good method for making a few bricks whenever you have a spare half hour.

There is no problem mixing rammed bricks and ordinary mud bricks together when building.

A FASTER METHOD. Because the rammed brick contains less moisture it dries much faster than a mud brick and so can be used that much sooner.

SUITED FOR DRY AREAS. Mud bricks require access to water to prepare the mud, but the rammed brick uses only the moisture that is already in the soil. This is why it is popular in the low rainfall areas of China.

This is also why the soil is taken directly from the ground into the moulds in dry areas, for if it was stacked it would soon lose its moisture and be of no use for brick making.

A SOLID BRICK. Ramming produces a harder denser brick, but for all practical purposes this is of no great importance.

DISADVANTAGES OF RAMMED BRICKS

MOULD CONSTRUCTION. The mould used is much more elaborate than those used for ordinary mud bricks, and so takes longer to make.

REQUIRES MORE ACTIVITY. The making of rammed bricks is a much more physical activity than making ordinary mud bricks, though no great strength is required. Even so the workers that I spoke to produced the same number of bricks by ramming as are produced by the ordinary method.

Two workers will make 500-700 bricks a day.

WEATHER PROBLEMS. Once in a wall a rammed brick will resist rain even better than an ordinary mud brick because it is denser, but when stacked in the open to dry it is very easily damaged by rain because of its relative thinness.

This is probably why this method is used in the drier north-west part of China rather than in the wet areas.

REQUIRES PRACTISE. Anyone can make a successful mud brick, but it takes a little time to learn the technique for making rammed bricks. You have to get the feel of the earth so that you know when the brick has been rammed firmly enough to be safely lifted from the mould.

MATERIALS NEEDED

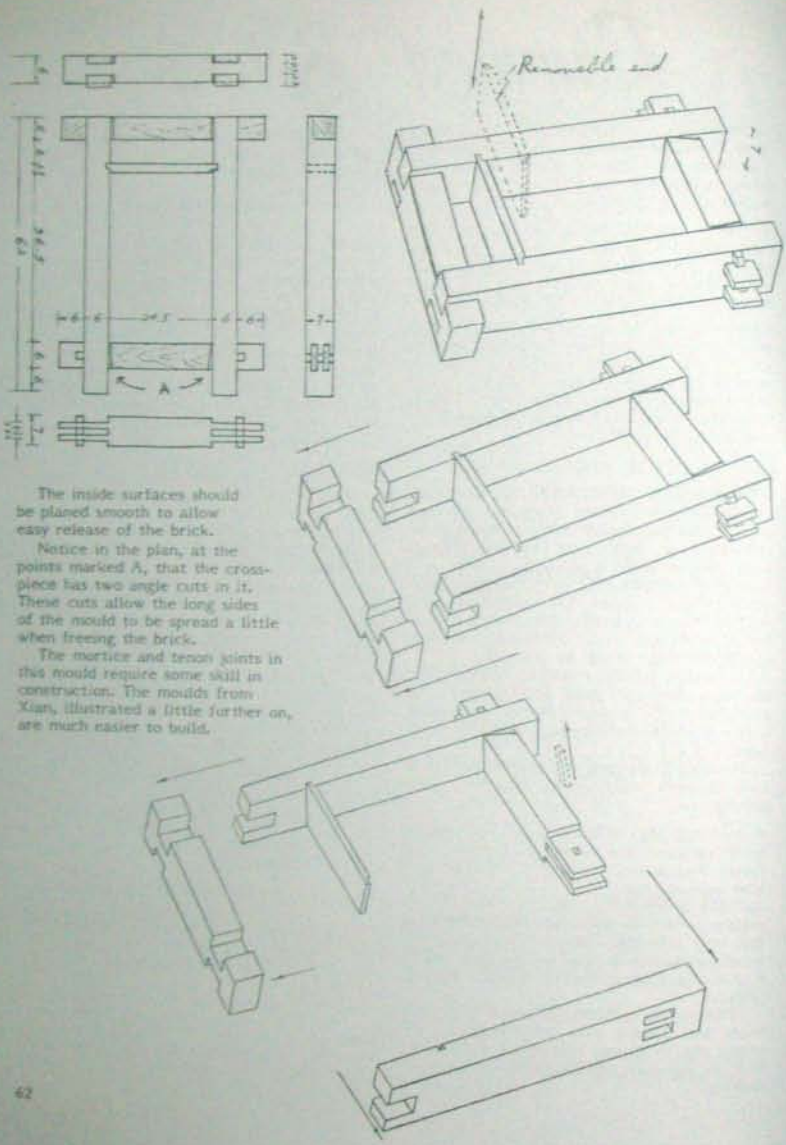
A brick mould.
A slab of stone or cement .
A tamper.
Digging tools

MOULD USED FOR RAMMED BRICKS

The first set of drawings was prepared by Lin Wei-hao, and I have also included sketches showing some variations on this pattern.

His dimensions are given in centimetres.

As the mould has to be very robust only hardwoods are used in the construction. Walnut is considered a good timber, but any strong, hard timber can be used.



The inside surfaces should be planed smooth to allow easy release of the brick.

Notice in the plan, at the points marked A, that the cross-piece has two angle cuts in it. These cuts allow the long sides of the mould to be spread a little when freeing the brick.

The mortice and tenon joints in this mould require some skill in construction. The moulds from Xian, illustrated a little further on, are much easier to build.

DIMENSIONS OF RAMMED BRICKS

Earth Builders in China do not worry about standardised measurements. Rammed bricks conform to a general shape but each mould differs in actual dimensions.

The one factor that all rammed bricks have in common is that they are all relatively thin. This causes problems in handling when they are newly made, as they break easily, but this cannot be helped.

The bricks must be made thin so that they can be firmly rammed with one filling of soil. If the mould was deeper the brick could not be rammed firmly throughout its full depth.

Lin Wei-hao's mould produces a brick 365x245x70 with a volume of .0062 cub.m. The Hueko village mould gives a brick 380x230x50 with a volume of .0047 cub.m. while the Black Dragon Brigade's bricks were 370x270x55, volume .0054.

There is quite a marked difference in volume here, from .0062 to .0047, though the finished bricks do not look much different.

It is interesting to compare these dimensions with the table of mud brick dimensions from various parts of China. The average for the rammed bricks is 338x235x58, volume .0049 cub.m., while the average for the mud bricks is 300x160x75, volume .0036 cub.m.

The extra weight of the rammed brick, plus the fact that a certain amount of body weight is needed when stamping the earth into the mould, means that rammed bricks are usually made by men.

By contrast the making and laying of mud bricks is shared equally as no great strength is needed.

SOIL QUALITY

Clean sandy clay is the best material for rammed bricks. It should be free of organic matter, and also large sticks and stones.

It will soon become apparent if the soil is not suitable as it will be impossible to pick up the newly made brick.

However do not reject the soil on this account if you have not had practise at making rammed bricks as a certain amount of skill is required in both the ramming and the lifting.

Most soils can be used for rammed bricks.

SOIL MOISTURE

The great charm of the rammed brick method is that the soil is used just as it comes from the ground. If it requires moistening then it may be as well to consider making ordinary mud bricks.

The exception would be if you wished to use the top layer of soil. In this case the soil would need breaking up and moistening.

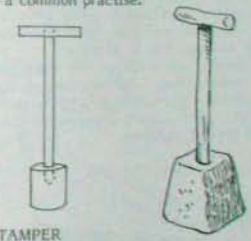
Generally the top layer of soil is too dry for brick making, but soil with sufficient moisture may be found as close as 100mm below the surface.

USE OF STRAW

Usually rammed bricks are made without straw, but if it is available then it certainly can be used. Its use helps bind the soil together and so makes it so much easier to lift and stack the newly made bricks.

The straw is cut into 100 mm lengths, roughly, and added to the mixture in the ratio of 5 kg of straw to 1 cubic metre of earth.

Slaked lime can also be added to bricks if desired and would help make them more weather resistant, but this does not appear to be a common practise.

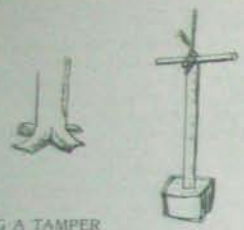


THE TAMPER

Lin Wei-hao provided the diagram of the tamper on the left, and my sketch of a similar one is a little further on. The head is of stone, and the wooden handle is held in place with twists of rag and rough wooden wedges.

I only noted one square faced tamper in the Xian area, all the rest were round. The reason for this was not clear, as a square one would get into the corners. However it seems that a round faced tamper consolidates the corners quite well even though it does not come down directly onto them.

The tamper weighs 10-12 kilos overall.



MAKING A TAMPER

In the absence of a stone head a tamper can be made quite well from any heavy timber.

I have made a satisfactory one from cement with a handle of steel water pipe. The end of the handle was split and spread to provide a good anchor in the cement.

Making the head was simple. I suspended the handle from a rope around a rafter and used a plastic icecream container as a mould.

A mixture of three parts of sand to one of cement was poured into the carton. The first tamper broke because I did not leave it long enough to cure,but in my excitement tried to use it after only a couple of days.

The next one was kept moist for a week and so became much stronger. The overall length was 620mm. The stone head of the tamper that I had sketched in Xian had a bottom diameter of 220mm and a height of 130mm, and I chose a container close to these dimensions.

THE SLAB

A firm surface is needed on which to ram bricks. In China this is usually a stone slab the same size as the mould or a little larger.

Although the cutting of a stone slab takes a long time the village people consider the effort well worth while as it can be used for generations.

In our Western society stone slabs are not readily available, but a cement slab will do the job just as well.

Because such a slab is quite heavy I have found it more convenient to pour the cement where the bricks are going to be made rather than have to move the slab from somewhere else.

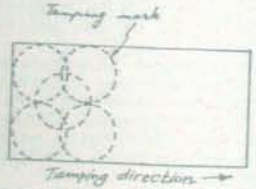
I made the slab 500x700x50.

MAKING BRICKS

A detailed description of brick making in Hueko village is given a little further on, but briefly the system is as follows.

The mould is placed on the slab and both mould and slab given a light dusting of dry earth, sand or ash. This is necessary to prevent the brick sticking to the slab or the mould.

Earth is shovelled into the mould and firmed down with the feet. The tamper is then used , directing firm blows to the soil and following the pattern shown in the sketch.



The tamper is then used around the edges of the brick, and finally a few light blows to even off the surface.

The dumbell shaped piece is removed from the mould(see next page)and then the two long sides can be slightly spread apart to free them from the brick and then lifted away.

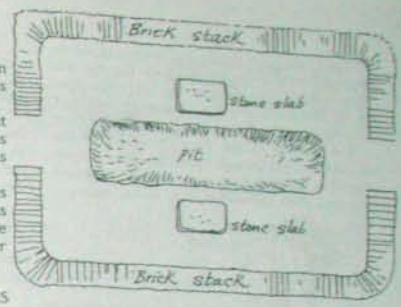
The removable end piece can also be put to one side and the brick carefully slid towards one edge of the slab, stood on end and then carried to the stack.

SPEED OF PRODUCTION

A pair of Chinese workers expect to make 500-700 bricks a day. The workers I timed in Hueko village took 45 seconds to make a brick and prepare the mould for the next one.

On the other hand, when making bricks by myself, without a mate, I have found that it takes about three minutes for each brick.

PLANNING THE WORKING AREA



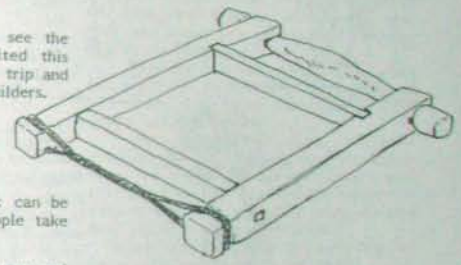
As in all earth construction the job can be done much faster if the working area is properly planned.

In this design the earth goes straight from the pit into the mould and the stacks are kept as close to the brickmaker as possible.

In Xian I noticed that the brickmakers preferred to have a series of small pits after this design rather than have a large pit which would have resulted in larger stacks and so longer walks to the ends.

FIELD NOTES ON RAMMED BRICKS

Prepared during a visit to the Xian area, March 1983.

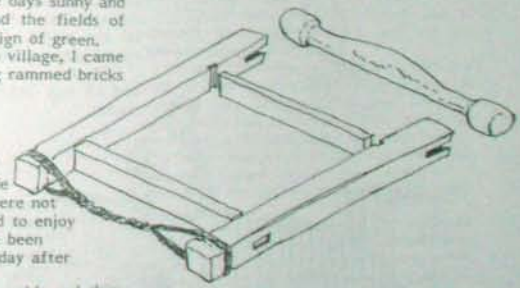


Most visitors go to Xian to see the terracotta army, but I had visited this amazing excavation on a previous trip and this time I was hunting for earth builders.

Winter had just ended, there was snow still on the mountains, and crossing them I had seen a still frozen waterfall. At this time of the year not much work can be done in the fields and so the people take the opportunity to build.

The air was cool, but the days sunny and bright. The air was dry and the fields of bare earth showed hardly a sign of green.

East of the city, in Hueko village, I came upon a group of men making rammed bricks and stopped to watch. They were all working in pairs, and thousands of bricks were stacked to dry.



The pair that I spent most time with said that they made 500-700 bricks a day. They were not sweating, in fact they seemed to enjoy the work, but they must have been very fit to keep up the pace day after day.

I did a sketch of their mould, and they said that it was made of a hard wood called black date, which was similar to persimmon wood. Even so the wood did not seem to be either very dense nor heavy, but it was certainly much stronger than the pine that is used for most construction in China.

This mould differed from that drawn by Lin Wei-hao in one important respect. If you look at his plan of the mould (page 42) you will see that the two long sides are held together at the right hand end by mortice and tenon joints.

If you look at my sketch of the Hueko village mould you will see that the end is held together with rope. The timber cross piece fits into a joint but is not pinned or nailed in any way. This make for easier construction.

The stone slab and mould were placed on the edge of the pit from where the soil was being dug. Although the top soil was bone dry, at 200mm down it held enough moisture to make bricks.

The worker in the pit first broke up the soil with a two pronged pick which was very effective in reducing lumps to a workable size, and then shovelled it up to his mate.

The man on top stamped the soil down with his feet and then grasped the tamper and rammed the earth down with solid blows. This only took a few seconds.

While doing this he stood on the edges of the mould. When the brick had been rammed he kicked one end of the dumbell shaped piece out with his heel and then stepped off the mould.

He then spread the side of the mould slightly and lifted it up from the brick. As it came clear he put the dumbell piece back into position and leaned the mould up against the tamper.

The brick was then carefully lifted and carried to the stack, only a few paces away. While he was doing this the man in the pit picked up the removable end piece and used it to scrape any remaining fragments of earth from the mould. He then laid the mould down again, inserted the removable piece and dusted everything with powdered dry soil, which was kept in a basket close to the mould. All this was done without stepping out of the hole.

By this time the top man had returned and all was ready for another brick to be made.

The bricks take only a couple of weeks to dry and are then ready for use.

The strength of these bricks may be judged from the fact that they are put directly into the drying stacks and are stood on edge with the width of a finger between each brick. These stacks are built up to 6 tiers high – as high as a man!

The handle of the tamper was held in place by a twist of rag and some wedges as described earlier, and the top man had to pause and hammer it firm from time to time.

One interesting aspect of brick making in the Xian area emerged as I was watching. The pit worker began to throw out large pieces of black pottery, and the clean edges showed that his pick had just broken what would have been a treasured piece in one of our museums.

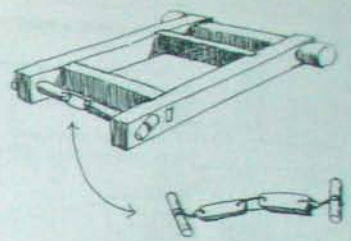
No one paid any attention, they were all too busy watching me sketch, until someone cried out "A tomb!", and we all ran over to see.

On the side of the pit his pick had exposed a hole, and we could see that it opened into a large cavity.

The worker made no attempt to enlarge the hole but threw some dirt over it and began digging in a different spot.

Doubtless he and his mate would have made a thorough examination after the audience had gone.

On another day I went out towards the Qian Tomb, about 80 km northwest of Xian and here, on the Black Dragon Commune, found another group of men making rammed bricks.



Their moulds were similar to those used in Hueko village except that instead of one end being held together with twisted rope they used small pieces of wood and wire to provide the hinge action.

Their daily output of bricks was the same, 500-700 for each pair of men. Instead of fine soil they dusted the mould with ash before making a brick.

They also had a slightly different technique for packing down the earth before using the tamper. Instead of stamping with alternate feet they held onto the tamper for support then sprang up and down bringing their cotton shoes down together.

It was noticeable that the earth was not moist enough to cling to their shoes.

I timed them and found that it took 45 seconds to make one brick and get the mould ready for the next.

After I had been watching for some time one of the workers remarked in a good natured way that as I had been watching him make bricks for quite a time he should now have a rest and watch me make bricks.

There was a lot of laughter and rough peasant humour about this idea, but I welcomed the chance to learn more about the technique.

I was surprised to find that the work was not as physically demanding as it looked, and I have since confirmed this when making bricks in Australia. It is a degree more demanding than making mud bricks, but it does not call for any great strength, only stamina.

I wielded the tamper till 10am when all the workers knocked off and went home for breakfast, their first meal for the day. As we moved away we saw crowds of people also leaving the fields, and soon the whole countryside was empty.

LAYING RAMMED BRICKS

The sketches show typical bonds noted in northwest China. The bricks are most commonly laid standing on their narrow edges.

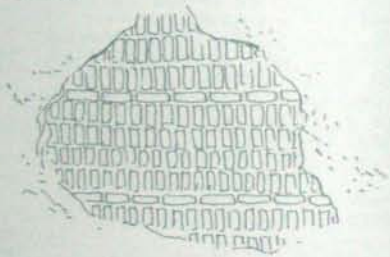
It seems that there is less chance of bricks breaking when laid this way.

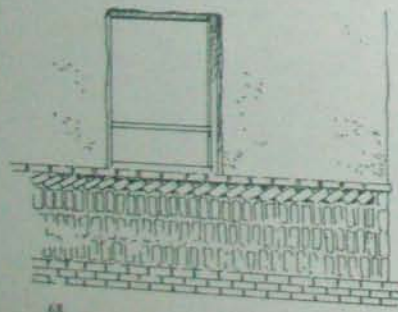
← I saw this wall during construction at Yumen (Jade Gate) a small town in the desert. This was once the end of the Great Wall.

The wall was being built to surround a house courtyard. A slightly domed layer of earth protects the wall from the infrequent showers.

→ A house wall at Yumen, the mud plaster has fallen away to show the method of construction. The occasional course of bricks laid flat helps strengthen the wall.

← A home being constructed at Dunhuang, even further into the desert. The foundations are of fired bricks, as is the course below the window.





A very clever use of mud brick is shown here. To get the windows at the right height required rather less than four courses of upright mud bricks. Rather than cut bricks to get the right height the builders laid the bricks at an angle, a fast and effective answer to the problem.

MUTIPLE MOULD FOR RAMMED BRICKS

Lin Wei-hao provided drawings and description of this multiple mould. I have not encountered such a mould myself and so cannot comment on its virtues or vices.

It is said to produce a brick of good quality and even shape. The dimensions, 380x185x240 , are closer to those of ordinary mud bricks.

Six logs are shaped at the top as shown and then set into the ground.

When the earth is being rammed a lot of pressure is exerted against the sides of the mould, and so the stumps have to be locked in place.

This is done by three connecting planks. These planks have holes in them which fit over each pair of stumps and so lock them together.

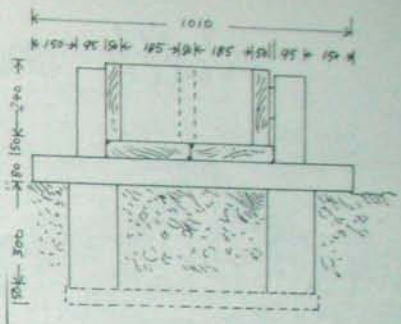
The mould is now put in place between the stumps. Unlike other moulds this one has a bottom, made up of two planks.

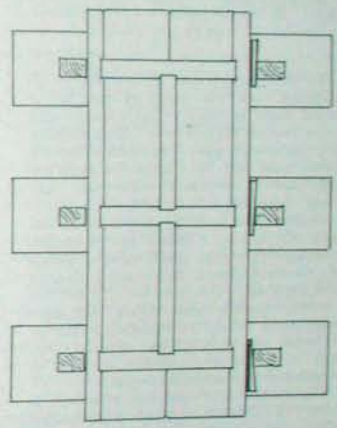
The sides have grooves in them so that each piece fits together neatly and in the right place. This mould consists of loose pieces, as it must be pulled apart to release the bricks.

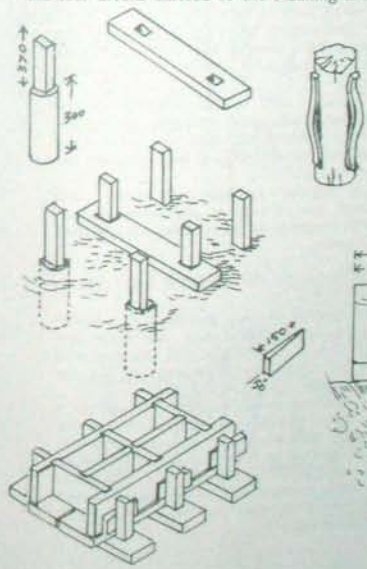
It is held firmly in place by the use of wedges on one side.

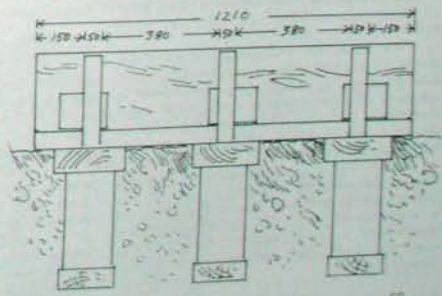
A heavy tamper is used for this type of mould, and the sketch shows one made from a log.

The brick making procedure is the same as before. Earth is placed into the mould and rammed firm. The wedges are then knocked out, the side planks removed, and the four bricks carried to the stacking area.









Wattle and Daub

Wattle and daub building near Mt Emei

The Oxford Dictionary defines wattle as interlaced rods and twigs as material of fences, walls or roofs'. The Chinese term for this method is Tu-ni-li-ba Qiang, literally smear-mud-fence wall. This shows that the Chinese also saw the connection between fence panels of woven sticks and this method of building.

Wattle and daub is used all over the world. Thousands of years ago herdsmen discovered that they could make a simple and effective fence by weaving flexible sticks together.

These panels were strong, yet light enough to be moved from place to place as the herds moved with the seasons. They could be quickly tied together to make an enclosure for the animals at night.

The term wattle does not refer to the timber of that name, and any flexible timber can be used for the job as long as it is reasonably straight and easy to work with.

The herdsmen undoubtably used these panels as a windbreak for themselves during bad weather. It would only have been a question of time before some idle hand discovered that the effectiveness of such a shelter could be increased many times if it was smeared with mud.

In this way a portable panel was turned into a permanent structure. A few panels plus a thatched roof quickly created a small cabin that took little labour and would last a season or two. In arid areas even the roof could be made with a mud smeared panel.

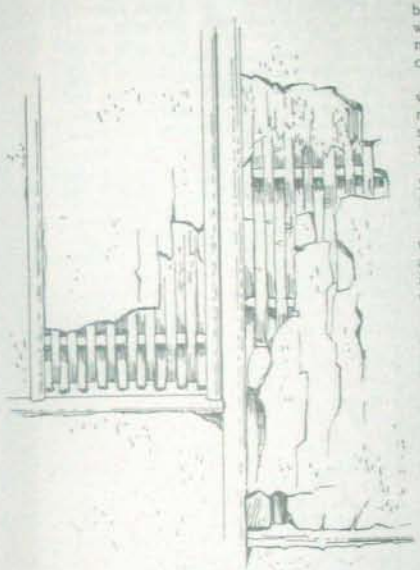
In this way the wattle and daub method probably evolved. Today it is used as both a temporary building method and a wall in-fill on permanent buildings.

ADVANTAGES OF WATTLE AND DAUB

1. Much less earth is involved than with any other earth building method.
2. If the wattles are readily available the method is fast. This is why many early gold miners in Australia chose it for their cottages.
3. It can be used to fill irregular shaped areas. The Elizabethan cottages of England with bent timbers set into the walls have the spaces between filled with wattle and daub.
4. With regular maintainance wattle and daub will last as long as any other method of earth building, as those same Elizabethan homes prove.

DISADVANTAGES OF WATTLE AND DAUB

1. The method is only practical if suitable timber is readily available. We built one wall of our kitchen by this method and found the collecting of timber to be the main problem.
2. The method is not suitable for any area where there is likely to be vibration as the daub will fall from the wattles. However this can almost be regarded as an advantage in an earthquake prone country such as Japan as less damage is likely to be caused by a shower of mud than by a solid earth wall collapsing.
3. Wattle and daub walls are thinner than other earth walls and so do not provide the same insulating properties. This applies to both insulation against temperature and sound.



WORKING METHODS.

1. PERMANENT BUILDINGS

The method is very flexible and simply consists of arranging a network of sticks between the framework of the building. As wattle and daub is not a load bearing method the frame of the building must be constructed first.

No great skill is needed in working with wattle and daub, the only point that really needs attention is to make sure that the sticks are firmly attached to the frame of the building.

← The sketch shows a wall in Guilin, September 1979, with some of the mud flaked off, possibly due to an earth tremor.

The wattles are of split bamboo and are woven around horizontal poles. These poles are 500 mm apart and fit firmly into holes in the upright timber frame. Mud is then worked over this from both sides.

When this has almost fully dried the wall is usually given a coat of mud plaster to finish it off neatly. The method is described elsewhere in the section on plastering.

There is no fixed method for weaving the wattles, in the next sketch the material has been taken horizontally, and it is a tighter weave.

The end wall had been plastered only half way up, and the area above this, protected by the eaves from the rain, had been left uncovered. This would allow a certain amount of light into the building.

This building was noted near Leshan, Sept 7, 1979, on the way to Mount Emei. There must be a ready supply of suitable sticks in this area for a lot of the farm buildings

were in this style with exposed timbers and wattle and daub.

Often the wattle and daub sections were whitewashed and contrasted strongly with the dark timber frame.

Wattle and daub is still used a lot in rural Japan, though visitors to the country will not be aware of the fact. This is because the walls are always plastered on the inside and usually clad on the outside.

This cladding used to be in the form of very thin pine planks, often only 8 mm thick. These were left unpainted and soon turned dark with age. Today very often a rather horrid type of sheet iron painted with wood grain is used.

The inside finish can also be rather unfortunate. In one traditional Japanese inn my room had been built with wattle and daub which had then been plastered with a mixture of glue, flock and glitter!

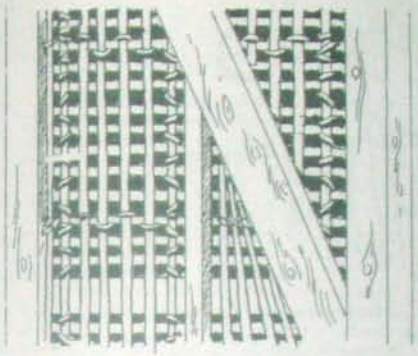
A freak gale one night lifted a corner of the roof to let in the rain causing a section of the wall to flake off revealing the mud and bamboo construction.

In the small fishing town of Hiwasa on Shikoku Island, Japan, April 1983, I noticed several new homes under construction using wattle and daub.

The framework is of pine and the wattles are bamboo. They are not woven together but are tied with synthetic cord every so often. (next page)

The house frame has holes drilled in it at regular intervals, perhaps every 300 mm and one of the bamboos will be secured at either end by the holes and so help keep the whole bamboo work rigid. When the bamboos have been fully tied as in the sketch there is no movement in the panels.

The vertical bamboo layer always goes on the outer wall of the building. If, in years to come, the cladding lets in the rain there will be less problem with erosion as the vertical sticks will shed the water better than horizontal ones.



The above sketch shows the frame of a new house.

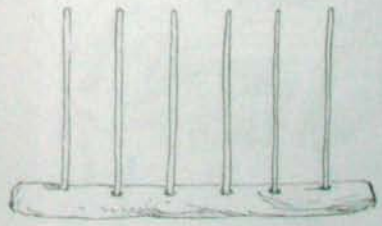
Also near Hiwasa, at Ebisu, I sketched the old deserted farmhouse on the previous page. The pine cladding can be seen on the lower part of the wall concealing the wattle and daub.

Above the cladding the exposed wall has eroded with decades of rain and the vertical strips of bamboo can be seen showing through the mud.

WEAVING THE WATTLES

In some parts of the world the wattles are woven on the ground and then fitted to the building.

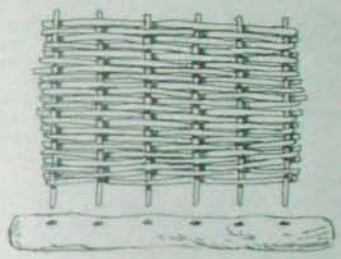
As mentioned earlier the making of wattle and daub is related to the making of wattle panels for fences. The early settlers in Australia brought with them a traditional British method for making these panels.



This consisted simply of drilling a number of holes in a heavy log. Sticks were then placed into the holes and the horizontal pieces woven around them.

When the section was complete it could be lifted from the log and used as a fence or be placed into a wall.

However a more common method in Australia seems to have been to simply wire or nail horizontal saplings to the uprights of the building and plaster the mud over these. This was mainly because of a lack of timber suitably flexible for weaving.



TEMPORARY BUILDINGS OF WATTLE AND DAUB

Because of its speed of construction and the small amount of materials involved wattle and daub is an excellent method of making temporary buildings.

The most dramatic use of this method that I have observed was in Beijing in 1977 not long after a disastrous earthquake. Many apartment buildings in the city were regarded as being unsafe, and people were allowed to build temporary shelters among the trees in the centre of the wide streets.

They lived in these small shelters right through a harsh winter, until they could return to their homes.

These earthquake shelters were made from whatever materials were readily available, and the most common walls were of wattle and daub.

This was usually built on a frame of a few sticks to which was attached old straw mats if sufficient sticks could not be found. Once a good layer of mud was plastered over this a serviceable wall was formed.

This provided insulation against the bitter winter winds and served the people well until the danger had passed.

Roofs were often made of timber with tar paper covering,held down only with a few stones.

On a visit to the same area the following year no trace of these thousands of shelters remained.

These shelters had to be made in a hurry due to the emergency conditions and could not be regarded as anything else than basic emergency shelter. However a visit to Guangdong Province in January 1980 showed how comfortable a temporary dwelling can be if some time can be spent on building it.

Here, while walking on a mountain, I came upon some buildings being erected by forestry workers.

The framework of these buildings was remarkably light, being constructed almost entirely from bamboo poles. The whole of the framework was then thatched with straw, both walls and roof.Tar paper was placed between the layers of thatch on the roof so that it did not have to be very thick in order to shed the rain.

The thatch on the walls was suspended from bamboo poles 400 mm apart. The walls were then plastered with mud, inside and out.

The mud stabilized the structure as well as providing insulation. It also lessened the risk of fire, and denied insects and rodents ready access to the thatch. The building was also easy to keep clean.

My sketch shows a nearly completed building, and behind it another under construction showing the thatched walls.

These buildings would be used for a year or so by the forestry workers and then abandoned. Without maintenance the roof thatch would rot in time and let rain in on the top of the walls, which in turn would crumble. Before long the whole building would return back to the earth, and grass and trees would once again grow on the site as if there had never been a building.

Cave Homes

Lanzhou is in northwest China on the upper reaches of the Yellow River. It is an ugly industrial city sprawling 40 kilometres along the banks of the river. The river flows into the city clear, ice-green, but when it leaves it is already stained and murky.

I arrived late at night, by train. The temperature had dropped below zero and it was soon to snow, but two officials were waiting patiently to welcome me.

They knew that I had come to study buildings, and had arranged a meeting with the city's top architect who was amazed when I told him that I had come to look at earth buildings. It seemed that it was a subject so common that no one had ever really bothered about it.

Even so he and the other officials went out of their way to help me during my stay, and I was taken up into the remote mountains to look at different villages.

It seemed that my interest in turn sparked off theirs, and the following week an article about cave homes appeared in the China Daily (Mar 12 1983) datelined Lanzhou and written by the vice-chairman of the Architectural Society.

It was estimated that 40 million people live in cave homes in the loess country of Shaanxi, Gansu and other northwest provinces.

It was considered that the caves had a number of advantages, including low cost and ease of construction. In summer the temperature in the caves is about 10 degrees centigrade cooler than outside and in winter it is 15 degress higher.

They did have some disadvantages, if they faced in the wrong direction there could be problems with light and ventilation, and they could be dangerous during earthquakes.

However these problems were considered to be secondary to the advantages of cave homes, including the important fact that as they were built into the hillsides they did not take up valuable farming land.

On the train from Xian to Lanzhou I had noticed caves in every hill, and in the hills 90 kilometres northwest of Xian I had sketched some.

The first cave that I visited in the Xian area was the home of the family of Ma Xinfa. Ma is a common surname among Muslims in this area. It means horse, and they were probably descendents of the roving bands of horsemen that had swept down from the north centuries ago.

The cave on the right had recently been excavated for a newly married member of the family and was still decorated with coloured red paper characters on the inside walls. (previous page)

The matriarch of the family was a friendly soul and quite happy to tell me all about living in caves. She said that they were very convenient, cool in the summer and warmer than above ground homes in the winter.

They cost almost nothing to construct, the only major expense being the door and window, which usually amounted to a total of A$40-50. In her case even this had been saved as her husband was a carpenter.

Most cave homes have a high wall built around them to form a courtyard. This gives security, privacy and protection from the wind but eliminates any view.

There were two tiny chairs against the wall of the type commonly used by the Chinese when sitting outside. The seats of these are usually no more than 150 - 200mm from the ground, and look rather like doll's furniture.

To the right of the new bride's home was another cave, its entrance covered with a removable woven screen. Inside lived the family mule, let out only when needed to work.

The outside walls of the cliff had been carefully smoothed and given a rendering of mud plaster to well above head height. This in an area of low rainfall, and so the plaster needed little maintainance.

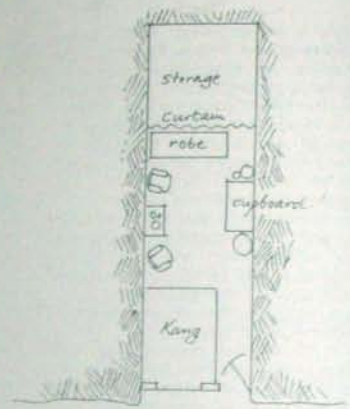
The caves are all built in loess country. Loess has been created by dust blowing in from the Gobi desert for over two million years until it has reached a maximum thickness of 180-200 metres.*

The caves that I visited were all furnished quite simply and all followed the same general plan.

Directly inside and below the window is the kang (pronounced kung). This is a bed made in the form of a platform with a hollow interior. It is made from mud bricks.

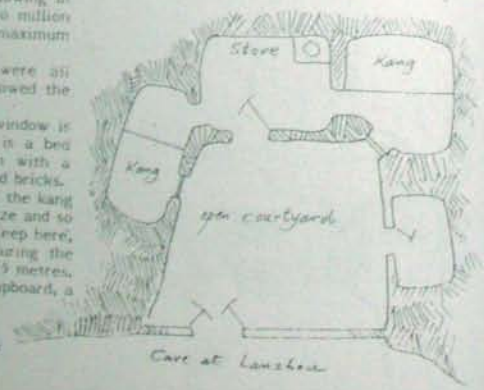
A small fire is lit at one end of the kang and the heat travels through a maze and so warms the top. The whole family sleep here, and it is also used as a seat during the winter. It usually measures 2.5 x 2.5 metres.

A little further in there is a cupboard, a wardrobe, a small table large enough to take a thermos flask and cups, and a couple of chairs. A curtain usually blocks off the



very end of the cave, and the area behind is used for general storage.

The dimensions of the caves varied. The cave of Ma Xinfa was 8.5 metres deep, 2.5 metres wide and 2.5 metres high, while another in the same area was 10 metres deep, 2.5 metres wide and 4 metres high. The higher ceiling allowed in a lot more light, but of course took a lot longer to dig out.



Cave at Lanzhou

All the caves that I saw in the Xian area were driven straight into the hills and followed the same general plan, but near Lanzhou I came across some old deserted caves that followed a different pattern.

Wherever there was a fold in the hill the builders had made use of it to create an L or U shaped plan. This allowed for more light and better ventilation. (previous page)

In this same area I also came across a row of six caves which had collapsed, probably as the result of an earth tremor, bringing scores of tons of earth down to fill the interiors.

Only two tools are needed to excavate a cave, a shovel to remove loose soil and a two or three pronged 'rake' for want of a better word.

The soil that is removed is all used. Some of it is turned into mud bricks to build the wall at the front of the cave and the rest for the wall that surrounds the courtyard. The kang also requires some mud bricks.

I sketched this digging rake in the An Family Temple Village near the Qian Tomb. When I asked how long it took to dig out a cave no one seemed sure, it seems that digging takes place over a period whenever there is a spare hour or so, but my host thought that four strong young men could dig a cave in four days. The actual final shaping of the walls and plastering etc would take much longer of course.

The complete construction of a cave home would probably take about a month.

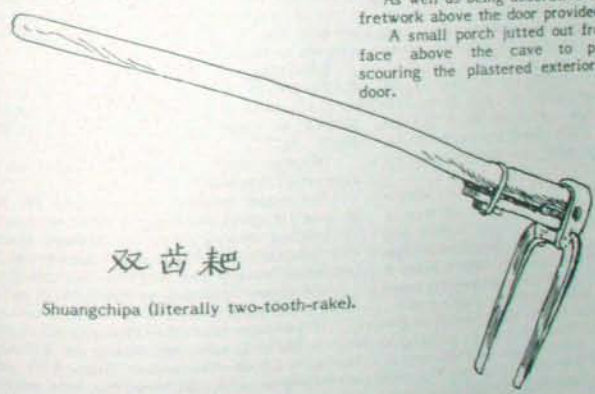
People who live in caves like to have glass windows to let in the maximum amount of light, but this has not always been possible.

At Dazhai, in Shanxi Province, North China, I sketched some cave homes that used wooden screens above the doorway to let in light and air.

This one was being used to store straw, but it had once been a home. The window to the left of the door was usually covered with paper for privacy and to cut out draughts.

As well as being decorative the elaborate fretwork above the door provided security.

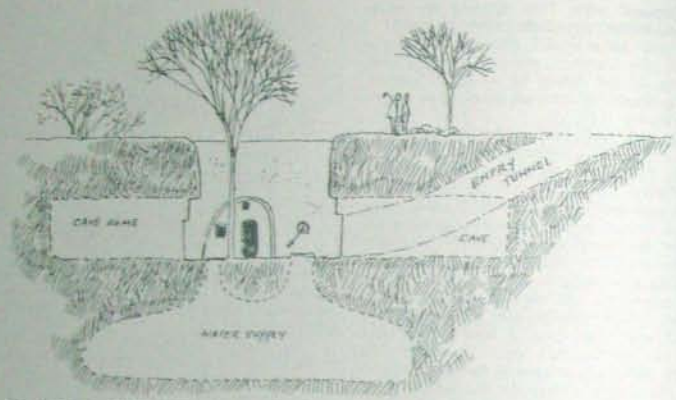
A small porch jutted out from the cliff face above the cave to prevent rain scouring the plastered exterior around the door.



双齿耙

Shuangchipa (literally two-tooth-rake).

Pit Dwellings



The most surprising type of home that I found in China was the pit dwelling. While in the city of Xian a local guide gave a rough description of such a construction and said that he could take me to see some.

The next day we drove 80 km northwest of the city. Here I was taken, unwillingly, to see the underground tomb of some long gone Emperor, and then to a dining room close by.

After a large lunch , on the part of the guide, we got into the car and drove off. When I asked how far away were the pit dwellings the guide said no such things existed, and we were now heading back to the city.

Rather annoyed at this, and faced with a large car hire I decided to at least have a look at some ordinary village homes and told the driver to stop at the first village we came to.The village was called Xibu, a small cluster of buildings looking the same as all the other villages on the dusty plain.

Walking down the lane that served as the main street I came upon a man building a new home and stopped for a look and a chat. I had with me my interpreter Wu, and the local guide stamping crossly some way behind.

The head of the household was an affable man with a bad squint. He greeted us like long lost brothers and handed round a heaped enamel plate of local cigarettes. His name was Liu Le-yi.

We discussed his new building, which was a normal type of mud brick home, and it seemed that there was not a great deal of interest to record.

I decided that I might as well take a photograph of the building, and walked down the back yard to get a better view. Here I noticed a tunnel going underground at an angle.

"What is this?" I asked, "The tomb of a very small Emperor?"

The owner laughed and beckoned me to go down. I could not imagine what he would be keeping underground, but walked down into the darkness. The tunnel curved and a few steps brought me out into the sunlight. I found myself standing at the bottom of a large rectangular pit.

There were cave openings in each wall, and a whole family was sitting in the sun having a meal! The owner laughed at my astonishment and said that this was where he and his family lived, plus quite a few assorted relatives.

This seemed to be a remarkably clever idea. Snug in their pit they were hidden from the bitter winter winds that constantly sweep across the countryside and could sit out in the courtyard and enjoy the winter sun. During the heat of summer they could always find shade on one side of the courtyard. I measured the pit and found it to be 10 metres long, 6 metres wide and 5 metres deep. Five caves had been dug into the sides of the pit, and each cave was large enough to house one family.

My new friend said that his great-grandfather had dug the pit one hundred years ago, and family legend had it that ten men took twenty days to dig the main pit.

I did a sketch of the pit from ground

level, looking down into it. Firewood and lumber were propped against the sides and a tall tree gave shade in the summer.

A white rabbit ran free around the courtyard, there was no need to have it in a cage down here. A pet today and a meal next month.

I asked if they ever had trouble with flooding during heavy rain and was told no. There is a windlass above an open well on the right side of the end wall, and also an opening to the well system on the left side of the courtyard, its circular lid held down with a couple of bricks. The rain drained away down into the well, leaving the pit dry.

He said that the well system was very large. When his great-grandfather had begun digging the well he had come upon some ancient tunnels, probably part of an old tomb, and had incorporated these into the complex.

In those days the villagers were in constant fear of a pair of Muslim warlords, Ma Bu-fang and Ma Huong-kui, who made regular raids on the area.

When they saw the attackers riding across the plains the whole family would run home and take refuge in the well, and there was even enough room there for their farm animals.

Not far from Xibu village you leave the plains and get into the hills, and here there are many cave dwellings. The pit provided a similar type of home for the people of the plains.

THE WORLD'S LARGEST SCULPTURE

While I was in this area studying pit and cave dwellings I also paid a visit to the Qian Tomb, the burial place of the Empress Wu Zetian of the Tang Dynasty, the only woman to have ruled China in her own right." The 1,300 year old burial mound has not yet been excavated. Although the guide books make no mention of the fact, a local historian who climbed the burial mound with me claimed that this was the world's largest sculpture.

It was a stiff climb to the top of the mound, and as we paused for breath we looked out at a scene as shown in my sketch.

A long avenue ran from the distance, over a small domed hill and up to the burial mound. My companion claimed that the whole area had been shaped to represent a woman.

The two distant hills topped with tapering towers were undoubtably the breasts. Agricultural terrracing and excavation had marred one , but the right hand one still retained a perfect shape.

Beyond them and just out of sight over the hill had been the original entrance, the head and throat. He said that the small hill closer to us once had a gateway on it , and this represented the navel.

The tomb itself was somewhere deep in the ground below where this sketch was taken.

I did not have a chance to take any measurements, but the complex must have spread over a kilometre.

Foundations and Piers

In simple farm buildings the earth walls are built directly on the rock foundation. In better buildings a foot wall is laid on top of the rocks, and the earth wall goes on top of this. The foot wall is of fired bricks, and can be as little as three bricks deep or extend up to the bottom of the windows. It protects the wall in the area where it is most liable to damage.

Foundations form the base on which the building sits. Weak, shallow foundations can cause walls to slump and crack.

Even so many simple farm buildings in China, such as pigsties and stables, are constructed directly on the ground without any foundations.

This is only done when the ground is well drained and very stable. In additon the walls are always relatively thick, so there is no chance of them tumbling if the building does slump a little.

Care is taken to see that the ground slopes away from the walls on all sides so that water will not run against the base of them during storms.

Walls cannot be constructed directly on the ground where the water table is close to the surface or where local flooding may occur.

Homes are always built on some form of foundation.

The foundations for a mud brick wall should be the same as would be used for a cement brick wall. In Australia these are specified in local building regulations. They are usually of reinforced cement.

In China rock rubble is frequently used, the gaps between the rocks being filled with mud or lime mortar.

The rock used for foundations is either used as it is found or roughly shaped by hand. Near Kunming I spoke to a farmer, Lai Yuxiang, who was preparing rock for the foundations of a new room.

Using only hammer and chisel he was shaping rough boulders into usuable blocks. He said that it took about half an hour to shape a block 600 x 300 x 300 mm.

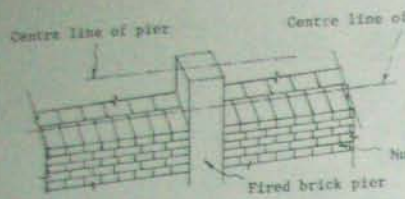
The sketch shows the foundations for a building at Shilin, Yunnan Province. The foundations are of local limestone and lime mortar. They extend 400 mm into the ground and 400 mm above.

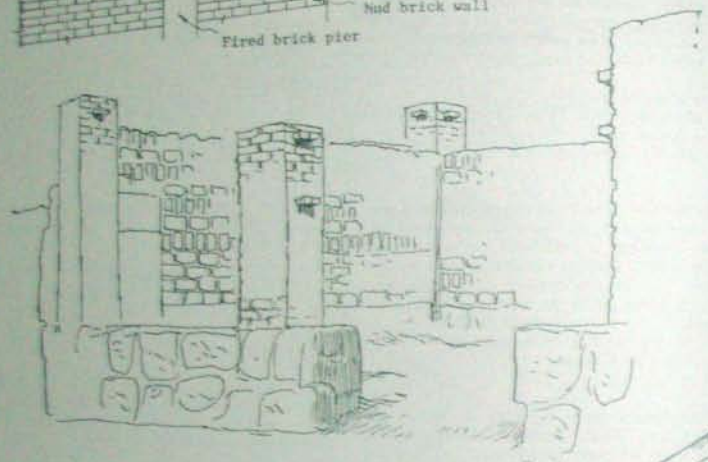
This view is from inside the building, and the floor will eventually be built level with the top of the rock foundation.

A foot wall of fired bricks is being built on top of the rock. Note how the first three courses have been laid along the wall in pairs and the final course goes across to tie them together.

Note also the base of a pier to the right of the worker. Fired bricks will be used to take this pier to ceiling height, and the weight of the roof will be taken by a number of these piers.

The reason that this pier juts into the room is that the walls are relatively thin. In most buildings the piers are flush with the walls as shown in the next drawing.





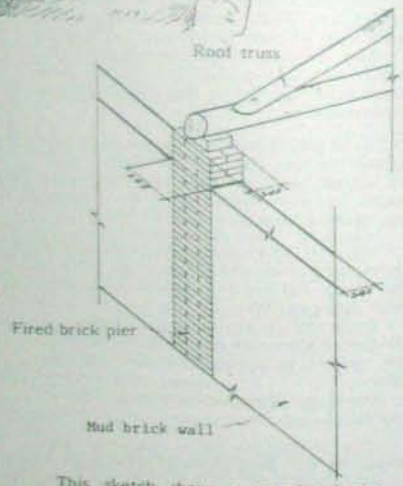
Near Kunming I sketched a building a little more advanced. This was in a village called Hai-yun-ya (Sea Cloud Margin).

Two of the piers are already to ceiling height and part of the mud brick wall has been built. The rock foundations are 500 mm thick and stand 800 mm above the ground.

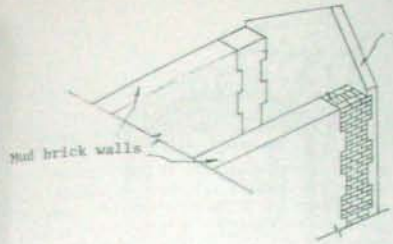
The piers measure 500x300 mm and stand 3-3.5 metres apart. Pairs of bricks stand out from the piers, and these provide a key for the mud bricks which will be used to fill the spaces between the piers.

The system of laying the bricks seemed to be fairly arbitrary, the first four courses were on their sides as can be seen , then they alternated.

A crowd of small children stood around me as I did this sketch, and their persistent sniffles were a reminder that winter had only just finished.

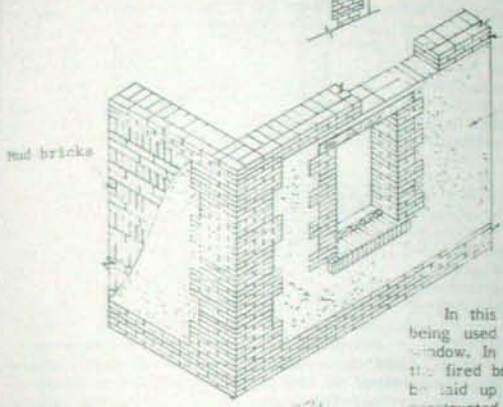


This sketch shows a completed pier supporting a roof truss.



Usually the piers are built as shown in previous sketches, with smooth sides, but sometimes they are built with stepped sides in order to get a better bond with the mud bricks.

This drawing shows how such a pier locks into a gable wall.



In this drawing Lin shows fired bricks being used on the corner and around the window. In this type of construction both the fired brick and the mud brick have to be laid up together, the whole wall being constructed as a single unit.

←

A recently built home in Five Trees Village, Yunnan Province, showing the use of brick piers. Fired bricks have also been used around the windows. The earth walls are 600 mm thick.

The foundations are of rock, and these in turn sit on an outcrop of limestone.

ADVANTAGES OF PIERS

1. Piers used at corners and doorways protect the building in the areas where mud bricks often get chipped.
2. In flood prone areas piers will still support the roof even if the earth walls have become badly eroded.
3. Fired brick sections do not require any maintainance.
4. When piers are used the mud brick sections of wall are no longer load bearing and so can be made thinner. This means that less mud bricks are required.

DISADVANTAGES OF PIERS

1. Fired brick piers do not add to the strength of the building. A thick walled solid earth building would actually be more stable than one with brick piers and thin earth walls.
2. It takes longer to construct a wall with piers than with plain mud bricks.
3. Athough the addition of fired brick piers, foot walls and door edging is a great convenience to the Chinese home builder it must also be admitted that to Western eyes the resulting buildings are not so aesthetically pleasing as the traditional home built entirely with earth walls.

PLASTERING OF FIRED BRICKS

In China when fired bricks are used in a building they are left in their natural state. The practical reason for this is that they do not require any protection from the weather.

However fired bricks can be plastered if desired, and this would probably be more pleasing to Westerners using the pier building technique, especially if the complete walls were to be finally whitewashed.

The mud plaster that is used on the earth walls is not suitable for fired bricks. North Australian Cement Ltd has suggested a plaster made from 1 part cement, one tenth of lime and 3 parts of sand, all by volume.

FIRED BRICK AS DOOR EDGING

Fired bricks do look quite good when used as a door edging. They are also practical as mud bricks frequently get chipped around doorways where there is heavy traffic.

Fired bricks can also be used to form arched doorways as in the sketch. Mud bricks can also be formed into archways, but probably require a little more skill in laying.

This doorway opened into a courtyard in Xian. In the centre can be seen the well from which the household drew its water. Fired bricks have been used all around the well area to avoid erosion. The rest of the walls are of plastered mud brick.

This building was over fifty years old.

MORTAR FOR FIRED BRICKS

1. LIME MORTAR

All the old buildings in Australia were constructed with lime mortar, and this method is still the most popular in China because the materials are both cheap and readily obtainable.

The mortar is made by mixing slaked lime with fine sand in the proportions, by weight, 1 part of lime to 2.5 parts of sand.

Another common mix is by volume, 1 of lime to 3 of sand.

Water is then added to make a workable mix and the batch is then left to mature. It may be left for anything from a few hours to a couple of days.

Unlike cement mortar lime mortar does not set in a matter of hours and so a batch can be mixed and left for some days as long as it is kept covered against the weather.

2. CEMENT MORTAR

Cement mortar is not used a great deal in China. However in recent years many communes have set up cement factories and as a result its use is increasing.

Lin gives the proportions for cement mortar as 1 part cement, 1.2 parts lime and 3 parts of fine sand, mixed with water to a workable consistency.

North Australia Cement Ltd give a standard mix as 1 part cement, 1 part lime and 6 parts sand, all measured by volume.

Unlike lime mortar cement mortar must be used within the hour.

Fired Bricks

MAKING FIRED BRICKS

Bricks made of clay and fired in a kiln are known in Australia as common bricks. However the common brick of China is the mud brick, and so in this book we are using the term fired brick for those bricks which have been fired in a kiln.

Nearly every district and large village has its own kiln, and the moulds for making the bricks vary from place to place. Here are my field notes describing a typical work team.

Mengla County, Yunnan Province, March 1 1983.

My interpreter and I were not far from the border with Burma, in the land of the Dai people.

Strolling along a country road and enjoying fried dumplings bought from a wayside stall we came upon some brickmakers at work. They had come from a northern province to work here on a contract basis as the Dai people do not practise the art of brickmaking. Although this work took them a long way from their homes they said it was worth while as they could make good money. The leading hand quoted a figure and the local bystanders all laughed and said that all potters were liars, and that their incomes were even greater than they claimed them to be. The leading hand changed the subject.

His figures for the record were that eight people were involved in the work and once a month they prepared and fired a kiln containing 40,000 bricks. These bricks sold for 7 fen each (4.2 cents Australian).

This adds up to a total of 2,800 Yuan (A$1680). The percentage that the Government got of this amount was not explained, but if the whole lot was divided among the eight they would each get A$210 which is well above the average wage in China. (per month)

The work took place right at the clay deposit. One worker was digging clay from the side of the hill and throwing it into a pit. Water was added and then he and his buffalo walked round and round until it became the right consistency. It was then lifted out and put into a large heap. The clay was patted down so that the heap retained a regular shape.

All the work had been planned so that from the clay in the hill to the newly made brick was only a few steps.

The young man who was cutting the bricks was at first very reluctant to be photographed or sketched. From the rude comments that his friends made to him we learned that it was not because he was shy but because he had such a terrible haircut !

One of his workmates had performed the operation and the result was a perfect pudding basin job, with a shock of black hair on top and nothing below.

Before he would begin work he borrowed a cap from a friend , who revealed an even worse barbering job, having been rendered almost bald!

With the cap firmly on his head he began work. Turning to the clay heap he picked up a cutting tool made of timber and wire and cut off a lump of clay.

He had previously dusted the ground at his feet with fine sand and he now thumped the clay into a cuboid shape, but with slightly tapered sides so it would drop easily into the mould.

The mould was made of timber with a removable end as shown in the upper sketch. When in use it sat as in the lower sketch with the operator to the right.

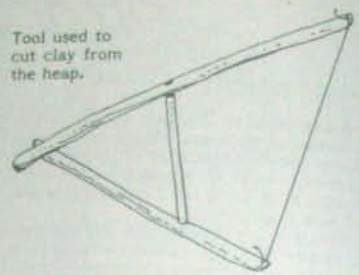
The inside width was 130 mm, length 260 mm and depth 160 mm. It produced three bricks at a time, each 260 x 130 x 53 mm. The young man thought that he made about 2,000 bricks a day.

The mould was placed on a small ledge just large enough for it. Next to it was a container, roughly made from bricks, which held a mixture of dry sand and ash. This was dusted on the mould each time before it was used.

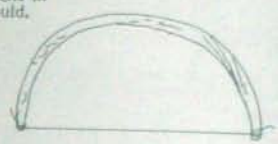
The worker slapped the clay into the mould with some force and then punched the top so that the clay filled the mould without any air pockets being left.

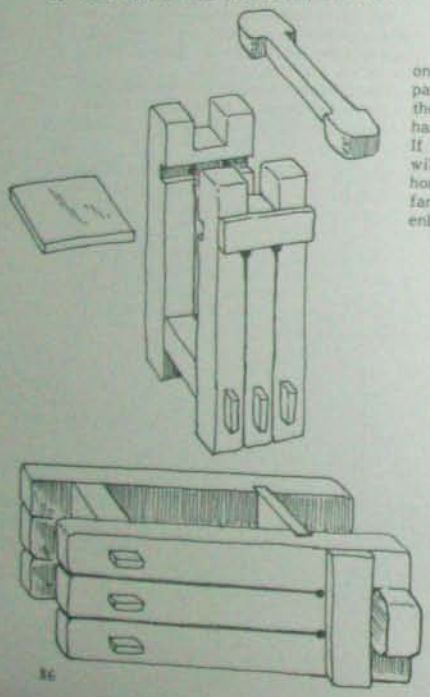
He then took a cutting tool, simply a bow of wood with a wire tied across, and with one cut sliced off the surplus clay. Without pausing he also ran the cutting wire into the two slits in the mould. In my sketch he has just completed cutting the upper slit. If you look at the drawing of the mould you will see that the cutting wire enters the horizontal slit from the left and goes in as far as the spot where the slit has been enlarged into a hole.

Tool used to cut clay from the heap.



Tool used to cut bricks in the mould.





He now removes the waste clay from the top of the mould, tilts the mould up and places under it a small board which has also been dusted with sand.

This board is about the same length and width as the mould.

The end of the mould is now removed, the sides spread a little to free them from the clay, and the mould then stood up on end out of the way.

The three newly made bricks are now standing on the small board. They are carried to the drying area on this board and are then tipped off so that they stand on end.

No attempt is made to separate them at this stage, but when they are dry enough to handle they are pulled apart and placed into large stacks to dry properly.

When the bricks are dry they are put into a kiln and fired.

In this case the workers had built a tunnel kiln up the side of a small hill as shown in the top sketch.

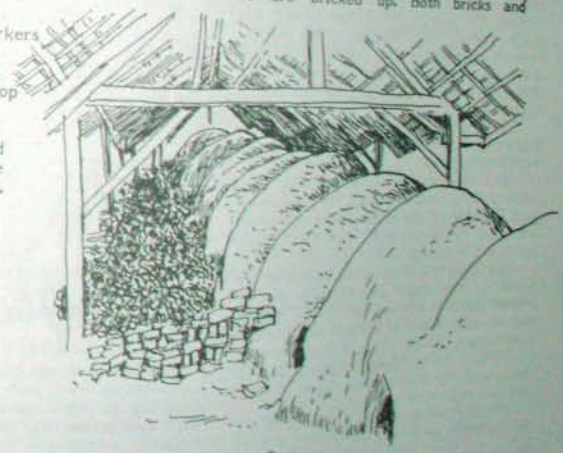
This kiln had been quickly built and would be abandoned when the contract was complete.

Tunnel kilns are not uncommon in this area, and the next sketch shows a more permanent one. This one consists of twelve domes built up the steep hillside. Each dome is connected to the next by a number of slots.

Great stacks of firewood are stacked on either side of the domes. In my sketch the bottom two have yet to be filled up and sealed.

Inside the domes measure 1.5 metres high and are roughly 2 metres in diameter.

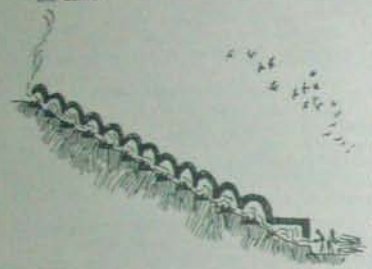
Each dome has a doorway and the items to be fired are stacked inside and the doors are bricked up. Both bricks and



pottery are fired in these kilns. The pottery ranges from the huge pots used to hold water and store rice down to small cups, in fact all the various pieces that the village people require.

The large pots are put at the top of the hill so that they will get the longest pre-heat and the smallest items are at the bottom.

Firing begins in a fireplace at the bottom of the hill. This is connected by a tunnel to the domes.



Two tons of wood are burnt in this fireplace before the first dome comes up to the right temperature. During this firing all the domes are competely sealed off except for an opening at the very top of the hill, and this causes the heat to travel right up through the tunnel. Temperatures are judged purely by colour. The worker removes a brick in the side of the first dome and looks in. When he judges the temperature to be right the bottom fire is stopped.

Now each dome is fired individually beginning with the one second from the bottom and working up.

Two men do the firing, working from opposite sides of the domes. They remove a loose brick from the lower side of the dome and push in lengths of firewood, equal amounts from either side.

The heat inside is so intense that the wood catches alight immediately, and the flames roar up through the tunnel. In this way as each dome is brought to the right temperature the one above it is pre-heated.

Half a ton of timber is used for each dome, and the whole firing takes 24 hours and uses eight tons of wood.

No fireclay was used in the building of the kiln, only local clay.

A kiln in Shanxi Province, north China. Even small villages have their own kilns. This was used to fire agricultural drain pipes, large storage jars and bricks. Roof tiles were also fired, in fact every item that the village people might need could be produced here.

Brick kilns are often set into the side of a hill and fired from a chamber dug into the side. I recall visiting one on a day of snow, and it was strange to walk from the zero temperature into the firing tunnel where a couple of men were stripped to almost nothing and glistening with sweat as they fed in more timber.

These kilns hold an enormous number of bricks, and the village may only need a few firings a year to supply all their needs.

This sketch shows girls unloading the still warm bricks from such a kiln and throwing them up to their companions on the top. This was at Dazhai, Shanxi Province, May 1977.

Plaster

PLASTERING TOOLS

For simple work only a hawk and a float or trowel are needed, but if a good, even surface is desired then the other tools are also used.

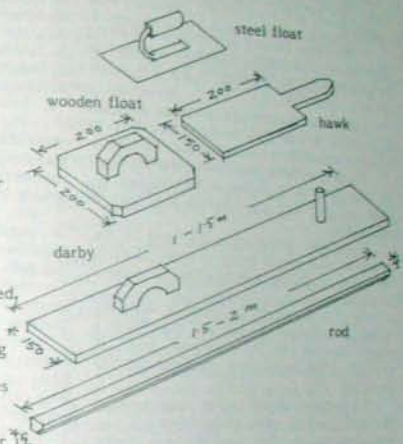
With the exception of the steel float all the other tools can be readily made from scraps of timber.

The hawk, shaped like a table tennis bat, is held in the left hand, and holds the mud. The worker has a float in his right hand, scoops up the mud plaster with it and applies it to the wall. The darby and rod are used to scrape and smooth the surface, and the steel float is used to get a final smooth finish.

A mud brick wall need not be plastered, but there are certain advantages. The plaster fills up irregularities and makes a smooth wall. This means that if driving rain strikes the wall it will be shed immediately as there will be no surfaces on which it can lodge.

If erosion does occur through lack of maintainance it will affect the plaster first, and this can be easily repaired.

A person building in earth has three choices as to the final finish.



1. The walls can be left as they are, with bricks exposed. In China farm buildings are commonly left this way while the main house may or may not be plastered, the custom varies from place to place.

The texture of mud brick walls can be modified by vigorously rubbing the surface with damp sacking. This smooths off irregularities and rounds off the corners of the bricks.

2. A single coat of mud plaster can be applied. This generally results in a slightly uneven surface which often shows numerous fine cracks.

Many Western earth builders find this finish attractive.

3. Good quality homes in China are given two coats of plaster. The first coat fills the surface and the second provides a fine, smooth finish.

The finished wall may be left to show its natural colour or it may be whitewashed. Interior rooms are usually whitewashed to make them lighter.

SINGLE COAT OF PLASTER

This is made in the same way as the scratch coat described below. It is a mixture of roughly chopped straw and mud with all lumps and stones removed.

The wise builder tries out a small patch first before doing the whole wall.

If the mud has a high clay content it might be necessary to add some sand to the mixture as well as the straw to prevent cracking. There are no fixed proportions, and again a sample patch is tried.

DOUBLE COAT OF PLASTER

SCRATCH COAT

The first layer is known as the scratch coat because when completed it is scratched to provide a key for the second coat.

The mixture is simply mud with a good amount of straw in it. This can be in the proportion of two of mud to one of straw, or three to one (by volume). The mixture will develop a better working consistency if left to cure for a few hours before being applied.

If the wall surface is very dry and dusty it may be necessary to lightly moisten it before putting on the plaster, but this is not usually necessary.

Lime can also be added to the mixture. Lime and water are mixed in a pit to a creamy consistency and then straw is added.

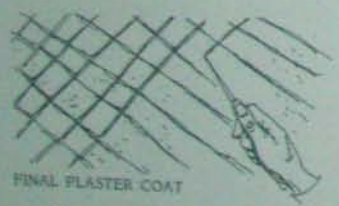
When the straw has been stirred around in the lime it is removed and heaped up, then left for five days. During this time it will soften.

It is then mixed with dry earth in the proportion of one of straw to three of earth by volume. Water is then added to make a workable mix.

Plaster is applied by hand or with the tools, and though the surface may have a rough texture it is made as level as possible. This is to allow the final coat to be a thin one.

The purpose of any plaster is to improve the quality of the wall, not to cover up poor workmanship, so the scratch coat should also be relatively thin if the wall has been well made.

The first coat is left to dry, but before it is quite dry the whole surface is scratched with a sharp tool to create a network of lines that will act as a key for the final coat. These lines can be 75-150 mm apart.



FINAL PLASTER COAT

To lessen the chance of cracking the final plaster coat is applied as thinly as possible. It should also be protected from drying out too quickly. It is best to work in the late afternoon, or when there is shade. If this cannot be done then some sort of temporary shade may be arranged.

There are quite a number of mixtures which can be used for this final coat, here are the most popular.

1. Lime and hemp fibre.
2. Lime, hemp fibre and sand.
3. Lime, straw and clay.
4. Lime and sand.
5. Lime and paper pulp.
6. Sawdust, clay and sand.
7. Mud and chopped straw.
8. Ground bricks and pig's blood.

The first two mixtures, incorporating hemp fibre, make a very good plaster. As mentioned earlier large quantities of cannabis sativa are grown in China for the production of hempen rope.

This material is not so readily available in Australia but it might be worth experimenting with some of the fibres from the bark of our native trees.

The hemp fibre is much stronger than straw, and so binds the plaster together so much better.

This type of plaster will last for centuries if protected from the weather. Even when used on exterior walls it has a long life if the eaves are wide enough to protect it from the driving rain.

Lin Wei-hao provided the information on the various proportions used to make these plasters. My contribution is the note on the use of paper 'tendon', and the plastering of a cave dwelling.

LIME AND HEMP FIBRE

This is considered to be the best plaster mix. 1 cubic metre lime putty (or 716 kg quicklime), 12 kg chopped hemp fibre. Add enough water to make a workable mix.

LIME, HEMP AND SAND

0.46 cubic metres lime putty (or 326 kg quicklime), 16.6 kg chopped hemp, 0.92 cubic metres clean sand. Add water to make a workable mix.

LIME, STRAW AND CLAY

0.07 cubic metres lime putty (or 46 kg quicklime), 29 kg straw, 1 cubic metre clay. Add water to make a mix.

Many of the cave dwellings to the north-west of Xian use this type of plaster. While sketching in this area I was invited into the cave of Zhang Huong-jin for a cup of tea and we discussed the neat plaster finish that he had achieved.

His scratch coat was of mud and straw as described earlier, and this was applied to the thickness of 25mm so as to cover all the marks made by the digging rakes when excavating the cave.

The second coat is best applied before the first one is completely dry so as to get good adhesion. When applying the scratch coat the walls did not need moistening, but the ceiling did.

For the top coat he used a mix of 1 cubic metre of well sieved soil with a high clay content, 50 kg of straw and about ten basins of lime. This gave a good white plaster.

If a dun coloured finish is acceptable then three basins of lime will suffice. The basin used was the common enamel one used to wash the dishes, it was 350-400 mm in diameter.

He also added that these proportions were only a rough guide, as in fact he did not measure anything as he prepared the plaster but did it all by eye, adding more lime until it looked white enough.

He then applied a little to the wall and waited till it dried before commencing the final application.

LIME AND SAND

1 part of powdered slaked lime, 3 parts of fine sand, by volume. Add water to make a mix.

LIME AND PAPER PULP

Lin wei-hao's recipe for this is one part of paper to ten parts of lime by weight. The paper is torn into small pieces and put into a pit with the lime and water and left to mature for fifteen days.

Visiting the home of Song Zong-feng near Lanzhou, March 8 1983, I was given a different recipe.

As usual the first scratch coat was of mud and straw. He said that once they used to roughly chop the straw into 25-100mm lengths, but now they simply collect the waste fibre produced when the wheat has been threshed by machine. This straw waste requires no further preparation.

As usual no one was quite sure how much straw would be needed in a batch, but he said that his room, which measured 3.2 x 5 metres required four large sacks of chopped straw.

The second coat was applied before the first had fully dried. Any dry patches were lightly moistened.

This coat incorporated the elusive 'paper tendon'. I had heard this term used in other parts of China but could never find anyone who could properly explain it to me.

The paper tendon turned out to be paper pulp, which he said was produced in one of three ways.

Waste paper was first torn up into small pieces and soaked in water for at least two days. They would then put it through some machine that was used to prepare food for the animals, which would crush it into pulp, or it could be put into a container and pounded with a stick.

But the most popular method was to rub it on the wooden washing board that could be found in every home. These boards vary in size, but the one my host had was 200 mm wide and 400 mm long with grooves chiselled across it by hand. The pulp could be produced quickly in this manner.

The plaster is made by mixing this pulp with slaked lime. As it is applied to the wall as thinly as possible, down to 2mm thick, it is important to sieve the lime and make sure that the pulp is free from lumps.

As to the proportions of the ingredients my host used a washing basin with a top diameter of 290mm and a height of 110 mm for measuring out the paper pulp, which had the consistency of thick porrige.

The lime was measured with a different

A large rambling old farmhouse near Changsha with plastered walls. Newly made mud bricks are stacked under the eaves to dry.

basin with a top diameter of 470 mm and a depth of 140 mm.

A basin of each was mixed to make the plaster. If my calculations are correct, and allowing for the taper of the basins, then the proportion was one of thick paper pulp to four of lime. Enough water was added to make a workable mix.

In some new homes this plaster was then painted with a PVC based paint, but for the most part it was left untouched.

SAWDUST, CLAY AND SAND

1 part sawdust, 1 part clay, 1 part sand, put through a sieve to remove lumps and water added.

If using ordinary soil instead of clay the amount of sand may need to be reduced. As before a trial mix should be made and allowed to dry before beginning work.

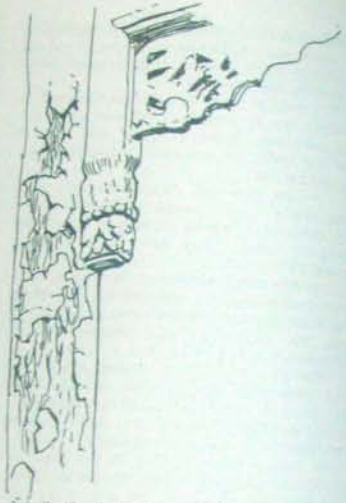
If the sample cracks then there is too much clay, and if the surface is powdery then there is too much sand.

I have used this mix and found it to be quite good. Lin Wei-hao notes that this is an example of using whatever materials are readily at hand.

MUD AND CHOPPED STRAW

The earth is sieved and then chopped straw added. The straw is often chopped to the consistency of chaff. The quantity used depends on the clay content of the soil, but could be up to one third by volume of straw. Apply a test patch before using.

Most of the larger buildings in the former Imperial Palace, Beijing, have the roof structure in part supported by huge wooden columns covered with plaster.



A detail of an old gateway to a private home in Beijing, known to be at least one hundred years old and possibly older.

The gateway was protected by a small roof, and the timbers had been covered with lime and hemp fibre plaster.

In the lower section, exposed to driving rain, the plaster had begun to break down, but close to the eaves it was still in good condition after at least a century.

GROUND BRICKS AND PIG'S BLOOD

The old temples of China have enormous roof structures supported by massive wooden columns. These columns are usually made from individual tree trunks.

They are always perfectly smooth and even, and most visitors assume that the timber was shaped down to a uniform finish.

In fact the opposite is the case. A close examination of old, weathered columns shows that the timber was only roughly shaped, and then layers of plaster were added to build up the desired shape.

The technique is very sound, a fact proved by the great age of many temples.

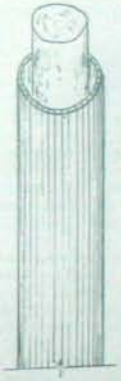
For everyday construction the columns would be plastered with the lime and hemp mixture described earlier, but for important buildings a special mixture of ground brick and pig's blood was used.

PREPARING THE COLUMN

The log is made smooth and cleaned of any dried sap, then washed with alcohol.

Cracks are cleaned out and any rotten wood removed. The gaps are then filled with bamboo pegs. Enough pegs are driven in to fill the gap and the area is then painted with tung oil (tung oil is used today as an ingredient in house paint). The tung oil fills up the spaces and makes the patching bond to the trunk.

If the trunk is too thin or irregular it can be encased in laths to bring it closer to the required diameter.



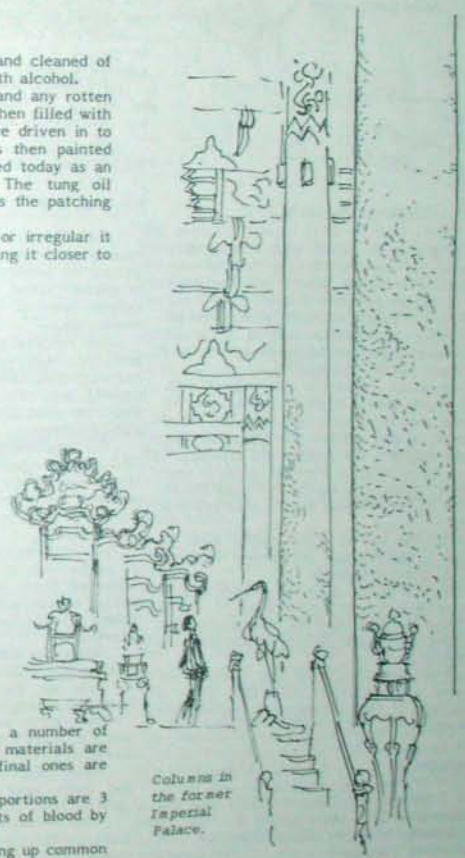
APPLYING THE PLASTER

The plaster is applied in a number of coats. In the first ones the materials are coarsely ground, while the final ones are very finely ground.

For the first coat the proportions are 3 parts of brick dust to 7 parts of blood by weight.

The dust is made by grinding up common fired bricks or roof tiles.

When the blood is obtained it has usually clotted. The lumps are first broken up with a straw whisk and then rubbed with the hands. A small amount of water is added and the liquid strained.



Columns in the former Imperial Palace.

A few drops of tung oil are added, and this helps disperse the froth than has formed. The blood is now added to the brick dust to make a workable plaster.

The plaster is applied with a steel putty knife or one made of ox horn. Special care is taken to work the plaster into the areas that have been patched.

When the plaster has dried it is burnished by rubbing the surface with a piece of brick, tile, stone or fragment of pottery. Sandpaper can also be used.

The whole column is now painted with pig's blood. Hemp fibre is combed out to remove any knots and laid onto the blood while it is still sticky. The fibres tie the surface together and prevent any cracking.

In some cases a layer of cloth is also wrapped around the column over the blood. In the former Imperial Palace pure silk was used.

When this has all dried another layer of plaster is applied, and yet another until the desired shape is realised.

The final plaster is in the proportion of 1 part of brick dust to 1 part blood.

When the final coat has been applied and burnished the whole surface is painted with boiled tung oil.

When this has dried the columns are painted and decorated, and then given a final coat of boiled tung oil to protect the surface.

WHITEWASH

In some parts of China exterior plastered walls are given a coat of whitewash, in other areas they are left untouched. Interiors are frequently whitewashed to make them lighter and reduce dust.

Whitewash is simply made by mixing 1 part of lime to 6 parts of water, plus a little salt, perhaps 5%. 2% of boiled tung oil is also sometimes added.

The water is placed in a container and the quicklime gradually added to it. This is not stirred but is left for 24 hours.

After this time it is strained and is ready for use. If it is too thick it can be thinned with more water.

In Australia the lime would not need to be left for 24 hours as we customarily buy our lime already slaked.

FIELD NOTES ON WHITEWASH

Kunming, Feb 22 1983.

My interpreter and I were out in the country when we came to a small village. Across the fields we could see thick clouds of smoke rising from a huge wok, so we walked down a narrow muddy pathway to investigate.

The wok really was huge, 1.1 metres in diameter, nearly big enough for a bath. In the country these great vessels are used for cooking pig swill, and builders also keep them for jobs such as mixing plaster and slaking lime.

The lime was in the form of quicklime. This was put into the wok in a dry state and then water slowly added. The lime is never put into the water as this would cause the water to boil over and could be very dangerous.

The water was poured onto the lime using a dipper on a long handle. When this happened there was a violent sizzling and boiling action, and the clouds of thick white smoke that had first attracted our attention.

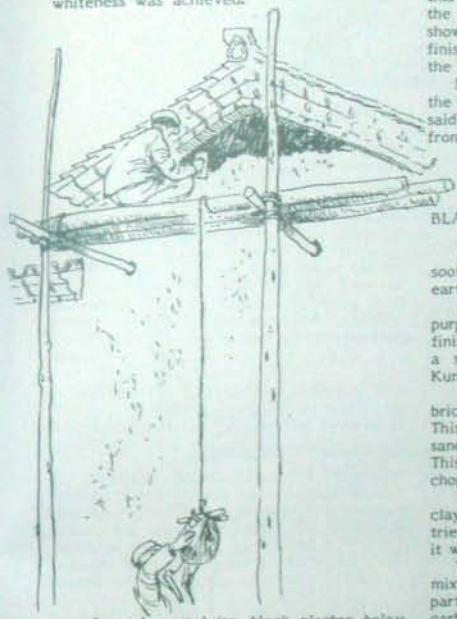
When the bubbling stopped the builder used another shallow dipper on a long handle to ladle out the white liquid and pour it through a strong wire sieve above a trough.

More water was then added to the lime and the process repeated until all the lime had been turned into useable whitewash.

Some lumps of lime would not dissolve and these were discarded as useless and used as rubble in foundations.

The whitewash was being used in this state, without any salt being added. The builder said that he sometimes added salt to whitewash for internal walls as it helped prevent it rubbing off.

Some builders in this area added natural yellow ochre to the whitewash to produce a cream tone, however for the most part the walls were simply given several coats of whitewash until an acceptable degree of whiteness was achieved.



A worker applying black plaster below the eaves. His scaffold supports have been fitted into holes cut into the earth wall. Three round poles form his working platform.

Another worker below hooks on a carry-bag full of plaster.

It is a traditional practise in this area to paint a band of black around the upper part of the walls. The sketch shows the smoking wok in front of a partly finished building. The left part has just had the black band painted on it.

My interpreter Wu quite logically called the paint for the upper part blackwash. He said that it was made from soot scraped from chimneys and mixed with water.

BLACK PLASTER

As mentioned above a simple mixture of soot and water will make a black paint for earth walls.

A black plaster is also used for the same purpose, and this gives a longer lasting finish. I saw this being applied to a house in a small village near the Golden Temple, Kunming, February 21 1983.

Before the plaster was applied the mud bricks were given an ordinary plaster coat. This was made from a mixture of clay and sandy soil with the addition of native grass. This grass was fine and did not need chopping.

There was no fixed proportions for the clay and sandy soil mix, a sample was first tried on the building, and if it did not crack it was considered suitable.

When this was dry the black plaster was mixed. The mixture was 1 part cement, 1 part lime, 2 parts sand, and sufficient carbon black added until the desired shade was reached.

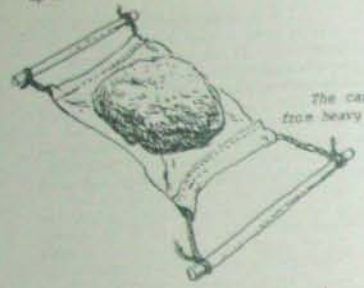
The cement and carbon black were bought from the village store.

The master plasterer said that in earlier days they made the black by collecting the ash and soot from burnt grass. No cement

was used and the plaster consisted only of lime, sand and soot. He said that such a simple plaster would last for one hundred years.

The workers held the plaster on a paddle shaped piece of wood, as illustrated earlier, and applied it with steel trowels. The plaster was carried to the base of the wall in canvas carriers with wooden handles. The men on top used a rope and hook to lift it up to where they were working.

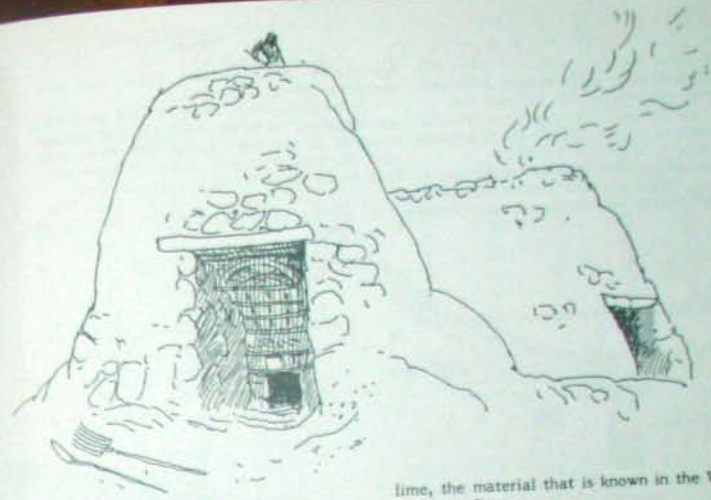
A wooden hook made from a natural bend in the timber. Growing branches are often bent and tied down so that they will grow into well shaped hooks.



The carry-bag full of mud. It is made from heavy cotton, rope and two sticks.

A derelict building on a commune near Changsha, Hunan Province. The elaborate, now broken, pottery ridge decorations show that this was a building of some importance in the old days.

The exposed end walls have been built from small fired bricks, while plastered mud bricks have been used for the rest of the building.



LIME IN ITS VARIOUS FORMS

In the course of writing this book Lin Wei-hao and I found some initial confusion when discussing lime in its various forms.

This was because the Chinese builder tends to get his lime in the form of quicklime, while in Western countries it is almost always in the form of powdered slaked lime. Lime is used in the following forms.

1. QUICKLIME , shengshihui (literally 'live lime'). Limestone is fired in a kiln as described later, and the resulting material is quicklime.

2. SLAKED LIME, shushihui (literally 'mature lime'). When water is poured over quicklime great heat is generated. When this action has been completed the result is known as slaked lime.

In the West this product is dried and bagged and sold simply as 'lime'.

3. LIME WATER. A Chinese term for whitewash, the making of which has been described.

4. LIME PUTTY. A term for slaked lime when used in a putty like consistency.

5. LIME WHITE. Dried and powdered slaked lime, the material that is known in the West simply as lime.

LIME BURNING

From my field notes, Kunming, Feb 20 1983.

On the way to the mountains I saw a lime kiln being worked and stopped to talk to the man on top.

He was producing two tons of lime a day on a contract basis, which meant that the more he made the more he earned. He lamented the fact that he did not have a large kiln as he could make up to five tons a day with the same labour force.

The kiln was contracted out to two families, but I met only one man and his two hired hands.

One of them was breaking limestone into pieces roughly 150 mm in diameter and smaller, while the other was carrying baskets of high quality coal which had been ground and mixed with charcoal.

The sketch shows the kiln with the head man working on top. To the right another kiln is being fired. The kiln is unloaded from the opening at the bottom. A rake and shovel lay on the ground at the left.

The kiln was 6 metres deep, with an inside diameter of 2 metres. It was lined with firebricks and open at the top, rather like a large squat chimney.

The kiln was loaded from the top. A

layer of coal was put in 200mm thick, and then a 400mm layer of limestone. Alternate layers were put in until the kiln was full.

The coal was set alight at the bottom of the kiln and as it slowly burnt the limestone was changed to quicklime.

If everything went well the firing was a continuous business, for days on end quicklime would be raked out from the bottom of the kiln and more coal and limestone added at the top.

It normally took three or four days for the limestone to travel down the kiln and be removed at the bottom, my informant said that the best lime was produced after four days in the kiln.

A TWO STORY FARM BUILDING

Providing that the ground floor walls are thick and foundations strong earth buildings can be taken to a second story without any problems.

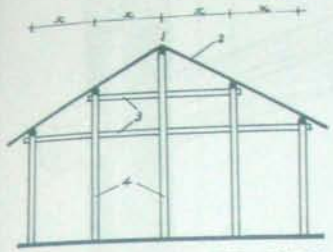
This sketch shows a large farm building in Hai Yun Village, near Kunming giving off a feeling of massive strength and enduring stability. The building is of mud brick . It had once had a coat of mud plaster and whitewash but most of this has long since washed off. Kunming has an abundant rainfall and yet the exposed mud bricks showed no sign of erosion damage.

The windows are closed with wooden shutters, and large pot plants sit along the ledge by the windows.

The storage building on the left is made from rammed earth and shows the characteristic holes made by the formwork and the cracking that is sometimes found with this method of building.

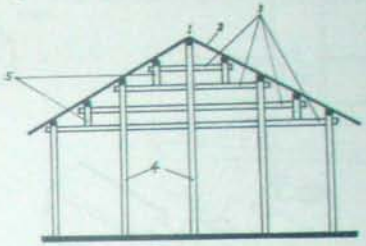
The eaves of the main building are shaped like this and covered with curved tiles.

TIMBER FRAME

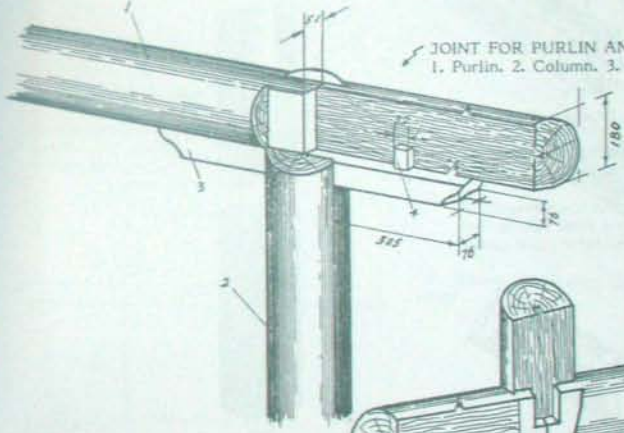


1. TRADITIONAL CHINESE THROUGH TIMBER FRAME .

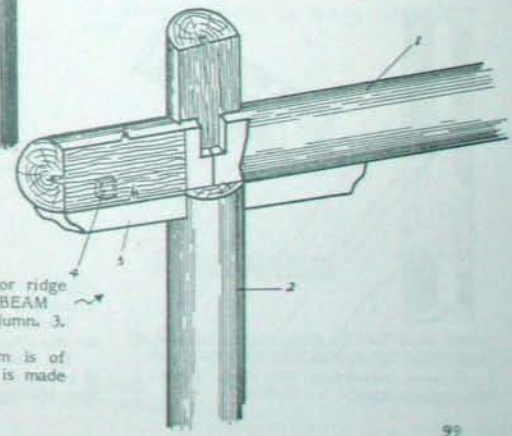
There are two fundamental forms of the frame as illustrated.



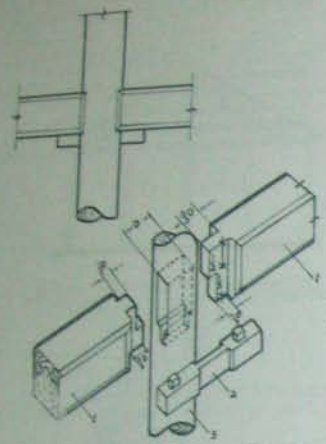
1. Purlin. 2. Rafter. 3. Through tie-beam. 4. Column. 5. Short column.



JOINT FOR PURLIN AND COLUMN
1. Purlin. 2. Column. 3. Bracket. 4. Dowel.



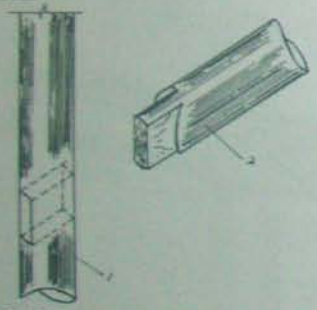
JOINT FOR MIDDLE COLUMN (or ridge purlin column) AND THROUGH TIE-BEAM
1. Through tie-beam. 2. Middle column. 3. Bracket. 4. Dowel.
NOTE. When the through tie-beam is of rectangular timber the tenon joint is made as shown in the following sketch.



1. Through tie-beam. 2. Bracket. 3. Middle column.

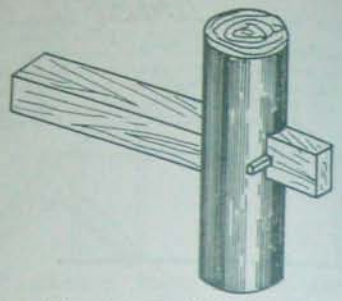
If the through tie-beam is of a single piece of timber then the bracket is not needed.

Great attention is paid to the strength of this joint as it plays plays a vital role in the stability of the building in earthquake prone areas.

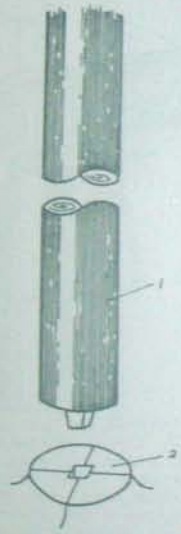


JOINT FOR EAVES PURLIN COLUMN AND THROUGH TIE-BEAM

1. Column supporting the eaves purlin. 2. Through tie-beam.



When the through tie-beam is of rectangular timber the joint is made as shown above.

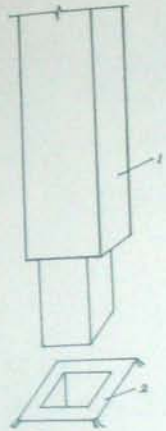


STONE COLUMN BASE

1. Column. 2. Base

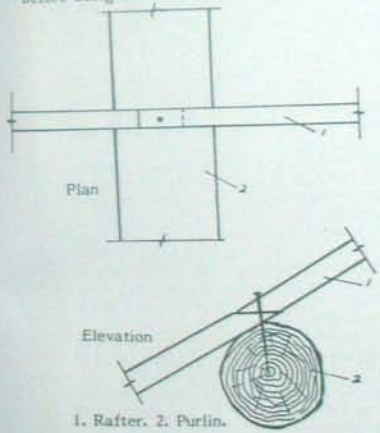
The length of the tenon is 3/10 - 1/5 of the diameter of the column.

The end of the tenon is tapered for ease of erection. The tenon prevents the column from moving.



1. Column. 2. Base.

When rectangular timbers are used the tenon may measure half the width of the timber. It should be treated against rot before being used.

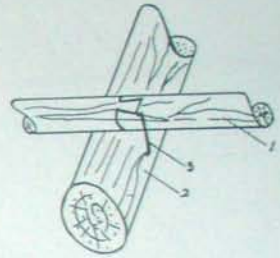


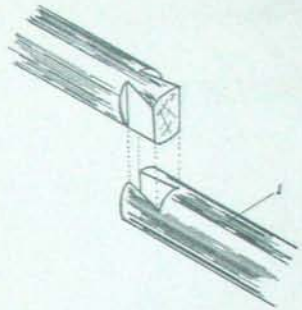
1. Rafter. 2. Purlin.

RAFTER JOINT

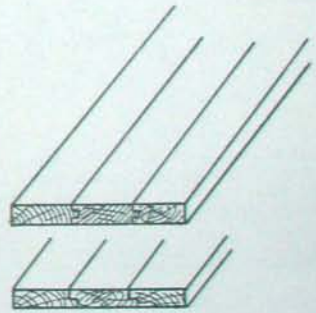
When the rafters are rectangular the joint is made as shown.

When the rafters are round this joint is used.



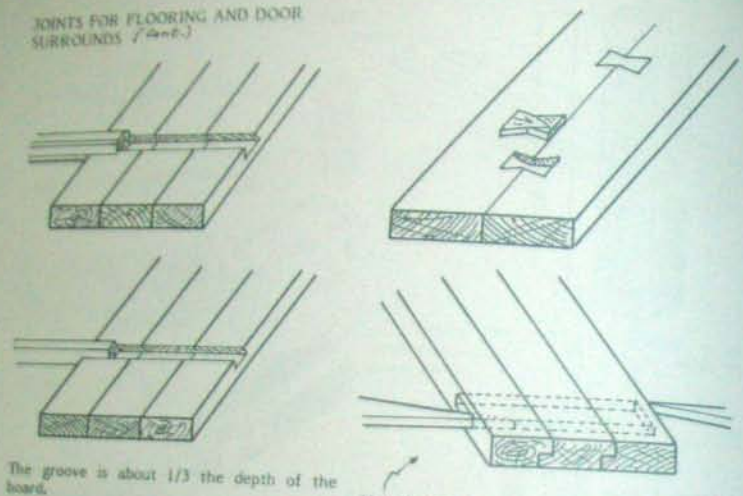


1. Rafter. 2. Purlin. 3. Cramp iron (iron dog)



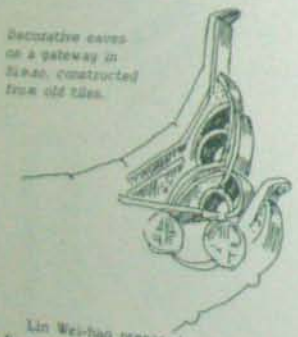
JOINTS FOR FLOORING AND DOOR SURROUNDS

JOINTS FOR FLOORING AND DOOR SURROUNDS (cont.)



The groove is about 1/3 the depth of the board.

Usually used for door surrounds.



Decorative eaves on a gateway in Simao, constructed from old tiles.

Lin Wei-hao prepared and illustrated the first part of this section. I am adding a few of my field notes which may provide some additional information on the building of frames.

FRAMEWORK FOR A BARN

Simao, March 2 1983.

The sketch on the next page was made in Pear Orchard Village, near Simao, at the home of Li Yu-cai.

He was building a barn and the sketch shows about one third of the frame. It had taken about 30 working days to get the frame to this stage.

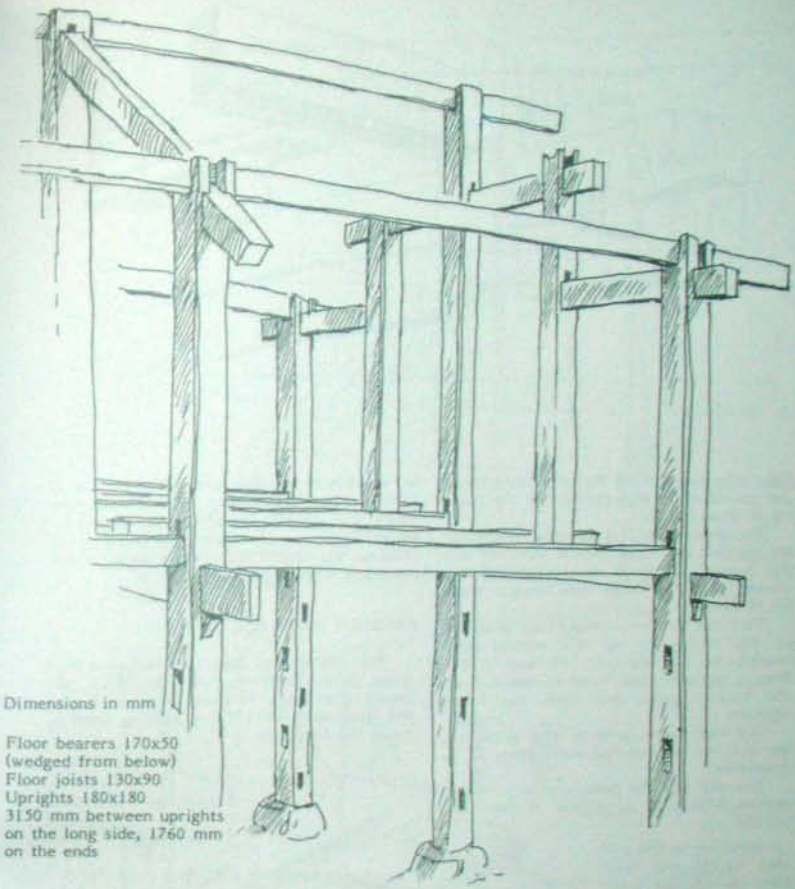
The holes cut into the lower part of the uprights will take timbers to form stalls for the animals, while the upper floor will be used for general storage and will have a wooden floor.

The roof will be of shingles, a common covering for farm buildings in this area as the people have access to a type of timber that splits easily.

In this type of construction each piece locks into its neighbour securely without the use of any bolts or nails. This type of frame is enormously strong, a very important factor in this area where earthquakes can occur.

As is the Chinese custom the whole building sits on a number of stones and is not attached to the ground in any way. Despite this the people say that they have never heard of a building moving on its foundations due to high winds.

The considerable weight of the tile roof helps keep the building secure, and the mud brick walls lock the frame firmly in place.



Dimensions in mm

Floor bearers 170x50
(wedged from below)
Floor joists 130x90
Uprights 180x180
3150 mm between uprights on the long side, 1760 mm on the ends

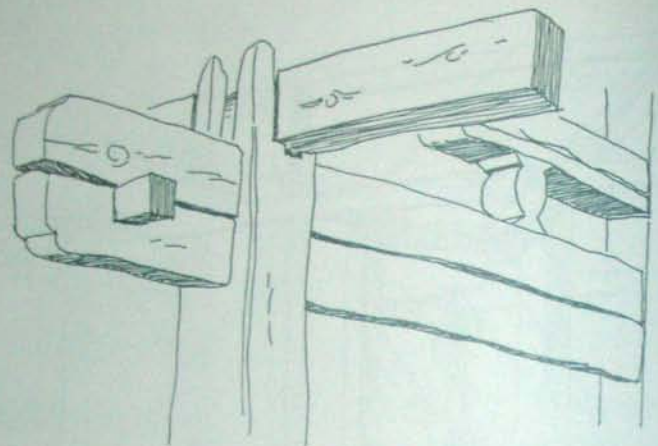
A HOME IN SIMAO

In another part of the Simao area I came upon the framework of a home being built on a small hill. There was no sign of anyone about, and I had commenced drawing the framework (next page) when a shy young girl came out of a nearby hut.

She was recently married and happy to talk about what was to be her new home. It was in an attractive setting, with the mountains behind and a view of the fields in front, the flooded rice paddies reflecting the late afternoon sun.

The home was to be in the local traditional style with the living part downstairs and storage on the upper floor.

There is still a lot of forest in this area so the supply of timber was no problem.



First they went to the Forestry Department and purchased enough timber for the house for 40 Yuan (A$24).

The timber was still growing, so she and her husband and some friends went off into the forest to cut it down. Nothing was wasted, even the twigs were brought home for firewood.

They had to hire a skilled man to square up the timber to all the various sizes needed, and this had cost 140 Yuan (A$84). Then a carpenter was hired to help with all the various joints that held the frame together.

The walls were to be of mud brick, and she and her husband had made them all by themselves.

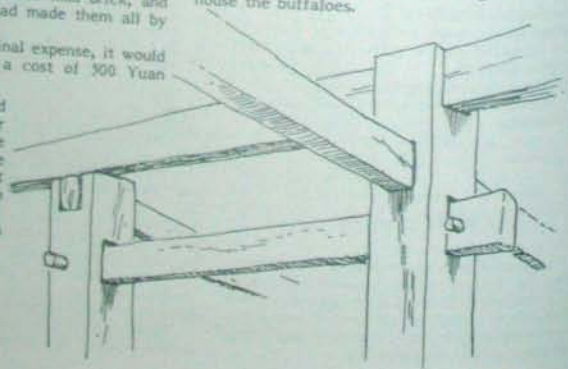
The roof was the final expense, it would require 8000 tiles at a cost of 300 Yuan (A$300).

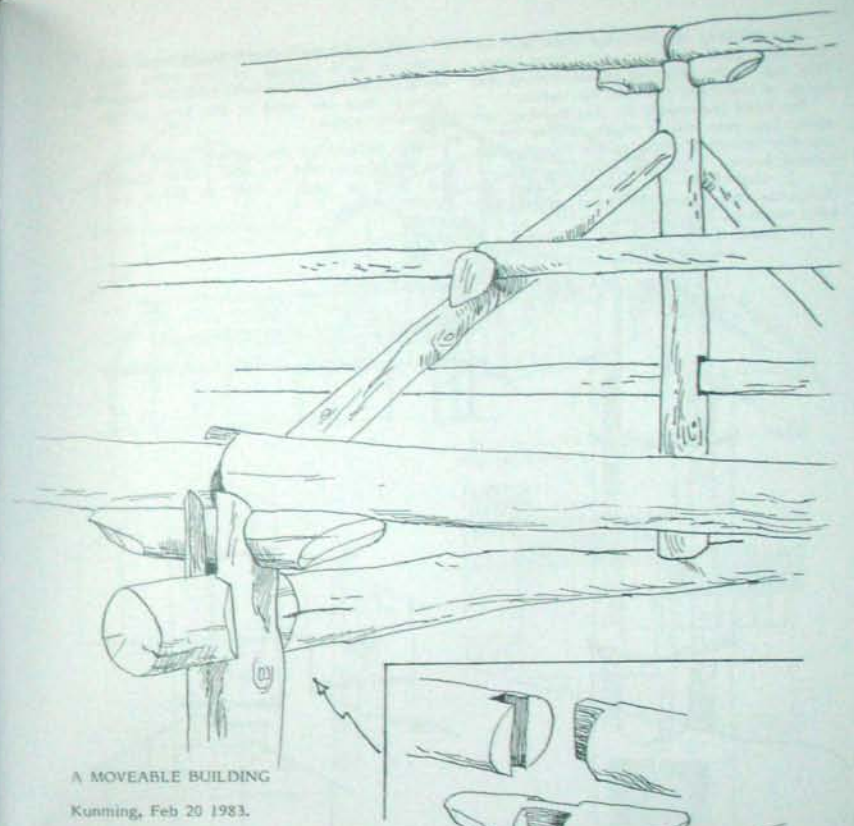
Summing up she said that having cut their own timber and made their own bricks the home will have cost them only 1000 Yuan (A$600) when complete.

The strength of this type of house framing is expressed in the old Chinese saying "Though the walls may tumble, yet the house will stand" , meaning that during an earth tremor even when the infill walls collapse the frame will still remain in one piece and support the roof.

ANOTHER FARM BUILDING

This sketch was done in a village a days drive from Jinghong, not far from the border with Laos. It shows some details of the framework of a farm building used to house the buffaloes.





A MOVEABLE BUILDING

Kunming, Feb 20 1983.

High in the stark limestone mountains above Kunming we entered a small valley and came on some men demolishing a building.

It had been part of a small village pottery and had been erected as a place for the making and drying of bricks prior to firing.

After three years the deposit of clay had been worked out, and now the building was being removed, and would be erected at a new site.

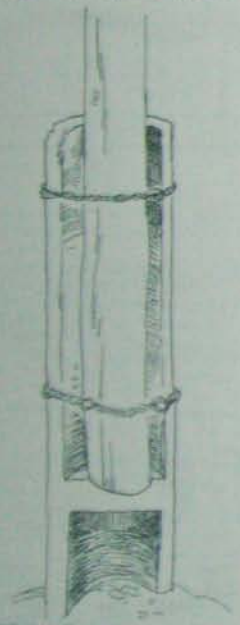
The main part of the building was 12 metres long and 5 metres wide, and there was a lean-to at one end.

The building did not need walls and the roof had been thatched with local grass. This was being removed as we arrived and would be discarded and used for mulch.

The stout framework for this building had taken ten men only a single day to erect, and this included cutting all the complicated locking joints.

It took four men only two hours to dismantle the frame once the thatch had been removed.

There were no nails used in the



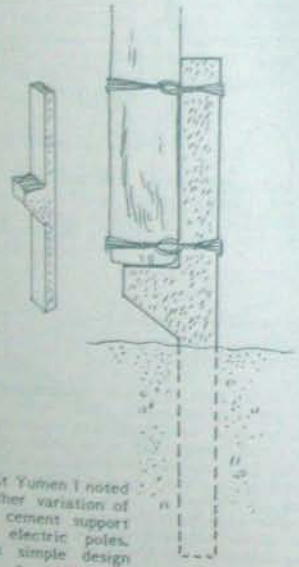
construction, all the main timbers locked together and the purlins simply sat in place and were held down by the weight of the thatch.

The sketches show the various joints that were used in the building.

The whole roof structure was supported by only eight poles, and these did not go into the ground but sat on flat rocks in the same way as the barn described earlier.

In this case there was a slight break with tradition as a couple of the poles were being supported by the semi-circular cement footings that are used in this area to hold electricity poles.

The bottom of the cement piece is set into the ground and the pole sits on a ledge half way up and is held in place with twisted wire.

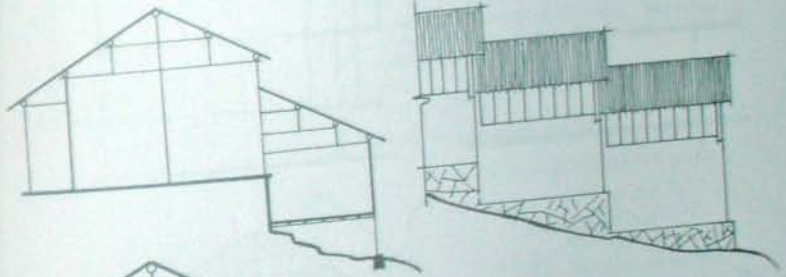


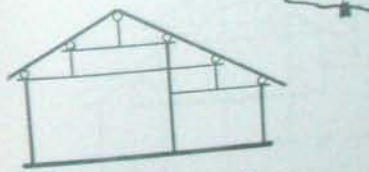
At Yumen I noted another variation of the cement support for electric poles. This simple design had a rectangular cross-section.

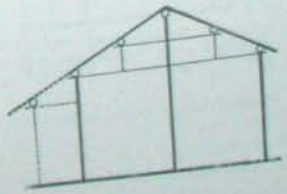
SOME COMMON FORMS OF THE THROUGH TIMBER FRAME

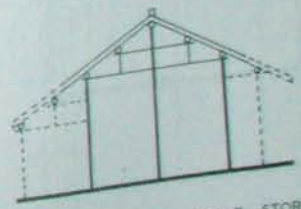
(A) SINGLE STOREY BUILDINGS

(In this sketch Lin Wei-hao shows a house built on uneven ground.)

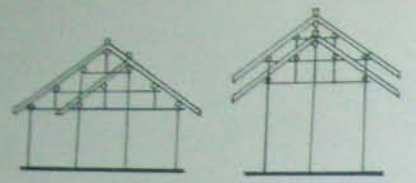




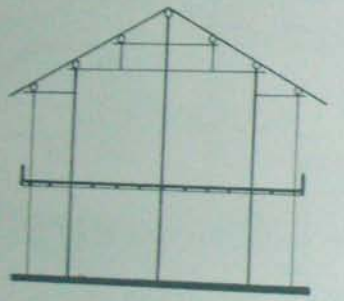


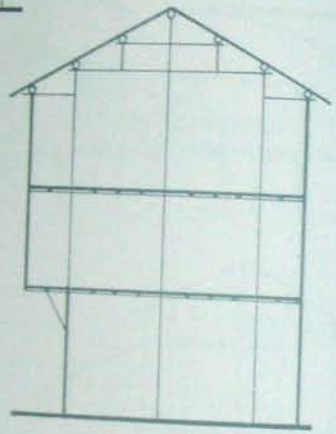


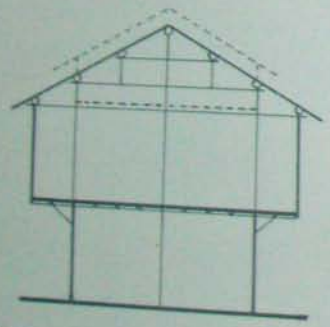
(B) EXTENSIONS TO SINGLE STOREY BUILDINGS. (Shown by the dotted lines)



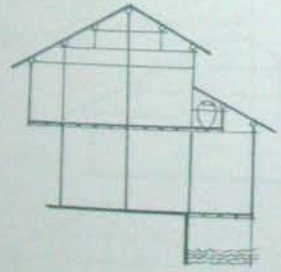
Two common extensions to gable walls.







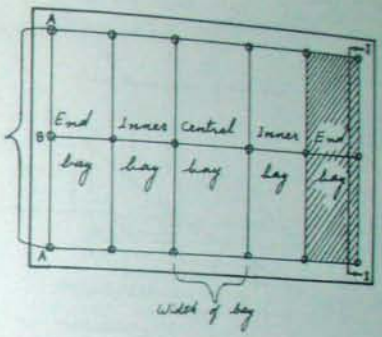
The dotted line shows an addition.



This building has a room jutting out over the water.

(C) FRAMES FOR BUILDINGS OF TWO AND THREE STOREYS

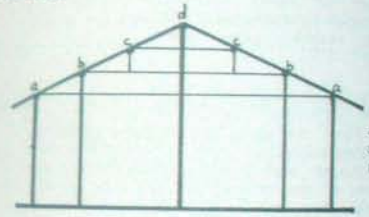
A COMMON HOUSE PLAN



Most homes are rectangular in plan. The building is divided into bays, and the shaded area shows the extent of a single bay.

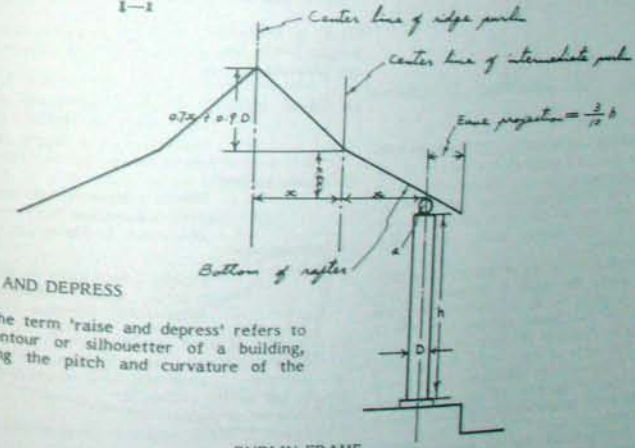
The room plans generally coincide with the bays, and a room may occupy one or two bays.

Most homes consist of three to five bays.



I—I

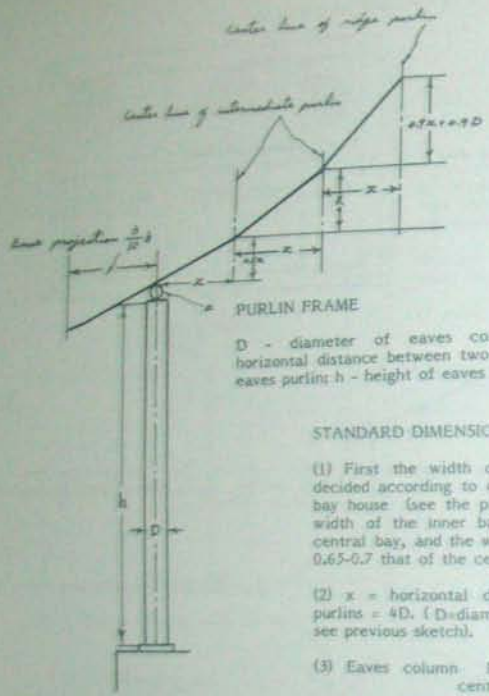
a,b,c,d – purlins. For ordinary homes the seven purlins shown here would be the maximum number used.



RAISE AND DEPRESS

The term 'raise and depress' refers to the contour or silhouetter of a building, including the pitch and curvature of the roof.

PURLIN FRAME



PURLIN FRAME

D - diameter of eaves column; x - horizontal distance between two purlins; a - eaves purlin; h - height of eaves column.

STANDARD DIMENSIONS

(1) First the width of the central bay is decided according to one's need. For a five bay house (see the plan shown earlier) the width of the inner bay is 0.8 that of the central bay, and the width of the end bay is 0.65-0.7 that of the central bay.

(2) x = horizontal distance between two purlins = 4D. (D=diameter of eaves column, see previous sketch).

(3) Eaves column Height=4/5x width of central bay (or 11D)
Diameter=1/11x height of eaves column

(4) Middle column
Height : dependent on the 'rise and depress'
Diameter= D+30mm

(5) Intermediate column
Height ; dependent on the 'rise and depress'
Diameter=D+30mm(or 25mm)

(6) Diameter of short column = 1D
(7) Height of column base = 3/10D
(8) Tie-beam : cross-sectional dimensions (height and width) ; 1Dx4/5D
(9) Diameter of purlin = 1D
(10) Rafter is 3/10D square in cross-section.

Although the figures given here by Lin Wei-hao may seem complicated there is a very interesting theory behind them. It seems that having decided on the width of the central bay all the other measurements can be calculated from this one measurement.

The plan at the top of the previous page shows where the width is measured. If the width is going to be 2.5 metres then the height of the eaves column will be 2 metres, its diameter 180 mm, and so on.

If the width of the central bay is going to be 3 metres then the eaves column will be 2.4 metres high and 218 mm in diameter, and all other measurements will increase in proportion.

The formula ensures that maximum strength will be maintained at all times.

IRON DOGS

Iron dogs provide a fast and secure means of fastening heavy timbers together. They are used in farm buildings all over China.

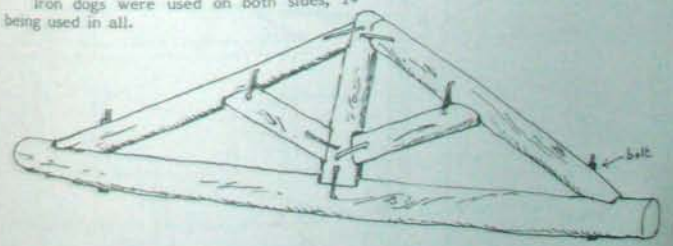
They are made by heating a length of steel rod and beating each end to a point, then bending them to the desired angles.

This is the most common shape.

This sketch was done on a commune near Wuhan and shows a brace attached to a ceiling beam with a dog.

I sketched this truss on a commune near Beijing, it was ready to be lifted up into position.

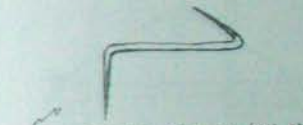
Iron dogs were used on both sides, 14 being used in all.



A temporary handrail on a bridge over Xuanwu Lake, Nanjing, speedily assembled with iron dogs.

One great advantage of this method is that the dogs can be removed easily and both the timber and the dogs used on another job.

They vary in thickness according to the job, for a farm building they may be 15mm diameter or more, while those used on this handrail were only 6 mm in diameter.



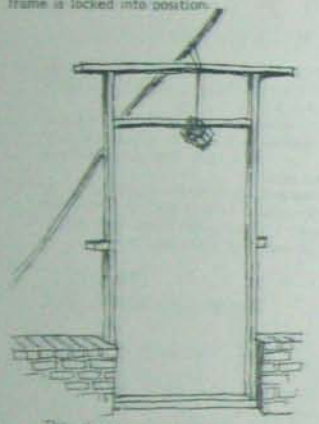
Sometimes the points are bent at opposing angles.

The sketch shows the dog being driven into the top plate and a rafter.

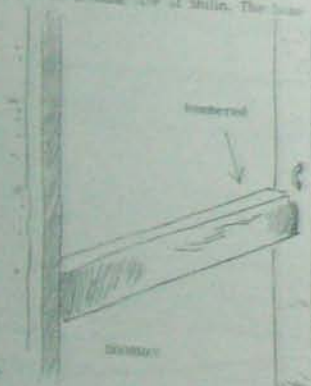
ATTACHING DOOR AND WINDOW FRAMES

In China the door and window frames are put together before they are built into the walls.

The frames usually have blocks of wood attached to them, and once the mud bricks have been laid around these blocks the frame is locked into position.



The sketch shows a door frame in position on a house site at Shilin. The lower



of the wall is of fired bricks and mud brick will go above this.

The door frame is kept firmly in place by the simple expedient of leaning a pole against it, on the end of which is a cord tied to three bricks.

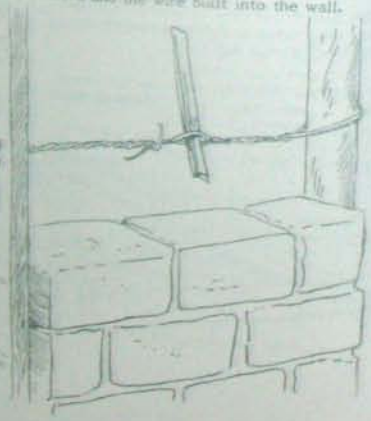
Steel strapping can also be used, but this does not seem to be so common.

When a wall is being built next to a doorway care must be taken to see that the door frame is not bowed out of shape during the brick laying.

A scrap of timber wedged into the opening will prevent this.

This sketch also shows another method of attaching a door frame, in this case by means of some wire twisted between two uprights.

The stick used to twist the wire is removed and the wire built into the wall.



The Roof

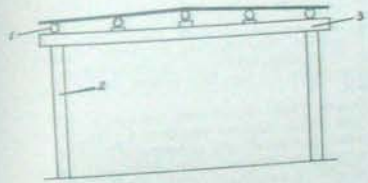
Lin Wei-hao prepared the English notes as well as the drawings for this section. I have also added a few sketches and field notes of my own.

1.ROOF PITCH. For flat clay tiles the slope is taken to be 21°48' - 45° (1:2.5 - 1:1), and for grey tiles and semicircular tiles similar to the Spanish tiles, 26°34' - 45° (1:2 - 1:1).

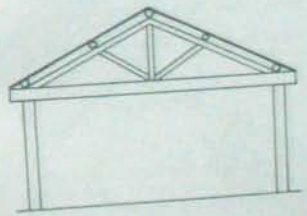
2. SUPPORTING STRUCTURE FOR PITCHED ROOF. The three common supports for a pitched roof are as follows.

2.1 MUD BRICK OR RAMMED EARTH GABLE WALL. Gables are used as bearing walls and purlins placed on the gables. According to the length of timber available gable walls are spaced 2.5 - 4 metres apart.

2.2 TIMBER FRAME: Timber frames are divided into four types as shown in the sketches.



(A)



(C)

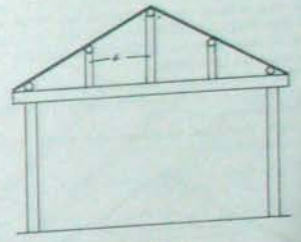
(A) The top ends of the two columns are shaped into tenons , and these fit into mortices in the beam.

(B) Short posts made to stand on the beam. The bottom of the posts are shaped into tenons and fit into mortices in the beam.

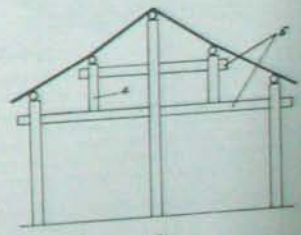
(C) A triangular roof truss takes the place of the beam, all timbers joined by mortice and tenons.

(D) The columns are joined together by horizontal timbers , using a tenon that passes through the column, this type of fastening is known as 'Chuandou'.

This type of frame has greater stability

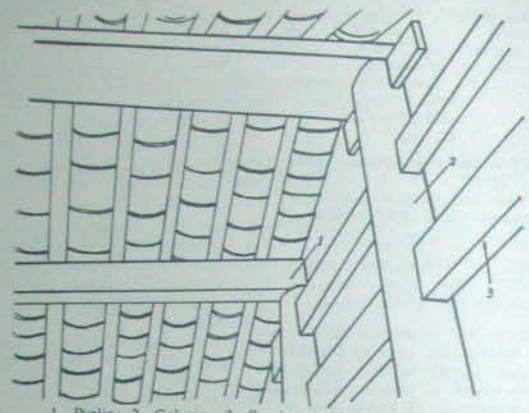


(B)



(D)

1—purlin; 2—column; 3—beam; 4—short post; 5—Tenon (or tail) through at rear; Tenon

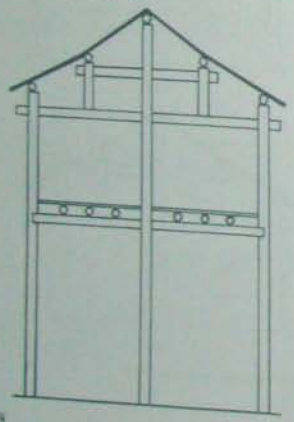


1. Purlin. 2. Column. 3. Passing tenon or balk.

than the others. It was in use as early as the Han Dynasty (206BC - 220AD), and has been widely adopted in China, especially in the southern provinces.

The columns also take the weight of the upper floor in a two story house as shown in the drawing.

With this type of frame the earth walls are not load bearing.



2.3 FIRED BRICK PILLAR. Fired brick pillars may be used to support the roof, with the earth walls only used as in-fill.

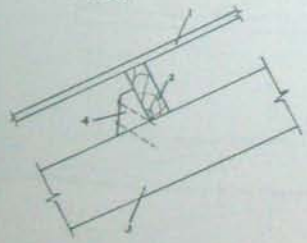
3. ROOF COMPONENTS

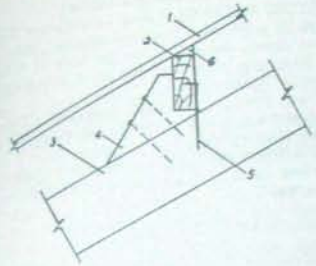
3.1 PURLINS: Purlins may be made of round or rectangular timber. It is considered more economical to use the timber in its round form.

In length they should not exceed 4.5 metres. The most common length is 3 - 3.5, but in cold parts of the country 2 - 3 metres is more acceptable. This is to allow for the weight of snow.

The purlins are spaced 600 - 2000mm apart and are placed on the top chords of the roof truss. They are equally spaced apart.

They may be placed in two different ways as illustrated.



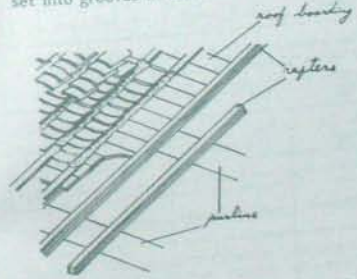


1. Roof boarding or rafter. 2. Purlin (when round timber is used the surfaces are trimmed so that they sit neatly at all points of contact). 3. Top chord. 4. Cleat. 5. L-shaped nail. 6. A triangular shaped length of timber used as a filler.

When the distance between purlins is relatively short (600-800 mm), roof sheathing may be place directly on them.

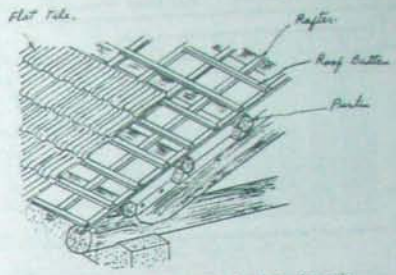
Where the purlins rest on the gable walls the parts that make contact should be given a coat of tar. Timber blocks can also be set into the wall for the purlins to rest on.

3.2 RAFTERS: When the distance between purlins exceeds a metre rafters should be arranged on them. The roof boarding is then set into grooves in the rafters as illustrated.



Rectangular rafters measure 30 x 70 or 40 x 60 mm, round ones are 40 - 60 mm diameter. They are spaced 600 - 1000 mm apart.

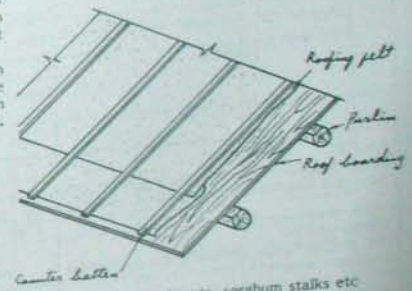
Sometimes, in order to save timber, roof boarding is not used, and the tiling battens are laid directly onto the rafters.



The problem with this is that the rain might leak in, and the room is not so well insulated.

3.3 ROOF BOARDING: The thickness of the roof boarding depends on the span and the load. They are usually 100 - 150mm wide and 15 - 30 mm thick. They usually span at least three purlins.

Roofing felt is placed on the boards and battens nailed on as shown.

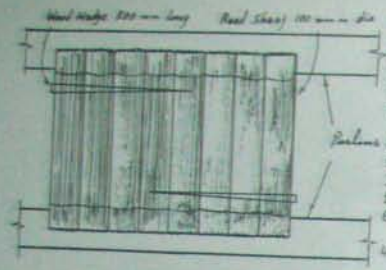


Bamboo or reed mats, sorghum stalks etc are used as a substitute for roof boarding, and roofing paper may also be used between a pair of reed mats.

Reeds have been used for many centuries in Chinese rural architecture. The average limit tensile strength of new reed is 10.64 kg/mm^2.

Under normal conditions they will last for many decades.

Reed sheaves are also used instead of roof boarding as shown. The wooden wedges go through four sheaves, which are also nailed to the purlins.



purlins should not exceed one metre.

3.4 TILING BATTENS: Tiling battens are 25 x 30 or 20 x 25 mm. They are placed 280 - 330 mm apart, depending on the size of the tiles. They are nailed to the roof boarding or directly to the rafters.

When there is no roof boarding the battens serve a dual purpose of securing the tiles and load bearing.

3.5 COUNTER BATTENS (Hold-down strips for roofing felt): 6 x 24 mm placed 400 - 600 mm apart.

4. TRIANGULAR ROOF TRUSS

4.1 MINIMUM SIZES OF MEMBERS: For a span of 6 - 9 metres rectangular chord members should have one face 100mm wide, in round timber a diameter of 110mm.

The web members should have one face 80mm wide in rectangular timber, or be 80 mm diameter in round timber.

A 50 mm layer of cob (clay with a high percentage of straw included) is laid on the reeds. When it has dried another 50 mm layer is added.

When using sheaves the distance between

5. TIMBER STANDARDS FOR LOAD BEARING STRUCTURES			
DEFECTS	TIMBER GRADE		
	GRADE I Tension member or member in tension and bending	GRADE II Member in bending or member in compression and bending	GRADE III Compression member
ROT	not allowed	not allowed	not allowed
KNOTS Along any part 150 mm in length on any face of a member the sum total of all knots	must not exceed 1/3 (1 for connecting parts) of the width of the face the part belongs to for grade I, 2/5 for grade II, and ¼ for grade III.		
CROSS GRAIN The average slope of the grain per metre must not exceed-	50mm	80mm	120mm
CRACKS (a) In the shear surface of a connecting part-	not allowed	not allowed	not allowed
(b) Depth of cracks near shear surfaces must not exceed ¼ in grade I and 1/3 for grade II. If cracks are opposite the depth is the sum total. For grade III there is no limit on crack depth.			
PITH	Should keep clear of shear surfaces	Not subject to restrictions	Not subject to restrictions

NOTES

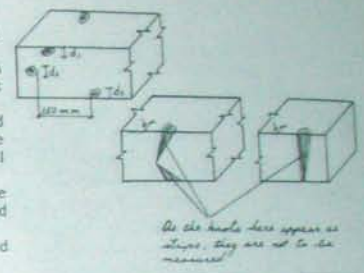
1 Check for loose or rotten knots and treat them.

2. The use of timber with a worm-eaten surface is acceptable, but the timber must be treated if worms are still present.

3. In regard to members of grade II and grade II hair cracks in the shear surface are acceptable if it can be judged that they will not affect the strength of the timber.

4 Knots are measured as shown in the drawing. If they appear as stripes they need not be measured.

Knots less than 10mm in diameter need not be measured.



STANDARDS FOR BOARDS			
DEFECTS	TIMBER GRADE		
	GRADE I Tension member or member in tension and bending	GRADE II Member in bending or member in compression & bending	GRADE III Compression member
ROT	Not allowed	Not allowed	Not allowed
KNOTS Along any 150mm of the face of a member the sum total of the sizes of the knots must not exceed 1/4 (1/5 for connecting parts), 1/3 for grade II, 2/5 for grade III.			
CROSS GRAIN The average slope of the grain per metre must not exceed-	50mm	80mm	120mm
CRACKS In and near the shear surface of a connecting part-	Not allowed	Not allowed	Not allowed
PITH	Not allowed	Not allowed	Not allowed

6. SUSPENDED LATHED CEILING

Note. 1. The distance between two hanging supports along a purlin ranges between 1 and 2 metres, usually 1.5m.

2. Distance between ceiling joists is 400mm.

3. For simple buildings short timbers are used as joists and are nailed directly to the bottoms of purlins.

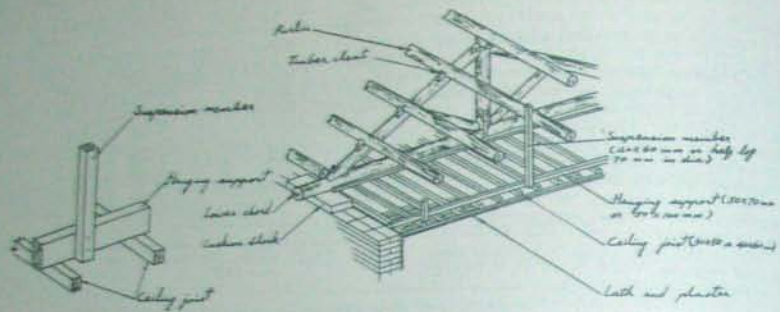
Wooden laths are nailed to these timbers and then plaster is applied to the laths.

4. Laths are laid 7-10 mm apart.

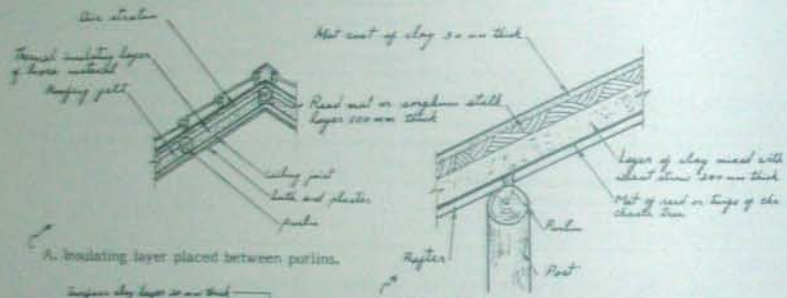
5. The lathed ceiling should be checked for level before the plaster is applied.

6. The centre of the ceiling should be made to spring. The springing height is about 1/200 of the width of the room.

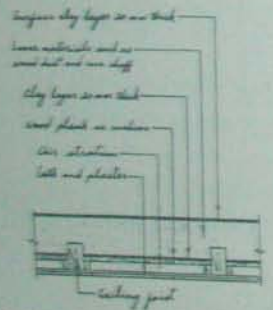
7. For the convenience of examining and ventilation there should be a 100mm gap between the lower chord and the top surface of the ceiling.



2. INSULATING LAYER



A. Insulating layer placed between purlins.



B. Insulating layer within a suspended ceiling.

C. Insulating layer placed on roof.

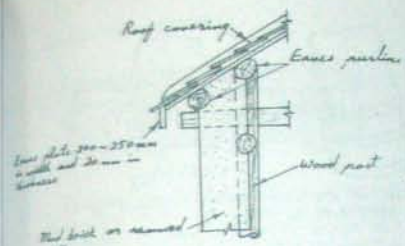
This practise is common in the rural areas of north and north-west China, and provides very effective insulation.

The practise is not common in the south, where roof boarding is often used instead of rafters. This reduces the weight of the roof and makes maintainance easier. However it means that more tiles must be used, and the roof is poorly insulated.

8. EAVES

Eave plates are not always used on simple farm houses, but when they are used they should be grooved so that they will not warp.

Two grooves are needed, 8 - 10mm wide, 100mm apart and 1/3 of the thickness of the timber deep.



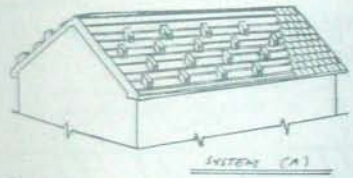
Eave plates

9. FIXING TILES

9.1. FIXING FLAT TILES

The tiles are supported by wooden battens, spaced according to the size of the tiles.

There are two common ways of stacking the tiles on the roof before they are fixed in place, as shown in the following two drawings.



(A). The saying is "Nine tiles for each step", meaning that the person laying the tiles will hang nine tiles before he takes a step backwards.

The tiles are placed in stacks of nine, double the width of a tile apart along the battens.

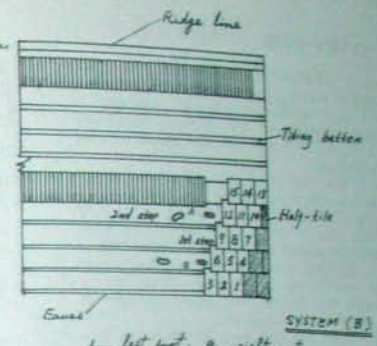
The first stacks span battens 1 & 2, the next lot span battens 3 & 4 and so on.

For ease of operation the stacks are staggered as illustrated.

(B). The tiles are stacked in a row standing on edge, with the reverse side of the tile facing the left.

In this system the saying is "Fifteen tiles for each step". The drawing shows the order in which they are laid.

If one complete side of a roof is tiled before the other the uneven weight will tend to distort the framework. For this reason the tiles should be brought up the roof from both sides at the same time.



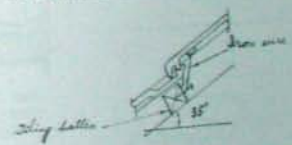
A— left foot; B— right foot

Before beginning a straight line is drawn along the eaves. The edge tiles, shown shaded in the sketch, are hung first.

The tiles are laid only from right to left along the roof, and from the eaves up to the ridge, following the order shown in the drawing.

The tiles along the eaves are secured to the battens by wire.

When the roof slope is more than 35° every other row is fastened to the battens with wire. One end of the wire is passed through the eye of the tile and twisted, the other end is wrapped around a nail sunk into the batten, as illustrated.



In windy areas where the roof slope is less than 35° only one or two rows of tiles are secured in this way.

In less windy areas on roof slopes of less than 35° tiles may not be wired down.

The ridge tiles are laid on mortar and should cover the roof tiles on either slope by at least 40 mm.

The mortar consists of 1 part slaked lime to 5 parts sandy clay, by volume. Water is added to make a workable mix.

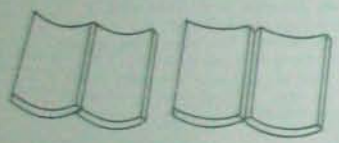
9.2 FIXING GREY, CURVED TILES

9.2.1 GENERAL: The first part of the base course consists of the twigs of chaste trees, or reed matting, straw, etc., whatever is readily available. This is made reasonably level and then covered with layers of mud and straw.

The mud is of the consistency to be spread with a trowel, and not too thin. Work begins at the ridge and proceeds downwards. Both sides of the roof are done at the same time to balance the weight.

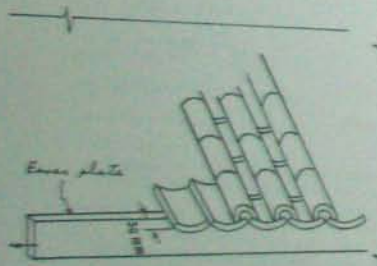
The first layer is 60mm thick and should be laid in two applications. When this is partly dry, but not fully dry, a top layer 20 - 40mm thick is applied.

There are two ways in which the tiles may touch, as shown in the drawing.

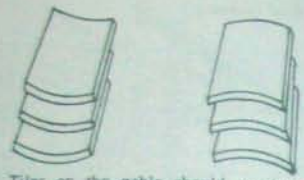


When the mud has dried the centre line for each row of tiles is scratched down the roof.

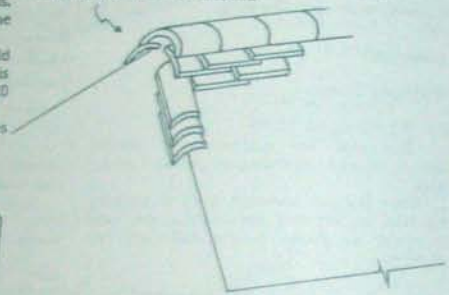
The tiles are laid from the eaves to the ridge. The first tiles overhang the eaves by about 30 mm.



Each tile overlaps the one before by two thirds of its length, so that only a third of each tile is left visible.



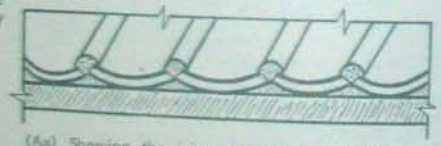
Tiles on the gable should overhang by half a tile's width as shown.



9.2.2 TYPES OF CURVED GREY TILES:

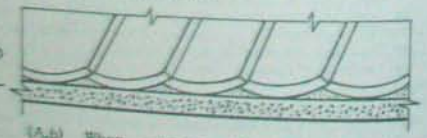
CONCAVE TILE ROOFING

Concave tile roofing (A) and mission tile roofing (B), as shown in the following sketches.



(Aa) Showing the joins covered with hemp fibre plaster.

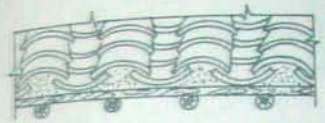
This type of roof consists only of concave tiles and plaster strips.



(A.b) When concave tiles are butted together in this manner the strips of plaster are not needed.

Note that a mud and straw mix has been used to fill the gaps beneath the tiles.

MISSION TILE ROOFING

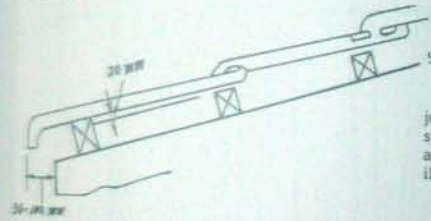


As before the tiles are laid into a mortar of mud and straw. The first row of convex tiles along the eaves does not follow the slope of the roof but are laid nearer to horizontal. In this way they help anchor the tiles above. *(see drawing : bottom of page)*

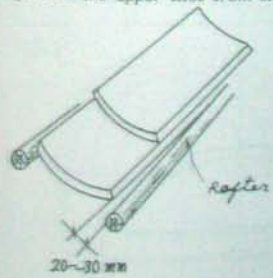
The upper row of tiles are laid with the curve up and overlap each convex tile by at least 40 mm.

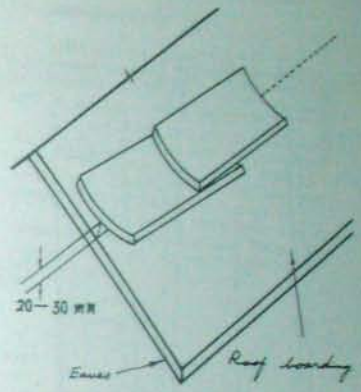
The ridge tiles are also laid on a mix of mud and straw. The mud mortar is not put in places where it is likely to be affected by rain.

The spaces along the two sides of the ridge tiles, and the areas shown in the drawing where the tiles meet the eaves are filled with hemp fibre plaster or lime and sand plaster.



These three drawings show how the bottom tile on the eaves is tilted up. This helps prevent the upper tiles from slipping.

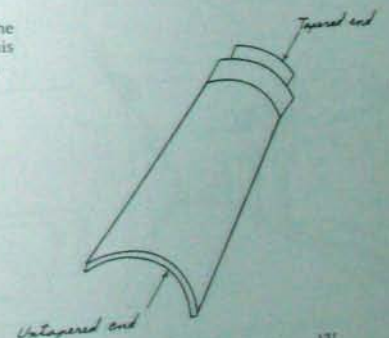


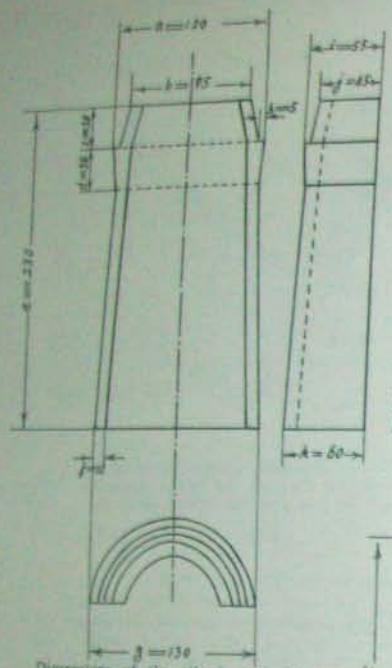


This is important when, as is often the custom, the tiles are not wired down but simply set into a mortar of mud and straw.

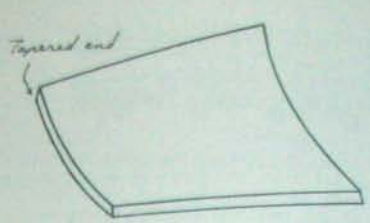
9.3 SEMI-CIRCULAR TOP TILES

The previous roofs were covered using just one type of tile. Another popular system uses shallow curved tiles upwards and semicircular tiles downwards. The first illustration shows the semi-circular top tile.



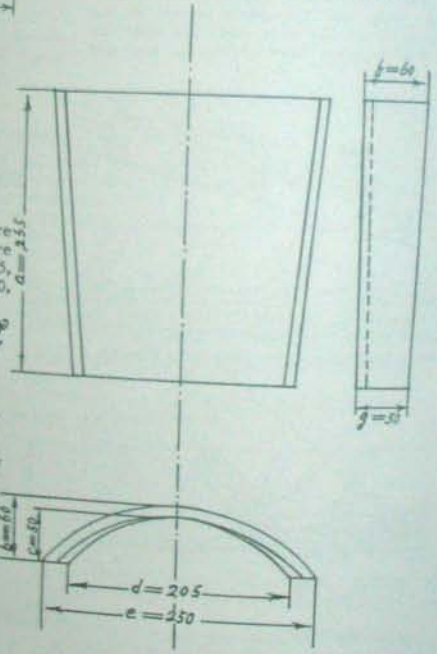


Dimensions of the tile in mm. These are typical dimensions, the following sizes are also used here (Kunming): a=135, b=105, c=30, d=30, e=290, f=15, g=150, h=10, i=60, j=30, k=60.

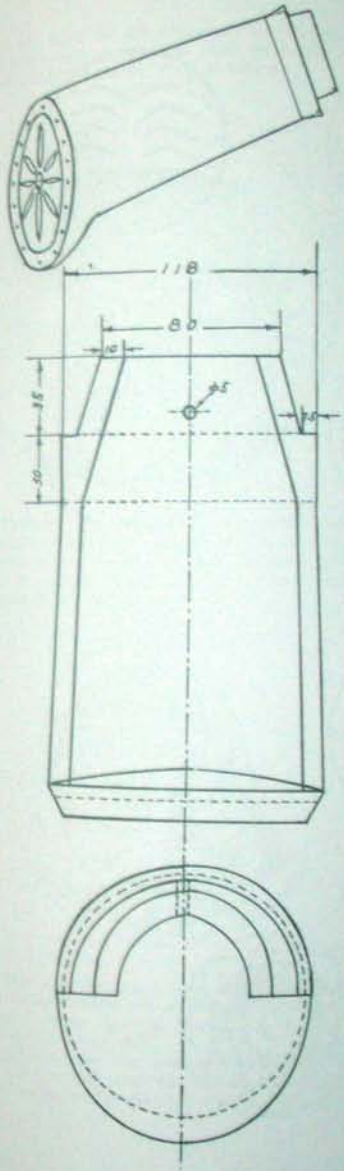


9.3.1 SHALLOW CURVED TILE USED WITH SEMI-CIRCULAR TILES

The dimensions given here are typical, and the following dimensions are also in common use:
a=195, b=50, c=40, d=180, e=215, f=30, g=40.



An old part of Beijing



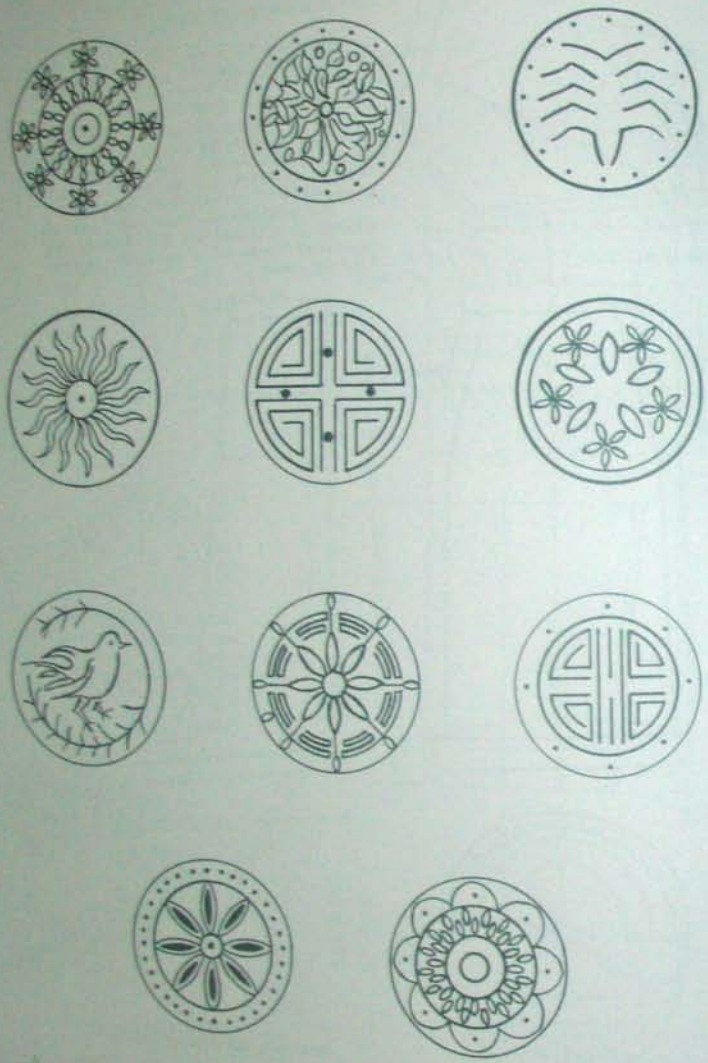
9.3.2 SPECIAL EAVES TILE

The special eaves tile is used in conjunction with the two previous tiles. It has a closed end so that mortar does not have to be applied along the eaves.

The closed end also prevents birds and mice getting under the tiles. Because of the extra work involved in making these tiles most farm houses do not use them but simply block off the ends with mortar.

The ends usually have some sort of decoration on them and Lin Wei-hao has illustrated some of those found in the Kunming area.

NOTE. Straight line AB = 250



I too find the tile ends very interesting, and the following sketches show three that I have collected during visits to China.

This one was found in the mountains near Dazhai in northern China. I was walking across some wasteland, and suddenly saw this small grey face grinning up from the ground at my feet.

This end, bearing a wild, snaggle-toothed demon had broken off an ancient building at Jiuquan (Wine Springs) near the western end of the Great Wall.

Once broken the ends are of no further use on the roof, and the Chinese are always quite happy to let the visitor have them.

This one was from the Great Mosque in Xian, discarded during renovations as the main part of the tile had broken.

Clay tiles have been found dating back to the Western Zhou Dynasty (circa 1100 - 771 BC), so clay tiles have a history of at least 3,000 years in China. These tiles are similar to the shallow ones illustrated earlier, and were 400-500 mm in length.

Semi-circular top tiles appeared during the Eastern Zhou Dynasty (770 - 256 BC), and this style of tiling has been used since that time.

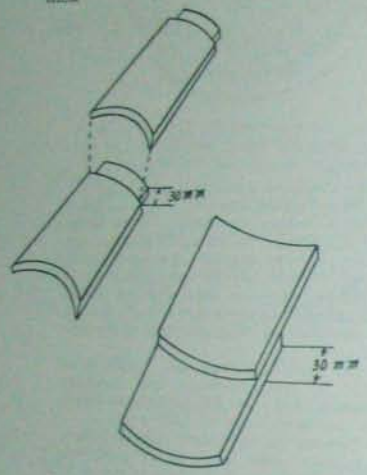
For special buildings tiles began to be glazed in the Northern and Southern Dynasties (420 - 581 AD), so glazed facing tiles have been in use for 1,000 years.

They are glazed in many colours, yellow, green, blue, white, royal purple, jade, etc. Such rich colouring is in marked contrast to the sombre grey tiles found in the countryside.

Cave home near Dazhai, the decorated tiles go above the doorway.

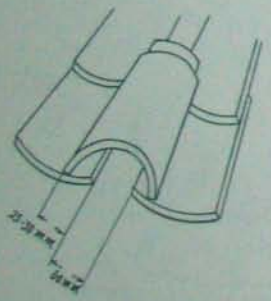
9.3.3 FIXING SEMI-CIRCULAR TILES

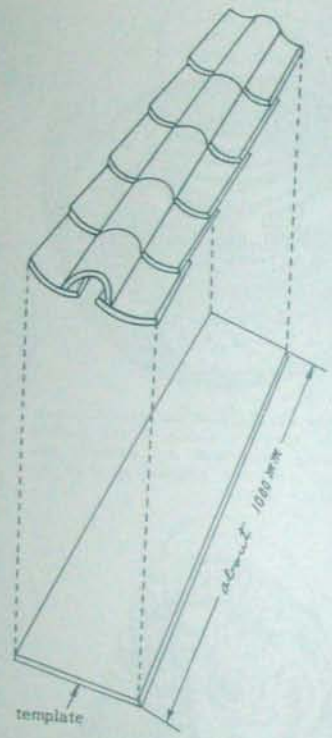
The semi-circular tiles are a little more complicated to make than the ordinary shallow tile, as will be explained later, but they have the advantage of not requiring such a large overlap as the plain curved tiles.



The semi-circular tiles fit as shown, and require only a 30 mm lap.

The shallow curved tiles are sometimes laid in rows 60mm apart as shown, though in the Kunming area they are frequently butted together.

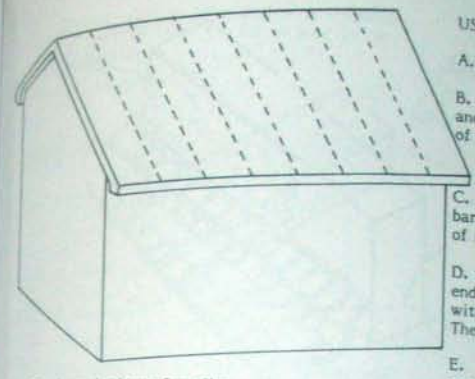




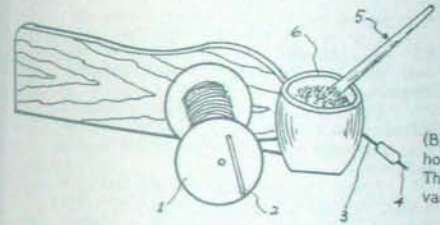
METHOD OF FIXING

(A) A few tiles are laid out on the ground as illustrated. When the correct spacing has been established a template is cut of the same dimensions.

The template is now used to mark out the position of the tiles on the roof. The outline of the template is marked on the mud and straw surface. This can be done with a carpenter's ink marker.



Roof marked out for tiles.



Carpenter's Ink Marker.

1. Spool holding the cord.
2. Spool handle.
3. The cord, which passes through two holes in the ink pot.
4. Steel fixing pin.
5. Bamboo piece.
6. Wooden pot containing silk floss or cotton, soaked with prepared Chinese ink.

USING THE INK MARKER

A. The marker is held in the left hand.

B. The cord is pulled out a little and the steel pin fixed into one end of the job.

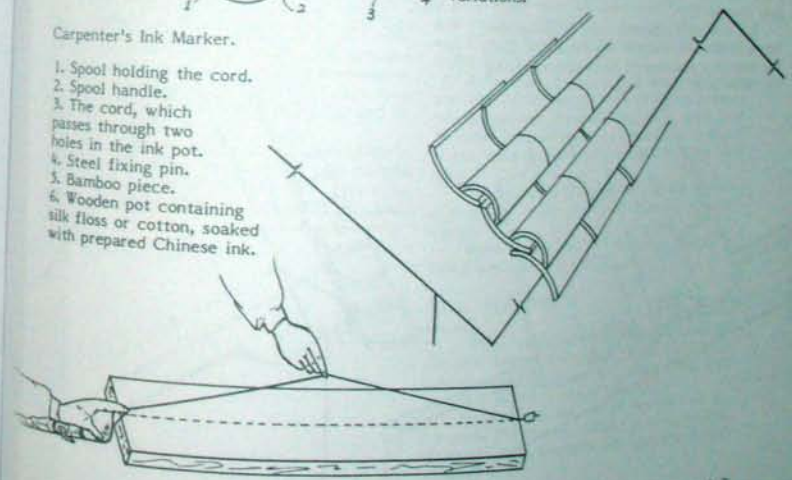
C. The silk floss is pressed with the bamboo piece so that it absorbs plenty of ink.

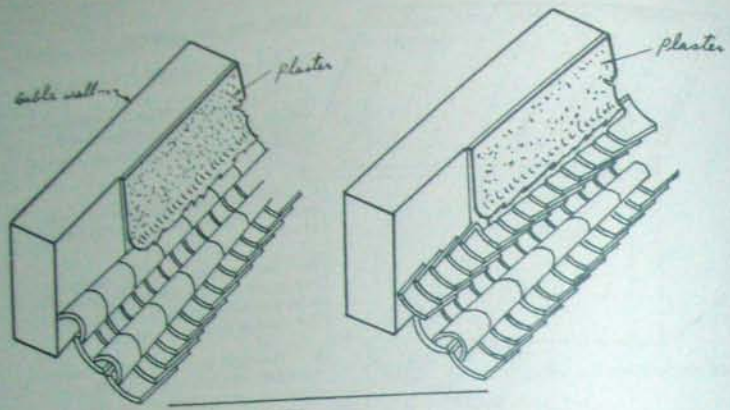
D. The marker is taken to the other end of the job and the cord held down with the index finger of the left hand. The cord is stretched taut.

E. The right hand lifts the ink-soaked cord and then lets it go, causing a black line to be made on the job.

This tool is used throughout China by carpenters whenever lines have to be marked on timber.

(B) The shape of the gable will determine how the tiles begin and end at this point. The following three sketches show some variations.





(C) The tiles should be moistened before being laid so that they will make a good bond with the clay mortar.

(D) Tiles are laid from eaves to ridge, and can be laid left to right or right to left.

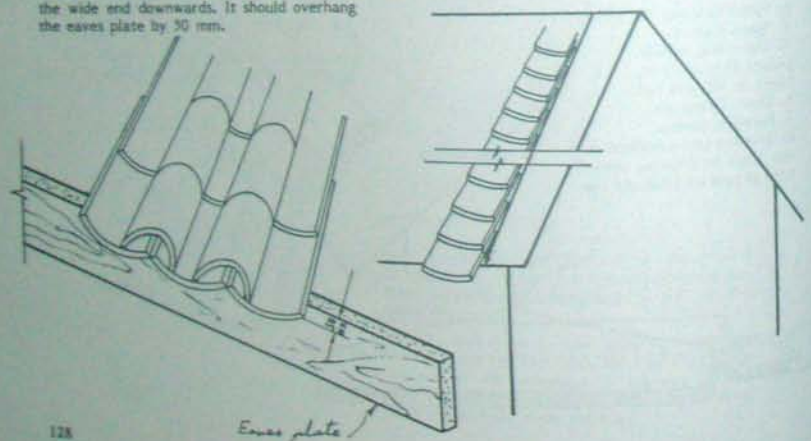
Both the semi-circular tile and the shallow tile used with it have a slight taper. The wide end of the shallow tile is placed on the upward slope, towards the ridge, while the wide end of the semicircular tile goes downwards.

The one exception to this is along the eaves, where the shallow tile is placed with the wide end downwards. It should overhang the eaves plate by 30 mm.

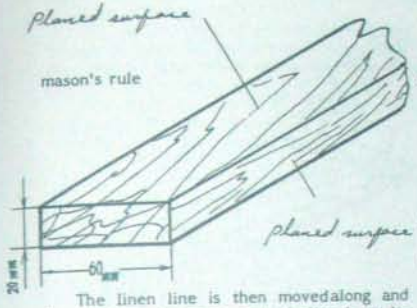
(E) All the gaps between the under and over tiles are filled with mud mixed with chopped straw or lime mortar.

The lime mortar mix is 213kg of quicklime to a cubic metre of sand. Brick or tile fragments are sometimes added to this as a filler.

(F) After a number of tiles have been laid a line, stretched tight, is used to check that the tiles are still being laid in a straight line.



When a row has been laid it is checked with a mason's rule 3 - 3.5 m long to see that it is straight.



The linen line is then movedalong and fixed where the next row of tiles is to be laid.

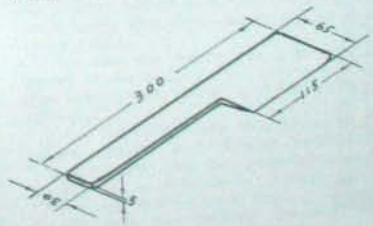
(G) The semi-circular top tiles can be laid as soon as each row of bottom tiles is in position. A mixture of mud and chopped straw is used to fill the gaps under the top tiles as mentioned earlier. The tiles are pushed firmly into place by hand so that the mud gets a good grip.

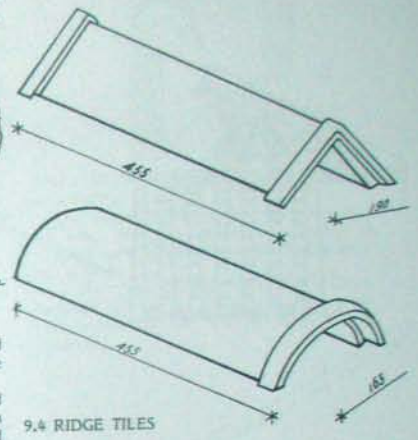
The linen line can be used to ensure a straight line.

(H) On a good quality building all the joints are filled with hemp fibre plaster (633kg quicklime, 10kg hemp and sufficient water to make a workable mix will produce a cubic metre of plaster).

When the tiles reach the ridge there may not be enough room for a full tile, and so they will have to be cut.

This is done using a steel bricklayer's cleaver . The sharp edge of the tool is used to make a notch in the tile and then it is struck a sharp blow to break it at that point.





9.4 RIDGE TILES

9.4.1 Typical ridge tiles. Three other sizes are also common, 380x190mm, 410x200mm, 440x200mm.

9.4.2 FIXING RIDGE TILES

The ridge tiles are laid with mortar (a typical mortar is 1 part of slaked lime to 5 parts loess soil, with water added to make a mix).

Two ridge tiles are laid with mortar at one end of the ridge, and two tiles without mortar placed temporarily at the other end. A cord is stretched between the tops of these tiles to give a straight line for the ridge.

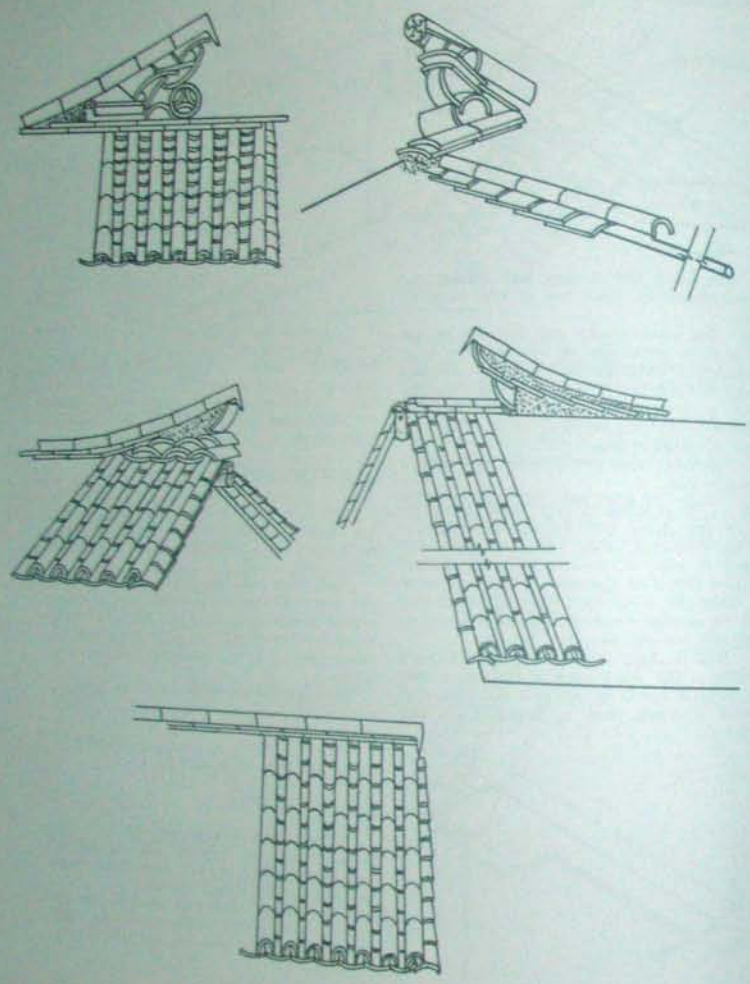
The ridge tiles are then set in the mortar, and should cover the roof tiles by at least 40mm.

When complete all the gaps should be filled with hemp fibre plaster.

9.4.3. RIDGE ENDS

The characteristic upswept ends on Chinese roofs are formed in a number of ingenious ways using the same tiles that have been used to cover the roof.

An amazing variety of designs can be created using these simple materials. The following five examples are common in the Kunming area.

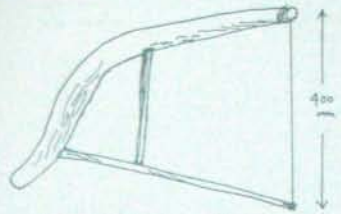


MAKING ROOF TILES

The following notes were made during a couple of visits to a small pottery near Kunming, February 1983.

The pottery was near Qing Qien (Clear Stream Village). It was situated next to the clay deposit and would be moved when the clay was worked out.

The freshly dug clay is prepared in a depression in the ground 4 metres in diameter and 500mm deep.



When the clay is ready to be used it is cut with the tool illustrated. The main arm of the cutter is a curved branch, and a wire is stretched between this and the thinner arm.

The wire is obtained from old truck tyres, and this wire, still with scraps of rubber attached, can be bought in the village stores.

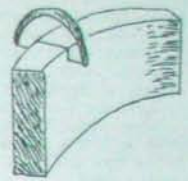
The worker in the pit rested the right end of the lighter arm on the ground, holding it in his left hand, and grasped the heavier curved timber with his right hand.

Pivoting the tool on the lighter arm he rotated the heavy piece in a half circle. This caused the wire to cut an arc through the face of the clay.

Another worker lifted out the cut lump, roughly 400 x 300 mm, and threw it to a worker on the edge of the pit, who in turn threw it to another, down a human chain of six people, two of them girls who staggered back every time they caught one of these heavy lumps.

The clay was thrown into a heap in the centre of the working shed, and each person then took it from there to build his own stockpile.

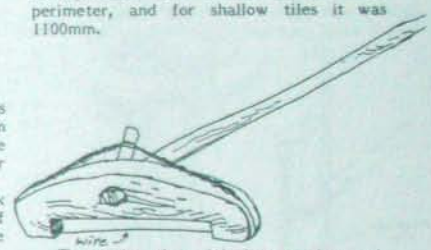
The stockpiles were built close to the pottery wheels and directly behind the tilemaker. The clay was built into a wall curving in a semi-circle, 270mm thick, 800mm high and 3 metres long. The top of this wall was carefully smoothed and



then a bow cutting tool was used to make a series of vertical cuts.

The distance between the cuts was judged by eye, and they differed according to whether semi-circular or shallow tiles were to be made.

For semi-circular tiles the distance between cuts was 370mm on the outer perimeter, and for shallow tiles it was 1100mm.



The worker then picked up another tool and used it to make a horizontal slice along the whole top of the wall.

This tool looks like a broom without the bristles. The handle is 700mm long and the head is 470mm across.

A wire is pulled tight across a gap at the bottom of the head, and the distance between this wire and the head, about 20mm, governs the depth that the tool will cut. The tool always cuts a uniform thickness of clay.

The wire is kept tight by tying it to four other wires which are twisted by inserting a short piece of stick. The twisting stick is left in place and can be seen in the sketch.

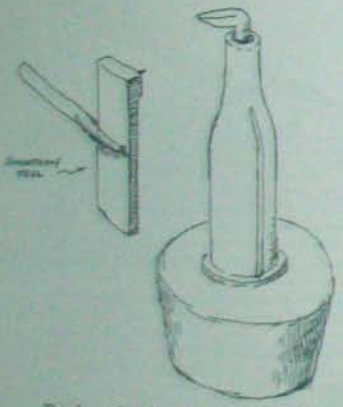
MAKING SEMI-CIRCULAR TILES

There were five pottery wheels in the shed,four were used for the shallow tiles and only one for the semi-circular tiles. The semi-circular tiles were made by the master potter Yang Shiao-bao, who was 68 years old and had been a potter for 50 years.

His wheel consisted of a stout pole sunk into the ground and tapered to a point. 40mm of the point was of metal. The potter looks for a small piece of scrap metal with a hole in it, nails this to the end of the pole and then files it to a point.

In this case an old ball bearing race had been dropped over the point to help the wheel rotate easier, but this is not always done.

The rest of the wheel was a solid wooden cylinder hollowed out underneath so as to fit over the ball race and the pointed timber.



The form for the tiles was permanently attached to that. It was a bottle shaped piece of timber, and attached to the sides were two raised ridges of bamboo. These would make grooves on the inside of the clay shape at the point where it was to be broken, for this form made two tiles at a time.

The top of the bottle shape had a hole in it, roughly square, and a removable handle was fitted into it.

The tile maker used this handle to revolve the wheel, and removed it when he was lifting off the finished shape. The wheels used in tile making do not have to spin around like ordinary pottery wheels as only a few turns are needed to make a tile.

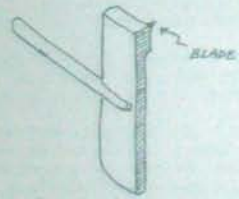
Before making each tile a cotton 'sock' is placed over the wooden form. This sock has a slit down one side and has a roll of material at the top large enough for the potter to get a good grip when he is lifting it off.

A length of string is attached to the bottom of the sock at one point on the inside and is placed so that it comes out through the top of the sock.

The wet sock is placed over the bottle shape, string hanging out at the top, and the slit down the side allows it to be folded around the bottle shape without any creases.

The potter now turns to his wall of clay and lifts off one of the pre-cut pieces. This is wrapped around the bottle shape and smoothed along the join.

The wheel is now revolved and the clay is hit with a paddle-shaped tool. When the clay has made firm contact with the form the



wheel continues to be turned and the tool is pressed against the clay to produce a smooth finish.

There is a small steel blade at the top of the tool and this cuts off the surplus clay at the correct height. The surplus is discarded and the shaping is then completed.

The turning handle is put to one side and the potter grasps the cotton sock by its rolled top and lifts it up, thus removing the clay shape from the mould. The clay sticks firmly to the sock.

He carries the shape in this way and takes it to the drying area and puts it on the ground.

Now the reason for the string can be seen. Pulling on it gently he can remove the sock from inside the still soft shape without distorting it.

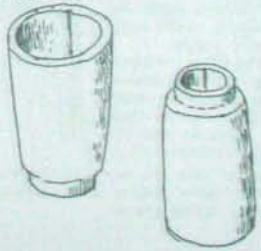
In this way he can make 250 shapes a day, which divide into 500 tiles.

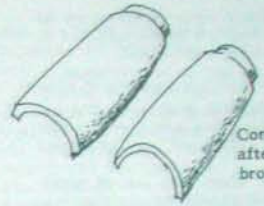
USING THE SOCK TO LIFT THE TILE

The shapes are left until they are leather dry and then a worker goes around with a very simple tool consisting of a piece of wire pushed through a hole in a stick and kept in position with a few twists.

He inserts this inside the shapes and scores a line at the points where the bamboo ridges on the form have made grooves. The shapes are then left to dry properly.

When dry they are simply pulled apart, and they break along the scores to form a pair of round tiles.

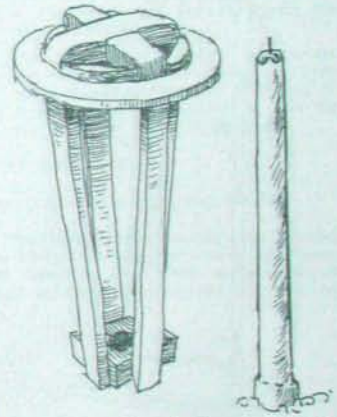




Completed tiles after being broken apart.

SHALLOW TILES

The shallow tiles are made on a different wheel and with different forms. The wheel is of much simpler construction. A pole is sunk into the ground, roughly tapered at the



top and with a nail partly hammered into it. The wheel fits on this.

The revolving section is constructed of reasonably light timber. It is droppped over the pole and revolves quite loosely, in no way a neat fit.

I had begun sketching just as the workers arrived in the morning, and the man whose wheel I was sketching was in such a hurry to show me how it worked that he picked up the revolving section belonging to the next wheel by mistake.

When he dropped it onto the pole it did not fit properly and, not realising his mistake, he siezed a saw and cut off the top of the pole.

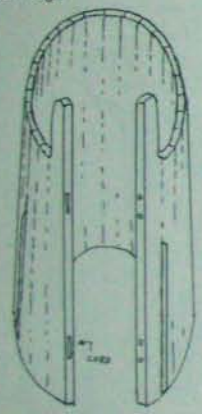
This made his wheel work properly, but

when the next potter came to start work he realised that he had the wrong top, and so took the top from the third wheel.

This did not fit and so he too began to modify his post. The third man now arrived and found that he was stuck with the top from the first wheel, and soon everyone was busy cutting and nailing and modifying their wheels.

Though the wheel may be of rough construction the form used for the tiles is a work of craftsmanship.

It is made from a large number of narrow strips of timber of around 20 mm in width, each of which has four holes drilled through the narrow edge.

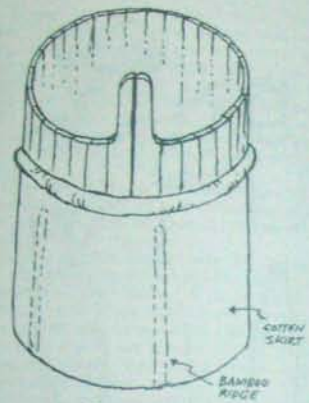


A cord goes through these holes joining each piece. The cord is visible only at one end where it fits into grooves. The holes at the other end are blocked up with dowels.

The pieces of timber at each end are longer than the rest and form a handle when the form is curved into a cylinder. This cylinder is 380 mm high (not including the handles) and is tapered, being 290mm diameter at the top and 340mm at the bottom.

As four tiles are made at once with this form there are four raised ridges of bamboo set into the timber at regular intervals.

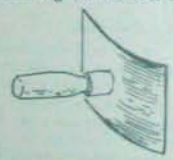
A cotten skirt with a rolled top goes around the form, and is made a neat fit,



without any slit. The potter places the form over the raised portion of the wheel, and this holds it in place.

He rotates the wheel by grasping the two tall pieces of the form, and wets the cotten skirt with a piece of rag fixed to a length of wire.

The clay has been sliced as described earlier, and is lifted off the clay wall and wrapped around the form, and the edges rubbed together to seal them.



A curved metal tool is then used with a quick jabbing motion to make the clay fit tightly to the form as it is being turned.

Next a wooden smoothing tool is applied while the form is being rotated. This has a small trimming blade at the top which removes surplus clay.

The worker lifts the form off the wheel by the two taller pieces and carries it outside to the drying ground.

The wooden form is flexible, and can be rolled smaller and withdrawn. The cotten skirt is then carefully removed and the clay cylinder left to dry.

Before drying is complete it is also scored on the inside in the same way as the semi-circular tiles. When dry each shape is broken to form four shallow tiles.

Each man can make 125 of these shapes a day, which is 500 tiles, the same number as the old man will make of semi-circular tiles.

1,500 tiles are needed to cover the average room. The tiles are sold by the hundred, 60 shallow tiles and 40 semi-circular tiles. They get 7 Yuan (A$4.20) for a hundred tiles.

It takes two months to make enough tiles to fill a kiln, the capacity of which is 50,000 - 60,000. Each kiln full brings in 3,500 Yuan (A$2,100) but of this 600 Yuan (A$360) has to go for purchase and transport of coal.

As the pottery is worked on a contract basis the State takes 10% of the income as its share, but there is no income tax on the rest.

Sixteen people work at the pottery.

A kiln was being fired a short distance from the tile shed, and I was invited into the tunnel beneath the kiln. Outside the temperature was chilly, but in the tunnel it was pleasantly warm until one of the workers pulled open the iron door to show me the fire. The searing heat sent me hurrying back down the tunnel, but not before I had caught a glimpseof the rows of tiles glowing in the heat.

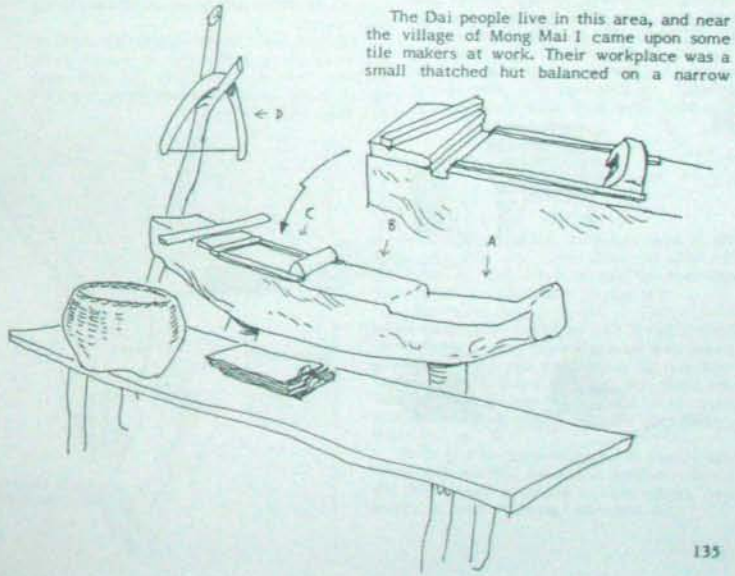
Two men tend the kiln during the day and another two take over during the night. It takes ten to twelve days to reach the correct temperature.

The temperature is judged only by eye. The master checks it constantly, and when he judges it is ready the fire is allowed to die down and the kiln is left to cool for three or four days before being opened.

FLAT ROOF TILES

Near the border with Burma, Feb 1983.

The Dai people live in this area, and near the village of Mong Mai I came upon some tile makers at work. Their workplace was a small thatched hut balanced on a narrow



raised bank between two rice fields.

The potters used a combination seat and mould to make the tiles. It was made from a log, and had two legs which were buried in the ground.

Straddling the log the potter sits at (A). He then places a large lump of clay at (B). He knocks this into roughly the right length and width and then brings it down with some force into the mould section (C).

The basket on the left of the sketch contains dry powdered clay or fine sand. Before each tile is made the basket is shaken over the moulding area. The dust falls through the weave of the basket and prevents the tile from sticking to the mould. When the clay has been slapped into the mould the potter takes the bow cutting tool (D) and draws it along the top of the mould towards him. This tool is simply a bent stick with wire tied between the ends.

The stick that can be seen to the left of the mould is then used in a to-and-fro motion to smooth and press the clay firmly into the mould.

The potter draws the stick towards him and then away, the tile is now ready to be removed.

There is a small wooden piece on the left side of the mould and this is removed. This allows the worker to get his fingers under the tile and lift it out.

Notice the depression cut into the end piece on the right of the mould. The tab of the tile is formed in this.

The finished tiles are placed one on top of the other on the bench in bundles of four. The sand prevents them from sticking together.

I made a few tiles in this mould and found that it was a simple enough process, though I was much slower than the potter who invited me to have a go.

The sketch shows a pair of kilns. The one on the left has the thatched roof. A tree stump is smouldering under this drying off the tiles. The right hand kiln has been fired and cooled and now the upper part is broken open so that the tiles can be removed.

The tiles are stacked 1.2 metres from the bottom of the fire opening, and 11,000 tiles could be fired at one time, according to my interpreter.

The only cost involved was the price of the firewood, and this was 36 Yuan a firing ((A$21). The tiles sold at 2.5 Fen each (A.1.5 cents) and the whole firing returned 275 Yuan (A$165).

Because the shed was perched between flooded fields there was no flat area to dry the tiles, and they were stacked directly into the kiln, still in bundles of four.

In any case this is an area of high rainfall and it would be a problem drying the tiles in the open. A thatched roof was erected over the kiln to prevent rain damage.

A slow fire was maintained in the kiln for six days, until all the tiles were quite dry and the whole kiln well heated.

The thatched roof was then removed and the kiln quickly brought up to firing temperature. This took only one day. Three days were then allowed for cooling.

MULTIPLE MOULDS

The tile makers were Dai people, the native people of this area. Further on, in the village of Man Dong, I came upon another group of tile makers. These men were Han Chinese who had come from the north to work here on a contract basis.

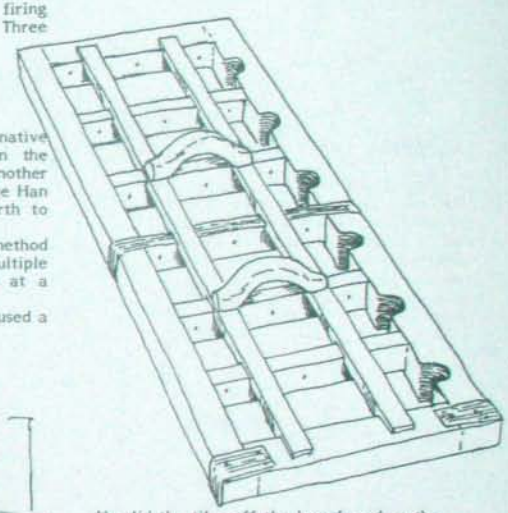
They used a much more efficient method for producing the flat tiles, a multiple mould that would cut out six tiles at a time.

First they built a wall of clay and used a tool similar to that described earlier in the section on round tiles to slice up the clay.

A long board was dusted with dry sand and the slice placed on it. The worker then picked up the mould.

This was well made, and had a lip of sheetmetal on the inside which was deeper than the wooden frame.

Grasping the mould in both hands the worker brought it down vigorously onto the clay, cutting out six tiles at once. He then threw the scraps to one side and carried the board to the drying area.

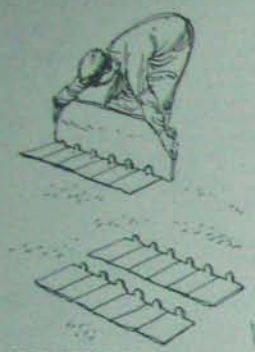


LIFTING A SLICE FROM THE WALL

He slid the tiles off the board, and as the ends with the tabs were about to slide off he tilted up the board so that all the tabs were bent at right angles to the tiles.

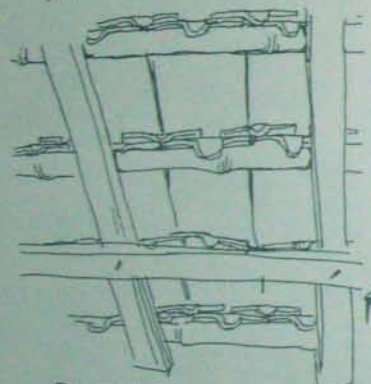
The tiles measured 270 x 160 x 5mm when made and shrank to 245 x 140 x 5mm when fired. The drying ground was rather uneven but this did not matter as the tiles were only left there till part dry. Sand was then sprinkled over them and they were stacked in bundles and pressed flat with a board.

Each potter could make 1,500 tiles a day using this method, while the method used by the Dai village people described earlier only produced 1,000 tiles per man in a day.



LAYING THE TILES

This sketch was done inside a home in Man Yuan Village and shows how the tiles are laid. The rafters were only 75 x 50mm and were laid on the flat 350mm apart. Split bamboos were fixed to them 180mm apart.



The tab of the tile is hooked over the bamboo, and not tied on in any way. As can be seen in the sketch two layers of tiles are used in each row.

I was told that such a roof would last for 25 years. In fact the tiles would last forever, but after a couple of decades the roof begins to sag and it is a Dai custom to rebuild the house at regular invervals.

A temple in Man Jing Dai Village with earth walls and a tile roof showing some ornamentation.

Many temples are being rebuilt in this area, and they are usually of earth wall construction, in contrast to the Dai houses which use only timber and tiles.

This is a tile roof on a room in a Dai house. The walls are of timber without windows, and light comes from the opening below the eaves and from gaps between the timbers.

A typical Dai village home in Mung Go Village with pawpaws and bananas growing in the yard which is surrounded by a fence of split bamboo designed to keep in the family pig, and keep out the tribe of other pigs that wander around the village lanes.

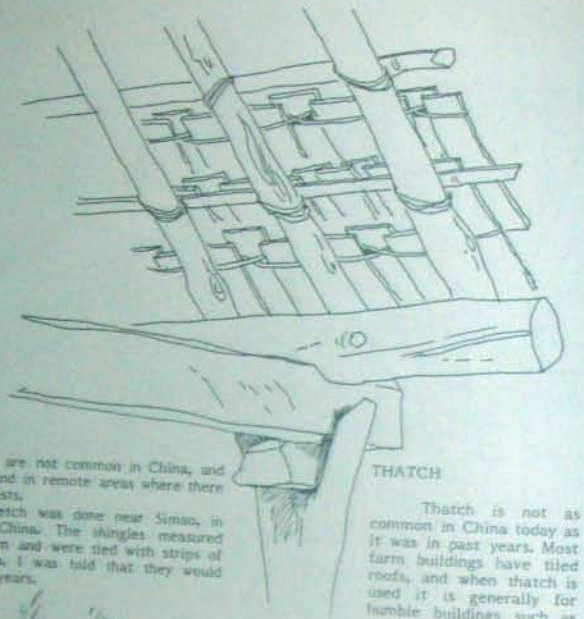
The home stands on poles well above the ground and has a roof of flat tiles.

The Dai people are very hospitable and I was often invited up into their homes for a glass of green tea.

In this remote area I needed two interpreters, a Dai girl, Yi Xiang-li who translated from Dai into Chinese, and my friend Wu who then translated the Chinese into English.

When we went further into the mountains it became even more complicated, for we had to pick up a third interpreter who spoke Aini and Lahu.

When I stopped to talk to village people all my interpreters got involved in the conversation !



SHINGLES

Shingles are not common in China, and are only found in remote areas where there are still forests.

This sketch was done near Simao, in south-west China. The shingles measured 470 x 110mm and were tied with strips of split bamboo. I was told that they would last 10 - 20 years.

A thatched stable near Zhengzhou. The thatch has been anchored on the eaves and ridge by a thick layer of mud and straw.

This makes the ridge watertight and also helps secure the roof during strong winds.

THATCH

Thatch is not as common in China today as it was in past years. Most farm buildings have tiled roofs, and when thatch is used it is generally for humble buildings such as stables and barns.

This is a partly thatched roof on a verandah near Guangzhou. Palm leaves are used, each frond jammed between lengths of split bamboo. The sketch is from the inside looking up.

One of the older Dai homes in Mung Ga Village. Nearly all the other village homes have tiled roofs. The heap of logs in the front yard indicates that this home is ready to be demolished and rebuilt.

Stairs below the house lead up to a covered porch. To the right is a platform which has a floor of springy split bamboo.

This open platform is common to all Dai homes and is where the women wash the dishes and prepare the food. A water jar can be seen on the platform.

The food is cooked inside the house on an open fire which burns on a sheet of tin on the timber floor. There are no chimneys and the smoke escapes through the ventilation holes below the ridge.

In Guangzhou I also noted this novel use of thatch. One of the walking tractors used to bring produce into the market had a thatched roof to protect the goods.

They are called walking tractors because they only have two wheels and the operator walks behind them. In this case a trailer is attached and the driver can bump along in relative ease.

A variety of thatching techniques are used in China. The most common is to fix the straw to the roof in bunches.

The Dai people of south-west China make thatch on long sticks and these are then tied down onto the roof.

The sketches on the next page were done in Man Yuan Village, in the home of Mi Wen Han. Her name means simply 'the mother of Wen Han' as the Dai people have no family names. When she was young she was called Special Jade.

She was sitting on a low stool, 150mm high, making thatch, and her hands moved so quickly that it took some time to sketch the process.

There were a pair of poles, one on each side of her and raised at one end, and on the raised end lay the thatching materials.

This was a stiff grass that resembled split palm fronds. She said that it took her a day to walk to the mountains, cut a bundle and carry it back.

In the sketch she is wearing the white towelling turban used by the valley people. The mountain Dai ladies wear black cotten turbans.

Across her knee she placed a 1.5 metre length of split bamboo. The thatch is tied to

It took 15-20 minutes to make a length of thatch 1.5 metres long. In this case it was being prepared for a hut in the fields 3.5 metres square.

Preparing a thatched roof of this size would occupy five ladies for two full days.

When I left she showed me her mud daubed beehive and this too had a simple thatched roof.

this using a length of bark fibre. The bark is collected in the mountains and brought down in 2 metre lengths, 100mm wide. The fibre is pulled off as needed, and not twisted in any way.

She slid five lengths of grass down the poles until they were under the split bamboo and tied them as shown.

To make the work easier a spare length of split bamboo rested between the layers and was withdrawn when the section was complete. This can be seen to the left of her hands.

EARTH ROOFS

Earth roofs are common in the dry areas of northern China. These sketches were made at the home of Kuen De-xu, high in the mountains beyond Lanzhou.

The people here are of Hui nationality and eke out a humble living in the arid mountains. Even though they have a tough life they are very hospitable, and the lady of this house insisted on preparing a large meal for me while I was sketching.

The smaller sketch shows a side view of a storage shed.

Roof construction in this dry area is simple and inexpensive. The rafters are little more than saplings 75-100 mm in diameter, spaced 200-250 mm apart, but even this material is hard to find in the bare mountains.

If the family can afford it a layer of thin laths is placed on the rafters at right angles to form a ceiling. If they cannot afford this they will use twigs, or a heavy type of reed shown in the sketch.

A layer of chopped straw is placed on this, cut roughly to lengths of 100mm and put on to a thickness of 50-60mm. This provides an insulating layer and also helps prevent moisture seeping through.

A layer of mud and chopped straw is put on this to a thickness of 50mm. When it is sufficiently firm it is compacted with the bare feet.

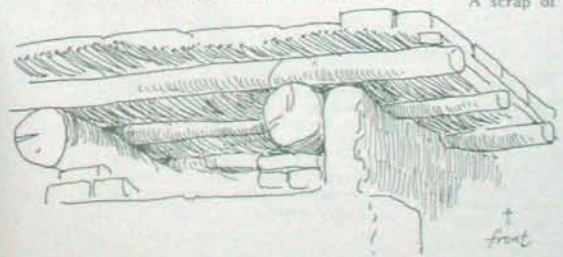
When this layer is partly dry another layer is applied and treated the same way.

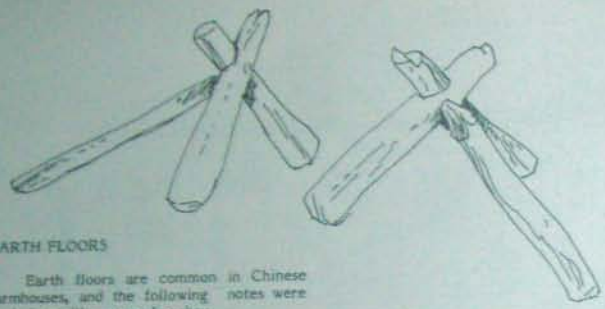
Sometimes a third , thinner, layer is applied composed of soil with 20%-30% of lime added. This gives a more waterproof finish.

The roof is given a slight slope, and this runs towards the courtyard. To prevent erosion along the lower edge when rain does occur a single or double row of bricks is placed along the lower edge with holes left every 2 metres.

A scrap of tile is often built into the roof below these holes to act as a lip and prevent the rain dripping down the mud edge of the roof.

The theory seems to be that the row of bricks slows down the water run off and confines erosion problems to the few places where the holes are placed, and where it can be more easily controlled.





EARTH FLOORS

Earth floors are common in Chinese farmhouses, and the following notes were made in a village near Lanzhou.

In this area there are three ways used to prepare the floor.

The most simple method is to dig up the floor and then ram it down again.

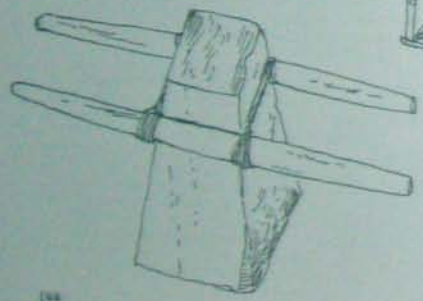
A better floor is made by digging up the floor and mixing freshly slaked lime with the soil before ramming it down.

My host said that the best surface is obtained by digging up the floor, ramming it down again, and then applying a 25mm layer made up of 1 part of freshly slaked lime, 7 parts of soil, and 2 parts of either ash or sand.

The mixture is made just moist enough so that it can be stamped flat. A common fired brick can be used for this job.

When a lot of floors or paths are to be rammed the tamper used for rammed earth walls can be used.

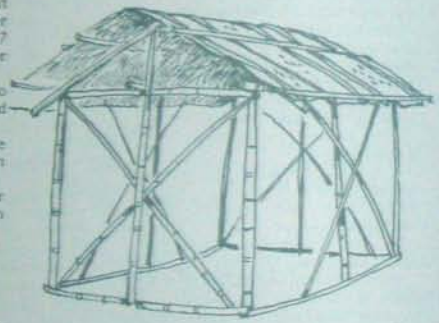
The sketch shows a two man tamper made from stone used to ram pathways on Mount Emei.



SAW HORSE

The sketches were done in Changsha and show a typical pair of Chinese saw horses, constructed quite simply from rough poles.

They are used in pairs, and the three legs ensure that they will stand firm no matter how uneven the surface.

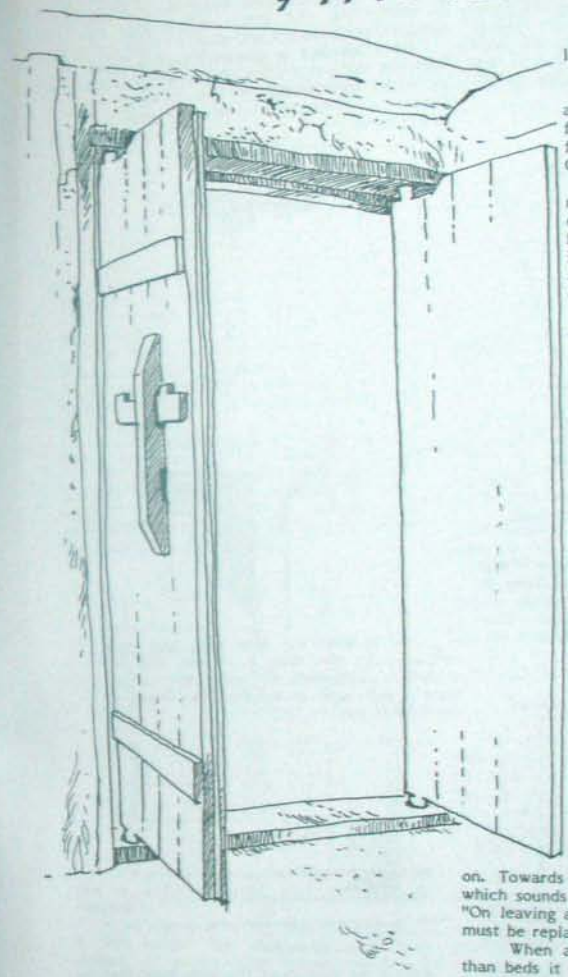


TEMPORARY BUILDINGS

On building sites the Chinese erect temporary huts using only bamboo poles tied together and covered with straw mats. Even the roofs are made waterproof with a few layers of mats.

Such huts can be speedily erected, and just as easily dismantled once they are no longer needed.

FITTINGS



1. DOORS

Many a Westerner looking at everything except his feet has taken a tumble when first entering an old style Chinese home.

This is because of the raised door sill that is a characteristic of the older buildings. This sill helps tie in the base of the building and also provides the place on which the doors pivot.

The sill increases in height according to the height of the doorway and the size of the building. The massive doors in the pavilions of the Forbidden City have sills that come nearly to knee height, and all visitors must step over them to enter the buildings.

The traditional doors do not have hinges as we know them but are fitted with pins which sit in holes in the sill and lintel. These doors are still popular in the country.

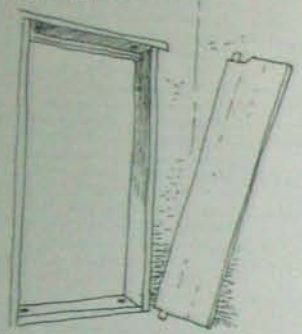
One advantage of this type of door is that the builder does not have to go to the trouble of purchasing metal hinges, but it has other, more unexpected, virtues.

During the Long March the troops were given a set of rules of conduct. These included such items as "Payment must be made for all goods obtained from peasants", "Prisoners must not be ill-treated", and so on. Towards the end came an instruction which sounds very odd to Westerners ears, "On leaving a house in the morning all doors must be replaced".

When a householder had more guests than beds it was a simple matter to lift the internal doors from their places and prop them up on some bricks to create a bed.

The troops were expected to put them back in the morning.

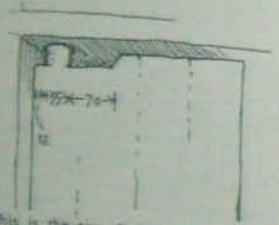
Walking passed the attractive old canal side homes of Suzhou it was interesting to notice houseproud ladies lifting off their front doors to give them a good scrub, and then leaning them against the wall on the street footpath to dry.



These doors are not difficult to make. The sketch shows the doorway and one of the pair of doors leaning against the wall.

The door is inside the room.

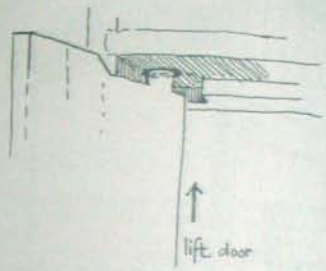
Even though the door can be easily lifted out of the doorway the design includes a clever feature which prevents a stranger on the outside from lifting out the doors. The doors are always made to open inwards for this reason.

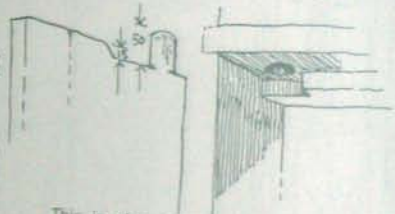


This is the top of the door in the closed position. To remove the door it must first be lifted upwards, but when closed this cannot be done.

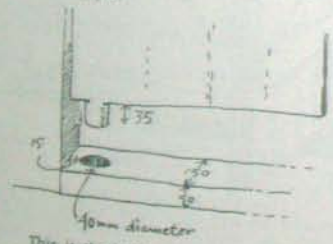
The measurements given here are only a rough guide, each door will vary according to the thickness of the timber used and the width of the door jambs. Once the principle is understood the measurements can be readily calculated for any door.

When the door is opened it will be found that the cut out section allows the door to be lifted high enough to free it from the bottom pin. Once this is done the door can be removed.





This is what the door looks like when removed. In this case a 15 mm cut out section is sufficient, but often the cut out section will need to be the same depth as the bottom pin.



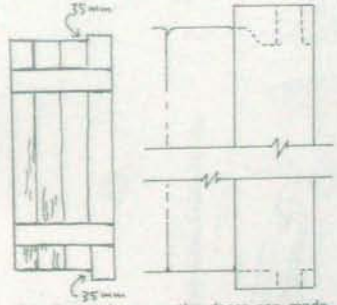
This is the bottom of the door, note that there is no cut out here.

There are two common ways of making the door. One way is to take a stout piece of timber and shape it into a pin at either end. The door is then fitted to this as illustrated.

This sketch was done on a commune near Guangzhou. The home was of two stories, consisting of kitchen, sitting room and three bedrooms. The rooms were not large but were adequate.

The house was of fired bricks and had cost 4,000 Yuan to build (A$2,400).

This was rather more expensive than building in earth, for instance a single storied 7 room mud brick building on a commune near Changsha had cost its owner only 2,000 Yuan (A$1,200).



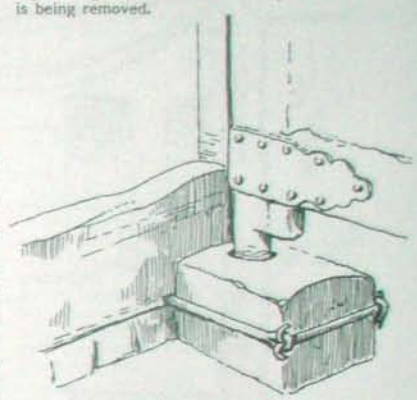
This is another way the doors are made, and is a little easier than the previous method.

When the door is put together one plank is left longer than the others and then shaped as shown. The measurements are only intended as a general guide.

When the shape has been cut out the pin is shaped by hand. Holes are then cut into the sill and lintel to take the pins.

The lower hole is made just a little less in depth than the pin, while the upper hole must be made deeper than the pin.

This is to allow the door to be lifted up high enough to free the bottom pin when it is being removed.



The lower part of one of the entrance gates to the Great Mosque in Xian, drawn from the inside looking out.

The high sill over which the visitor has to step is on the left. The door does not sit in a hole in the sill but in a block of stone which is attached to the sill with steel rods.

Note the interesting way in which the steel rods have been fastened together.

The next sketch was done on a bitterly cold day in Peach Flower Village, near Lanzhou, north-west China, March 8 1983. It had just begun to snow and an old man, Zhu Yan-chang, invited me into his home and sat me by the stove.

I did the sketch from this snug position.

He said that his father had made the doors in 1928.

In this case the doors do not sit in the high sill but rest in carved wooden brackets that are attached to the sill.

The windows in these older homes have no glass but are covered with paper. Security is provided by filling the window

space with a decorative grid of small timbers.

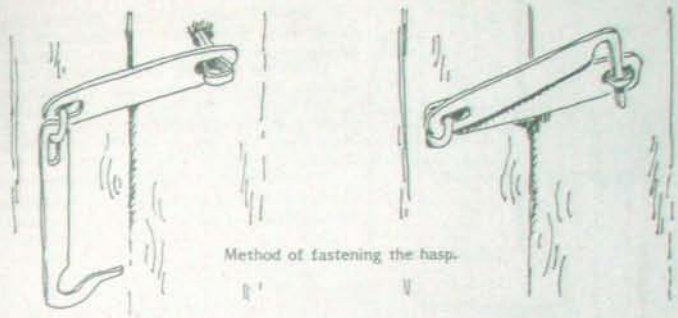
White paper was pasted over the grid, and in this case a red paper-cut of rather decorative lions was pasted in the centre of each window.

The curtain hanging in the doorway is common in this area in the winter. There is little or no wind here and so the door can be left open and the curtain hanging down in front is enough to prevent the cold air moving in and the warm air escaping.

My host hooked his curtain up while I did the sketch, but the other homes that can be seen through the doorway have their curtains down.

These doors are usually barred with timber bolts, but in this case the door was locked with a small but efficient iron hasp as illustrated.

The pieces measured 150 x 21 x 4 mm.



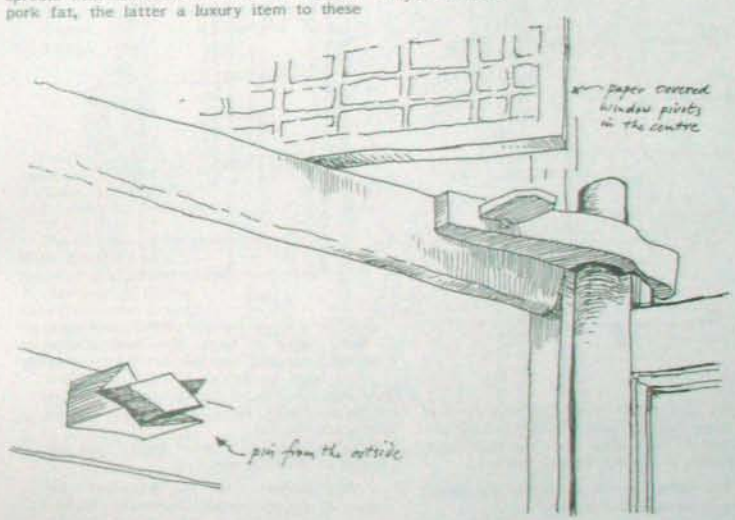
Method of fastening the hasp.

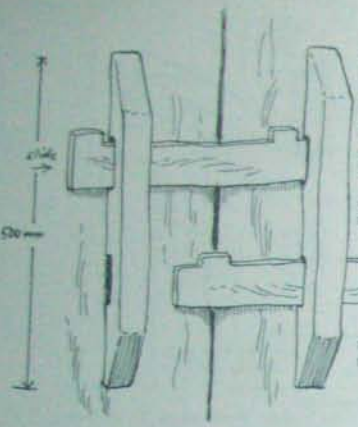
One benefit of travelling in northern China during periods of bitter cold is that people will often invite a visitor into their homes to get warm.

This sketch was also done from beside a stove, this time high up in the mountains above Lanzhou. The hospitable young housewife not only sat me by the stove but insisted on cooking me a meal of bean sprouts with some onion and small cubes of pork fat, the latter a luxury item to these mountain people.

In this case the door did not fit into the lintel, but revolved in a wooden bracket which was attached to the lintel with a wooden pin.

The smaller sketch shows the pin from the outside of the room. It has been cut into an ornamental shape, and although this looks complicated it is actually created with only 8 saw cuts.



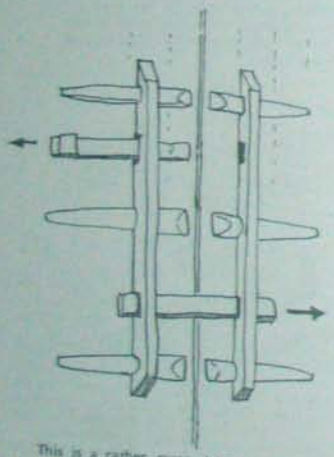


This is the traditional Chinese door catch. Made from timber it consists of two sliding pieces which fit into holes as shown.

There are no fixed dimensions for these catches, they are simply made in proportion to the size of the door. For an ordinary house door the uprights might be 500 mm while the sliding pieces will be just a little less than one half of the door.

The sliding pieces usually have some sort of an end on them to prevent them slippling right through the slots.

In this case the sliding pieces have been made so that they cannot slide through the slots at either end, and so cannot be lost.



This is a rather more elaborate form of the same type of lock, but in this case only one end of the sliding piece has been shaped to prevent it slipping through the slot.

The other horizontal pieces are simply there to strengthen the door.

This is a larger version of the same type of door, noted in Xian. This door opened from the courtyard into the street.

The level of the courtyard was higher than the street, and so the bottom sill is not evident here, but can be seen from the street side.

The bottom sill is never buried into the ground, as it would soon rot.

This sketch shows the door from the inside of the courtyard. Observant readers may already have noted one curious aspect of this type of lock. It can only be locked from the inside.

How then does the returning householder get inside?

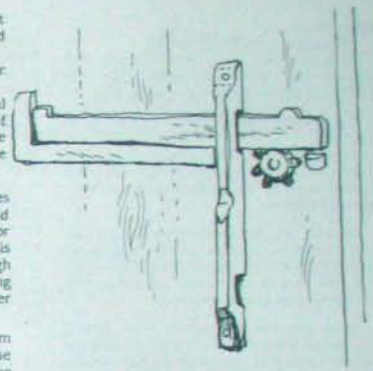
The answer is that in the traditional Chinese courtyard house a number of generations of the family will share the house, and so there will always be someone at home to lock and unlock the outer gate.

However when a doorway simply divides two courtyards within one household modifications can be made to allow the door to be opened from either side. One way is to cut a horizontal slit in the door through which a pin can be placed into the sliding part, and so it can be moved from either side.

Another solution to the same problem was sketched in Guangzhou. In this case there was a knob on the opposite side of the gate, and this was fixed to the simple wooden cog wheel shown in the sketch.

The sliding piece had holes drilled in its base, so that as the knob on the outside was turned the cog pulled the sliding piece open or shut.

Notice that the sliding piece rests on an L shaped piece of timber to keep it horizontal.



I made a pair of Chinese doors for our kitchen in Kuranda, and have found them to be very practical.

The walls are of mud brick plastered with a mixture of mud and straw. At the time of writing they have gone through two monsoon seasons without without even showing surface erosion.

Timbers for the rafters and frame came from our own logs, and were used in the round.

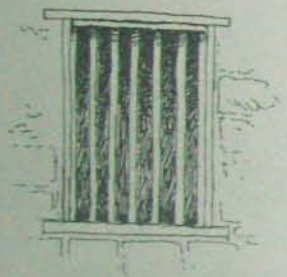
WINDOWS

Conventional glass windows are now common in the countryside, but the traditional windows are still also in use.

A window should fulfill a number of functions. It should let in the light and provide ventilation, but it must also be able to provide protection against high winds and driving rain. It must also provide security against intruders.

Security can be achieved by putting bars on the windows, and this practise is common in rural China. In owner built homes the bars are usually of timber as this is the most readily available material.

While a barred window lets in the light it also lets in driving rain and wind. In tropical Australia this was solved by fitting shutters that hinged outwards and upwards.



The Chinese solved the problem in the opposite way, fitting shutters that hinged inwards. The main reason for this is because it is difficult to open a shutter outwards when bars have been fitted to the windows.

A shutter opening inwards also lets in more light than one opening outwards, and this is important when the windows are relatively small.

In addition inward swinging shutters are not affected by sudden gusts of wind, and can be left open in all but the worst weather.

The sketches of a window from the outside and inside were made at Changsha, and are typical of the older houses in this area.

In other parts of the country the bars are not obvious as such, but are made up into decorative grid patterns.

Paper can then be glued over them to provide protection against the wind, as mentioned earlier in the section on doors.

In warmer parts of the country the paper is not needed, and the windows provide a decorative feature to the house.

Mud bricks, fired bricks and tiles can all be used to make windows secure as well as being attractive at the same time.

Curved roof tiles have been used to make this decorative pattern in the small window of a village home near Xian.

Sometimes the tiles are fixed with lime mortar, at other times they are only wedged into place and held on the outside with the mud mortar that goes around the window. This latter practise is common when the window is out of reach high on a wall.

These windows provide a good example of using up whatever spare materials are available around the place to produce a decorative feature.

A window high up in the wall of a village house near Xian. This particular design is common in the area, and is made by fitting curved roof tiles into the wall as it is being built.

This sketch shows an old temple in Golden Horse Village near Kunming. It has fallen into disrepair and is now being used as a commune storehouse. The peeling plaster reveals the mud brick construction, and the decorative ridge ends show that it was once an important building.

The circular windows on either side of the doorway show a complex pattern made up from nothing more complicated than ordinary fired bricks.

WINDOWS IN A WARM CLIMATE

Simao, March 2 1983.

My sketch shows a rammed earth home near Simao in the south of Yunnan Province. It was typical of this area and was in a cluster of a couple of dozen houses that made up Pear Tree Village.

This was the home of Yang Wei-gao. It was only four years old but looked a hundred, and had cost 2,000 Yuan (A$1,200).

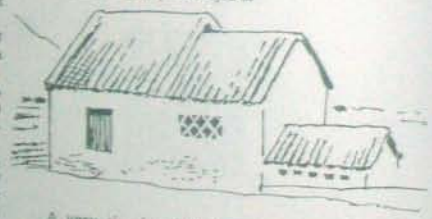
The rammed earth walls were very thick, 630 mm, probably because this is an area which sometimes suffers from earthquakes. The back wall was 4 metres high.

Most Chinese homes have high ceilings, but here the tradition is to have very low ceilings on the ground floor, only just above head height. And while people in other parts of China prefer to sleep upstairs here the living quarters are all downstairs.

The upper floor is devoted to storing grain, corn and farming gear. Although the walls are also low upstairs the area is much more spacious because of the roof cavity.

The windows have no glass but instead are made up into patterns with pieces of timber. This allows light and ventilation while providing security.

I sketched this from the door of the family woodshed, with a wooden plough leaning against the wall. Then the farmer's wife brought out tea and we sat on tiny stools in the sunny courtyard.



A very simple window can be created by simply leaving gaps between the bricks when building the wall.

In this sketch of a farm building near Guangzhou. The large window is secured with a wooden shutter. Even when this is closed light and air can still get into the building through the diamond shaped holes in the wall.

These have been created by laying bricks at an angle during building. The pigsty to the right has small windows created by leaving gaps between bricks.

THE KANG

The kang (pronounced kung) is the traditional bed of northern China. Constructed of mud bricks it is a hollow platform which is heated in the winter. As well as being the family bed it also provides a place for sitting during the day.

I did this sketch on March 8 1983, in the home of Song Zong-feng, Liu Jiaping Village, near Lanzhou.

An iron stove sits in the centre of the room and on it a kettle and two glasses of green tea. Behind the stove is the kang.

I was sitting with my back against one wall to do the sketch, and although I saw the area in the sketch as being one room my host described it as two.

When I asked why he pointed to an exposed beam that cut across the ceiling and said that by convention this divided the area into two rooms.

The kang actually occupied the whole of one of these 'rooms'. It was 3.2 metres wide and 2.4 metres deep.

The family valuables are kept in locked trunks that sit on the kang, probably kept there so that the contents will not be affected by dampness.

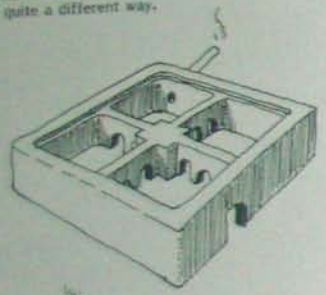
The family bedding was folded on the other side of the kang, and reproductions of paintings and calligraphy were pasted on the walls. This kang was of average size, but later in a century old house I saw one that measured 3 x 3.5 metres. Both the kang and the house were of mud brick and still in excellent condition.

A fire is lit in the kang each day before nightfall during the winter months. The fire is only small by our standards, and as soon as it begins to die down the entrance is closed so that cold air will not enter.

One farmer said that it took about an hour to heat the kang, and used a basket of mixed horse dung and twigs. He said that sometimes they used coal to heat the kang and he found that 3 kilos would last for 8 days.

The interiors of the kangs are designed in a variety of ways, but once complete it is impossible to see the interior maze.

One broken kang in a deserted house showed a herringbone pattern inside, but an old man near Lanzhou described his kang in quite a different way.



First an outer wall of mud brick is built with an opening for the fire on one side and an outlet for the chimney on the other. In some places, such as the cave homes of Xian, the fireplace is inside the room by necessity, but in conventional homes it is usually outside.

A column is built in the centre of the kang and four mud brick walls radiate from this. There are openings in the bottom of the walls for the heat to pass through.

The top of the kang is made with large panels when this type of design is being used. The sketch shows a mould used for making the panels. This makes a brick 920 x 800 x 70.

The mould was put together with a simple mortice held by a peg, and in addition twisted strings held it together even tighter.

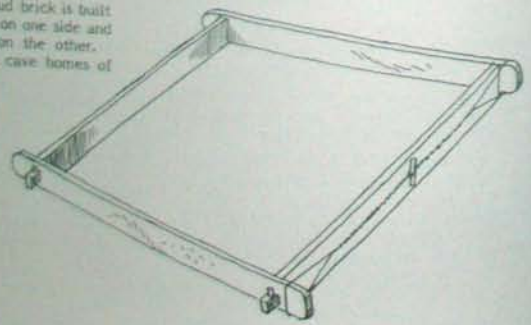
When making the bricks 8 mm steel reinforcing was placed in it for added strength. The steel rod was tied together with tie wire to form this shape ⊠ . The brick was made from clay (not soil) with plenty of straw in it.

When dry the top panels were fitted to the kang, and rested on lips cut into the mud bricks, or perhaps the lip was built up with smaller mud bricks. In either case the panels sat flush with the top of the outer wall.

The whole top surface was then given a smooth coat of mud and straw plaster, similar to that used on the walls.

When this was dry a couple of stiff mats of split bamboo were placed on the top, and then blankets. No mattress was used.

Not only is the bed hard, but in the country the pillows are equally as rigid, often only a house brick wrapped in patterned paper, or a special shape made from pottery. There is a superstition among some of the old people that such a pillow is a safeguard against certain illnesses.



INDEX

THE CHINESE are probably the world's greatest builders in earth. Everything from the humble hen house to the Western part of the Great Wall of China is of earth. It was estimated in 1983 that there were at least 90 million earth homes in China.

This book looks at the various ways that earth can be used in building, and explains various techniques used by the Chinese which would be of great interest to any Westerner planning on building in earth.

RON EDWARDS

Born October 10 1930 he is best known for his books on Australian crafts and folklore. Among these are *Bushcraft 1- Australian Traditional Bush Crafts, Bushcraft 2 - Skills of the Australian Bushman, Basic Rammed Earth, Mud Brick Techniques, Building a House in a Day – Cob building techniques*

Between 1977 and 1991 he made 14 trips to China. The sixth visit was sponsored by the Australia-China Council, a Federal Government body, for the purpose of gathering material for this book. Because of the semi-official nature of this visit the Chinese Government allowed him to travel freely to many remote villages not normally seen by foreigners. He made roof tiles in a village near the Burmese border, helped build a rammed earth wall in Kunming, and made rammed earth bricks in a village near Xian.

He has incorporated various Chinese earth building techniques into his home at Kuranda, north Queensland, to prove that earth building techniques are practical even in monsoon areas.

Left, Ron Edwards working on a rammed earth wall in Kunming, China

LIN WEI-HAO

Born November 28 1944. Following the Chinese custom the family name comes first. At the time this book was written he lived in south-west China in Kunming, known as 'the city of eternal spring'. His research has shown that 95% of the buildings in the countryside around Kunming are of earth construction, so his writing on the subject comes from firsthand observation.

He met Ron Edwards by chance in Kunming in 1979, and so began a firm friendship that led to the writing of this book. At the time he worked at the Yunnan Provincial Research Institute of Architectural Science, translating writing on building and architecture from English into Chinese, German into Chinese and Chinese into English. He now lives in Sydney.

Right, Lin Wei-hao making mud bricks in Kuranda, Australia

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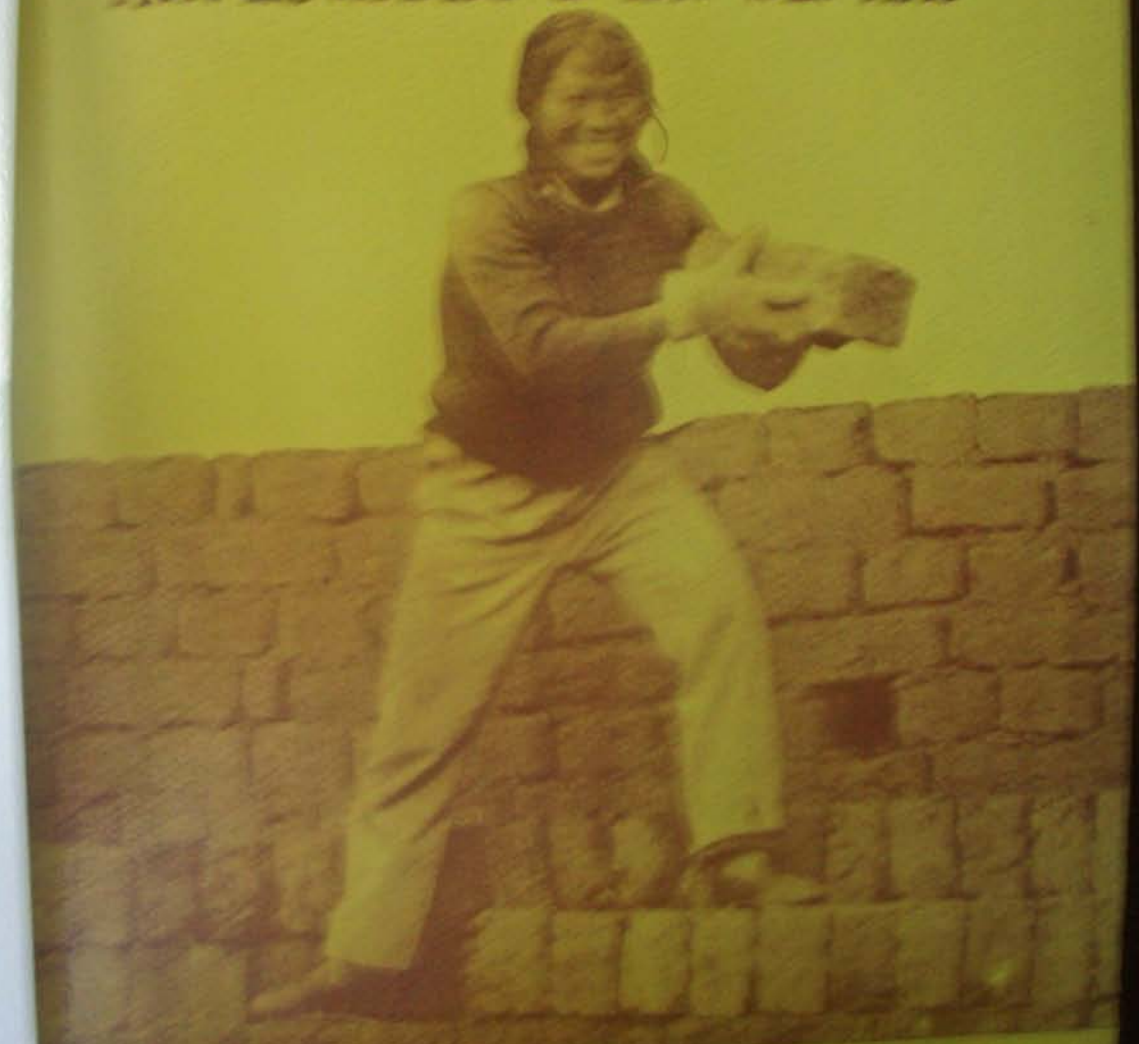
RON EDWARDS & LIN WEI-HAO



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