DEVELOPMENT TECHNOLOGY UNIT

Working Paper No. 35

Materials for Low-Cost Building in North East Nigeria

1991

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Building Materials Survey

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Introduction:

The survey was undertaken in two parts. In the first, visits were made to a variety of educational and government institutions and building material manufacturers in Northern Nigeria in order to assess present practices, availability and cost of materials, and their advantages and disadvantages. In the second, a visit was made to the North East Arid Zone and several villages and other sites were visited to assess present building practices.

Samples of some typical masonry building materials were taken and their compressive strengths evaluated at the Department of Building and Civil Engineering at RAMAT. The results are contained in Table 1, and show that there is considerable variation in quality and that some, concrete blocks and the stabilised soil cement blocks used by the Borno State Housing Corporation, are of a consistently low quality.

Suggestions for improvements in building and building materials were made particularly with respect to RAMAT and RAMCAT involvement with NEAZDP.

Prompt action on there recommendations would ensure that they could be incorporated in planning for 1992.

Relevant references for additional information have been included where appropriate.

Table 1 Compressive strength of some Northern Nigerian masonry building materials

	Clamp fired bricks [MPa]	Kiln fired bricks [MPa]	Concrete blocks [MPa]	Stabilised earth blocks [MPa]
	2.42	3.70	2.62	0.62
	3.11	5.46	2.86	0.99
	4.18	6.04	3.10	1.23
	4.69	6.24	3.34	2.09
	4.79	6.63	3.58	2.46
mean	3.84	5.61	3.10	1.48
standard deviation	1.04	1.15	0.38	0.77

NB. No aspect ratio correction has been made.

Earth Blocks

Outside the largest cities earth blocks are the traditional and most common building material.

The earth blocks are made from a blending of the soil profile (relying on feel and experience to assess its suitability), mixing it with sufficient water to make a soft mix, and forming the blocks in simple wooden moulds.

The blocks are sun dried and turned regularly to minimise cracking or warping through uneven drying.

At Kaska and Yin in the North East Arid Zone a considerable quantity of fine dry grass is also added to the mix.

The mortar and render which are more durable than the blocks, are made from the same soil with cow dung added. Split Azara palm was used for reinforcing. Roofing, either flat or domed was formed by short lengths approximately 1m long, of split Azara palm, covered with Azara palm woven mat and further covered with a layer of earth of the same composition as the walls. Internal walls were protected with a white clay whitewash with no additives. Durability of the earth walls and roofs was the major problem identified. Some roofs had collapsed.

Sadly, the Emir's palace at Yorgoram which was in excellent restored condition just six months ago was now in a serious state of disrepair, with walls and roofs collapsed, including a portion of the entrance gate. A significant factor in this deterioration apart from the poor durability of the soil, would appear to be termite attack of lintels, arch supports, reinforcing and other timber parts of the structure.

On some sections of the Emir's palace coatings of bitumen (roof of toilet) had been used to significantly improve durability. Another technique was to take the shell of the fruit (Kuba) of the Dorawa tree, soak it in water and use this water mixed with earth to make a hard, black protective coating.

At Yin, termites also appeared to be a significant factor in the deterioration of earth buildings. Bitumen disolved in kerosene and added to the earth render was reported to greatly improve its durability. The bitumen costs about N45 per 50kg bag and with the kerosene would be comparable in cost to cement stabilised render. Bitumen was reported to not always be easy to obtain in the market.

Used unstabilised and unprotected from rain earth blocks need regular attention to maintain their structural integrity. Renders are often employed to protect the earth blocks. These may be of a similar composition to the block itself, a gypsum(?) plaster or a sand/cement render. Studies conducted at ABU by Solanke (1984) have shown that the sand/cement render is the most durable but has poor adhesion to the earth blocks. Mud and gypsum plaster/renders adhere better but are less durable. It would appear that few attempts have been made to make stabilised blocks thus largely negating the need for a render. Similarly, no studies have been done to assess the cost difference between cement stabilised blocks and un-stabilised blocks with a cement render.

Earth blocks may be improved by attention to the mix composition and the mixing process, compression, stabilisation and curing, by rendering, and by attention to the design and construction of the building in which they are used (eg. overhanging eaves or verandah, damp course, positioning of windows and doors to minimise structural stresses). Siting of the building and choice of roofing materials may also imporve its comfort and usefulness. Secure attachment of roofing to earth buildings seems to be poorly understood. A brief description of various suitable techniques is given by Middleton (1987;3).

Palm Building Materials

Some buildings utilised Goruba palm in Y shaped post and beam construction with Azara palm woven panels for walls and roofs. Sometimes a thinner bent frame was used. The woven Azara palm lasts 2-3 years before it has to be replaced. The Goruba palm is very durable and is termite resistant. It is recycled from old buildings when they fall into disuse. Small quantities of galvanised iron were used, usually for doors and for open spouts to conduct water from earth roofs.

Recommendations

Essentially there are two main problems to address; the poor durability of the earth material and the termite attack of timber in the buildings.

1. Earth Durability

The durability of the earth material itself can be improved in various ways; by attention to the making of the blocks, by the development of effective protective coverings, by design changes to the buildings or by a combination of these.

Making blocks.

Some improvement in the durability of the earth blocks is likely with more thorough dry mixing of the materials, i.e the earth should be dried and crushed to a powder, mixed, then water added slowly as it is returned to a mouldable condition. Whether the extra work involved is justified by the improvement in durability achieved should be determined by some simple tests conducted in the villages and under RAMCAT/NEAZDP supervision.

The binding quality of the clay may also be improved by ensuring the water used is acidic. This can be simply achieved by testing with pH indicator strips and adding citric fruit juice. RAMCAT/NEAZDP should again supervise.

Further and much more significant improvements in the durability of the blocks may be achieved by stabilisation of the mix with small quantities (approximately 5% - 10%) of cement or bitumen and by forming the blocks in a simple hand operated compression machine. Research has shown that compression is most important in improving water resistance of earth blocks (Ola, S.A. and Mbata, A; 1990).

However, an initial inspection of the earth block making machine (made by RAMAT and based on an existing design) which was used by the Borno State Housing Corporation in their recent Maiduguri hosuing project, indicates some serious deficiencies. It appears that the machine applies very little compression to the blocks, particularly as it becomes clogged in use.

This was supported by the general "loose", uncompacted appearance of the blocks and also by their very poor compressive strength (mean 1.48 MPa), despite containing 10% by volume of cement. They are not likely to be very durable although fortunately most of the buildings are rendered. It is of great concern that in the first really significant application of compressed, stabilised, earth block building that such poor results have been obtained. There is an urgent need for RAMCAT to be further involved in this project in order to monitor the performance of the buildings, to review the block making and construction process (very quick but poor quality) and to evaluate other block making machines, of which various types are available. It is likely that the most appropriate block making machine will be of a simple and uncomplicated design, robust construction and able to be used effectively by unskilled labour.

Some other points to examine include:

- the adequacy of the mixing procedure
- the use of the coarse laterite material which was transported a considerable distance
- variations in cement content
- Cost comparisons of stabilised blocks with unstabilised, rendered blocks and other building materials/construction methods
- the residents' response to the houses and housing development in general. (RAMCAT and RAMAT Dept of Architecture and Town Planing) This is known as post occupancy evaluation and provides useful feed-back for future improvements.
- pressed blocks made with a cinva ram type device could be tried with interested block makers to assess the response to this technology. (RAMCAT/NEAZDP)
- a joint project with ABU could examine the problems associated with render durability and adherence.

The durability of blocks can be assessed using a water erosion test rig for which Warwick University has a design. Durability of blocks should also be assessed but the project should not be delayed while the water erosion test rig is built. The previously mentioned evaluation of block making machines and construction processes is more urgent at this stage.

Protective Coverings.

Earth walls can also be made durable with a protective render or other protective covering. Various possibilities exist which should be evaluated by RAMCAT in association with NEAZDP and preferably with builders rather than in the laboratory.

i) cement stabilised render

ii) bitumen stabilised render (also more likely to deter termites)

iii) render made from termite mound soil

iv) protective coating of vegetable oil or vegetable oil/clay mix. Palm oil and ground nut oil should be evaluated. Linseed oil has been found excellent in Australian conditions but does not appear to be available. Other possibilities for earth wall protective finishes have been tried in Ghana (Schreckenbach, H, 1991;21).

Design Changes.

Protection of earth walls can also be achieved by simple design changes in buildings;

i) use arches for doorways and windows as this reduces the tendency for cracking and hence water ingress. It also conserves the wood that would have been used in lintels and reduces the possibility of termite damage. Arches require wooden form-work for their construction but this can be reused. A technique using car tyres as arch form work has been used elsewhere (Stulz, R and Mukargi, K. 1988) and should be tried with Nigerian earth builders.

ii) Fix panels made from Azara palm woven mat to the walls to keep them dry.

iii) Extend the roof to have approximately 1m eaves or surround the building with roofed verandahs.

iv) Make the roof structure independent of the earth walls using termite resistant Goruba palm posts and long Azara palm roof timbers and woven mats. An earth coating could be optional. (see Figure 1)

v) Give roof structures sufficient slope (pitch - greater than 10^o) to ensure water run off. (see Figure 2)

vi) Site buildings on raised ground and place drainage channels to keep surface water away from the walls. (see Figure 3)

vii) A radical suggestion is to build underground but thorough assessment of the suitability and stability of the soil, particularly in the wet season, is essential before this is done.

RAMCAT/RAMAT/NEAZDP should initiate and conduct courses on site in villages building model buildings to illustrate some of the above points. In particular basic design and construction techniques appear to be the least costly for builders to implement yet should result in significant improvements.

2. Termite Resistance

Termites are attracted to wood or biomass materials which contain cellulose which is their food. Some woods contain oils and other chemicals which repel termites making them termite resistant. Termites live underground, from where they gain entry to wood in contact with the ground. They perfer dark moist conditions. It follows that if timber parts of buildings are not in contact with the ground, and the amount of timber or other biomass they contain is small, then the chance of termite damage is greatly reduced. Use of termite resistant timbers also reduces the possibility of termite damage. Periodic inspection of exposed timber sections of buildings is also a good preventative measure as any termite conduits found can be destroyed before damage becomes serious. Reducing the amount of non-termite resistant timber in buildings and grass (biomass) in earth blocks will reduce the attractiveness of the building to termites. The use of termite resistant timber where ever possible, and particularly in hidden applications, is highly desirable.

The use of chemical barriers (soil impregration with chlordane or similar chemicals) must not be used because the water supply will become contaminated. Chemical impregration of timber or coating with waste oil, creosote or similar materials is likely to be costly and not necessarily very effective.

The introduction of some of the other recommendations, such as stabilisation and design changes, should enable durable buildings much less susceptible to termite damage to be built. RAMCAT and the Department of Agriculture at RAMAT will soon be commencing a project to improve grain storage structures. This would provide an ideal opportunity to trail the above recommendations in a practical and small scale manner.

The association with NEAZDP should provide access to well organised field offices and villages, for constructing the trial structures.

Fired Clay Bricks

Fired clay building products are made by techniques ranging from extremely simple, through intermediate to highly sophisticated. At the extremely simple end of the continuum clay and sand which occur naturally together in river banks are mixed with water and kneaded by foot to a soft plastic state. The bricks are formed in simple wooden moulds, sun dried and fired in a wood fired clamp kiln. The clamp kiln is very inefficient and costly to operate and the bricks produced are of a very variable and low quality. In particular, they appear to be neither very strong nor durable. They sell for N0.30 per brick. These brickmakers are disheartened by the lack of follow-up from earlier studies of brickmaking and lack capital to improve their production facilities.

The British built Government brickworks at Maiduguri is over 50-years old and represents an intermediate level of brickmaking technology. Similar materials and preparation as described above are used by these brickmakers. The bricks are made on a moulding table in simple wooden moulds and dried slowly under cover before firing in a downdraught wood fuelled kiln. This kiln is well maintained (internal walls are replastered with clay/sand mix after every 3 firings) and relatively efficient. Each firing contains 25,000 bricks of which 3,000 are rejects (ie 12%). Some of these are salvageable as half bricks.

The bricks sell for N0.20 per brick and are of a fairly consistent quality. About 30 people are employed and live on site with their families. Brickmaking appears to have become a family tradition and they are proud of their work and achievements.

During the early 1980s a continuous clay product extrusion plant was built in Maiduguri by a German Company. This plant only operated for about five years. The major reasons for the failure would appear to be inadequate assessment of the raw materials, poor quality control of the materials in the factory and lack of adequate technical training of personnel to operate the plant, including the gas/oil fired tunnel kiln, when the German management left.

About the same time a similar plant costing N5m was set up nearby by the Federal government. The plant utilised two large oil fired Hoffman kilns. This operation also failed reportedly due to a lack of marketing management expertise; the company being unable to adjust successfully to fluctuations and competition in the market.

The critical need for precise technical control in continuous production operations makes such systems inappropriate where the requisite skills are lacking or not developed. They are also inflexible manufacturing systems.

Other large scale brickmakers were observed; some closed and others operating. The viability of such operations depends on many factors which can vary, sometimes quite quickly (eg. markets) and so require skilled and flexible management as well as technology. Capable, well trained management able to plan and adapt to changing conditions is an important aspect of the success of such plants.

Recommendations

Further improvements to intermediate technology brickmaking plants may include:

* improved mixing and moulding with a drier mix and simple hand press.
* Use of simple kiln monitoring techniques such as pyrometric cones to identify cool/hot spots in kiln and to reduce these to give a more consistent product.
* Sorting and pricing of bricks according to quality and intended use (likely to be difficult while bricks are in short supply).
* Setting up of similar intermediate technology brickmaking in other areas.

* Reduction of fuelwood use by incorporation of waste oil burners of the flat plate drip feed type.

RAMCAT should make contact with the Maiduguri brickmakers to discuss the above points and plan action where necessary. Specific technical backing may be provided by Warwick University and other useful information is provided by Beamish, A and Donovan, W (1989).

RAMCAT could also conduct basic bricklaying courses and investigate the need for multi-skilled builders courses.

<u>Concrete Blocks</u>

Small and medium scale concrete block makers are common throughout Northern Nigeria.

A typical small scale concrete block maker employs three people and produces about 320 blocks per day from seven bags of cement and 35 barrows of sand. Cement costs 65-75 Naira per 50kg bag, sand about N200 for $10m^3$. The price of cement is rapidly escalating at present, from N65 to N90 in less than a month.

The mix used is usually quite lean, 1:10 by volume, and the blocks are often dried in the sun and sold after 3 or 4 days. The concrete is mixed by hand but a mechanical press is used to form the blocks. Waste oil or similar material is used as a release agent. Water may often be contaminated with organic matter. The blocks sell for around N4.30 each.

A larger plant with a multiple mould machine was seen at Maiduguri. This plant was designed to produce three times the present production but as machinery became in-operable it was scavenged for spare parts. Minor maintenance and repair did not apppear to be of concern. (A simple repair to a mould, which would have been easily within local capacity, was not attended to even though it produced a defective block). It appeared that because defective blocks could still be sold at the full price there was no perceived need to repair the production equipment. At this larger plant mixing was mechanical and the mix was transported to the block making machine by a mobile skip. Blocks were also wet down each day. A sample of blocks from where the blocks were wet down four times a day for three days were tested. Their compressive strength was poor, averaging 3.10MPa. (See Spence, R.J.S. and Cook, DJ 1983;89). It should also be noted that there blocks had undergone the best curing regime seen; others would be much worse.

The effects of cultural differences in perceiving and understanding production problems with concrete blocks has been discussed by Harder (1991) who suggests that special training is probably necessary.

Recommendations

Improvement to the quality of concrete blocks made could be achieved through:

* proper mix ratios/water content
* proper moist curing
* maintenance of machinery and equipment.

RAMAT could organise short courses held in afternoons, on simple concrete block making technology, including maintenance of equipment. RAMAT could sponsor a block making industry group to discuss common problems in the industry with the aim of improving standards of production.

Roofing Materials

Traditional thatch materials are used in some areas but have largely been replaced by galvanised iron. Light gauge galvanised iron costs approximately N520 for 20 standard 8ft x 4ft sheets. Corrugated fibre cement sheeting is slightly more expensive, costing almost N27 per m^2, for the cheapest sheet.

Galvanised iron is easy to transport and fix, but has a limited life. Fibre cement sheet requires some special skills to fix, but is more durable than galvanised iron. Fibre cement sheet also keeps the building cooler than galvanised iron.

The sole Nigerian owned fibre cement sheet manufacturer, Turners Building Products Limited at Kaduna, is currently trying to eliminate the use of asbestos in its products.

Wooden roofs with earth cover are also used occasionally but require significant maintenance.

Recommendations

* RAMCAT to conduct short practical courses in rural area, on fixing fibre cement sheets.
* RAMCAT to develop and run courses in rural areas on the fixing of roofs to earth building.
* RAMCAT to explore the possibility of a joint research project with Turners on the elimination of asbestos from fibre cement sheet. Apart from the obvious health benefits such a project also means import replacement as asbestos is currently imported from Canada.
* RAMCAT/NEAZDP to investigate the potential for intermediate technology fibre cement roofing tile manufacture in rural areas.

Miscellaneous

Some general points of interest;

* products developed by students and staff at the Institute of Agriculture Research at ABU are advertised in the local press to find manufacturers. The manufacturers have the right to the design in return for a donation of money or equipment to the Institute. Manufacturers may also sponsor further product design and development.
* Some University staff and students see development oriented projects, particularly those of a practical nature, as being of low prestige. Reward systems to alter this perception should be instituted in tertiary educational organisations.
* During travels in Nigeria it has become apparent that there are many geographic similarities with parts of Australia. Problems of development and the role of appropriate technologies in remote communities lacking in resources are also common to Australia. Study tours or other means of Nigerians living and working in selected parts of Australia may be very useful training and educational experiences. The Centre for Appropriate Technology in Central Australia may be a useful model on which RAMCAT and NEAZDP can improve their mode of operation.

Acknowledgements

The author would like to thank Ibrahim Mshelia, Head, Department of Civil Engineering and Building at RAMAT, Habu Yalwa of RAMAT, John Higham and Alistair Dunn of Warwick University for their assistance in the collection of the data on which this report is based.

Thanks are also due to the Rector of RAMAT Alhaji Baba Gara Tijani, Bellar Mamza, Head of RAMCAT and Gaban Tembo of NEAZDP for their support and the Warwick/RAMAT linkage for making this study possible.

The author is also very grateful to those individuals and organisations which gave freely of their time. Without their contribution the study would have been superficial and of little real value.

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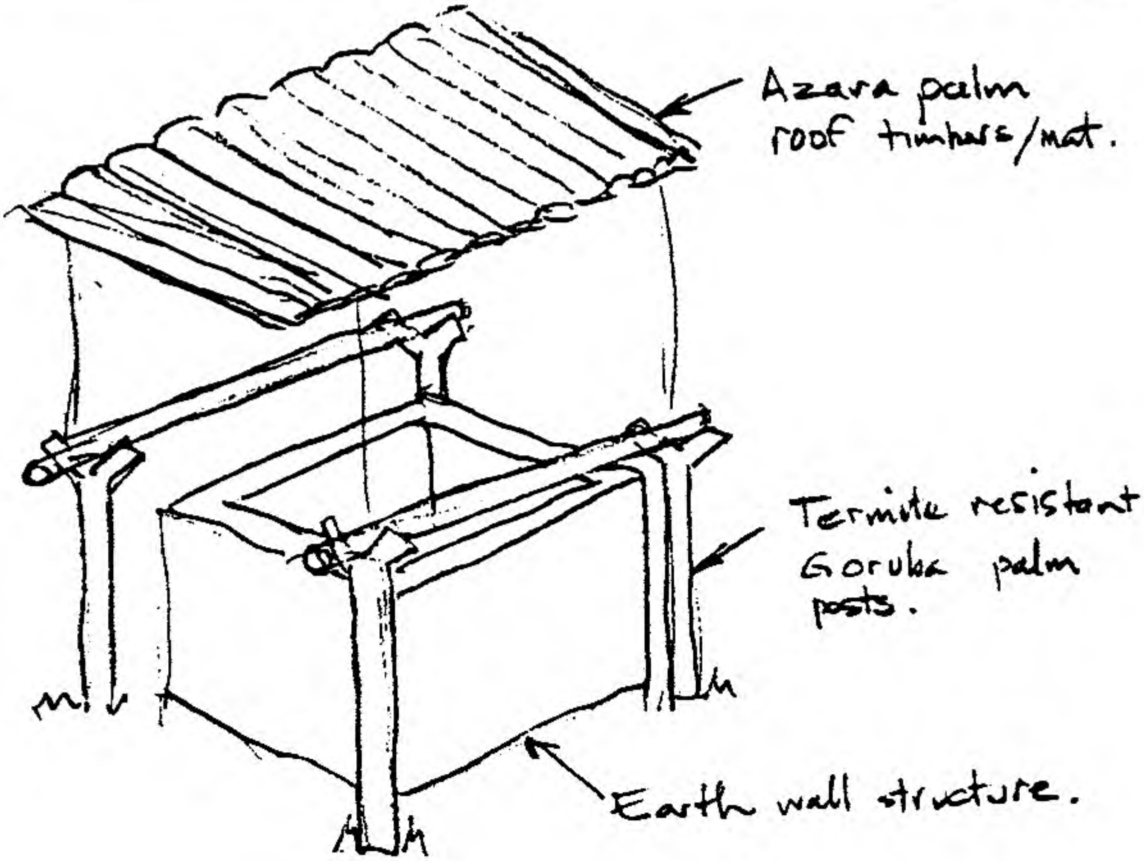


Fig 1. Schematic representation of structural separation of earth walls and roof.

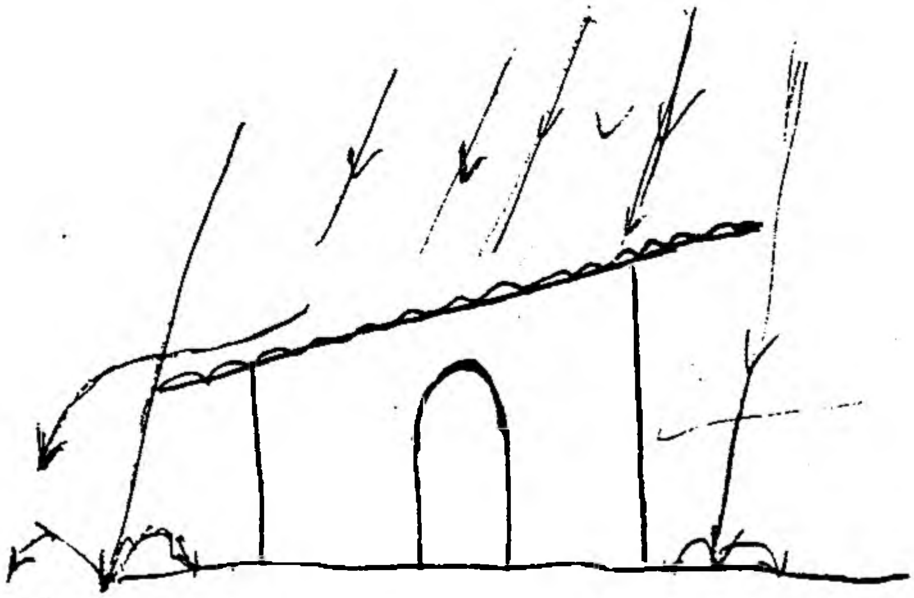
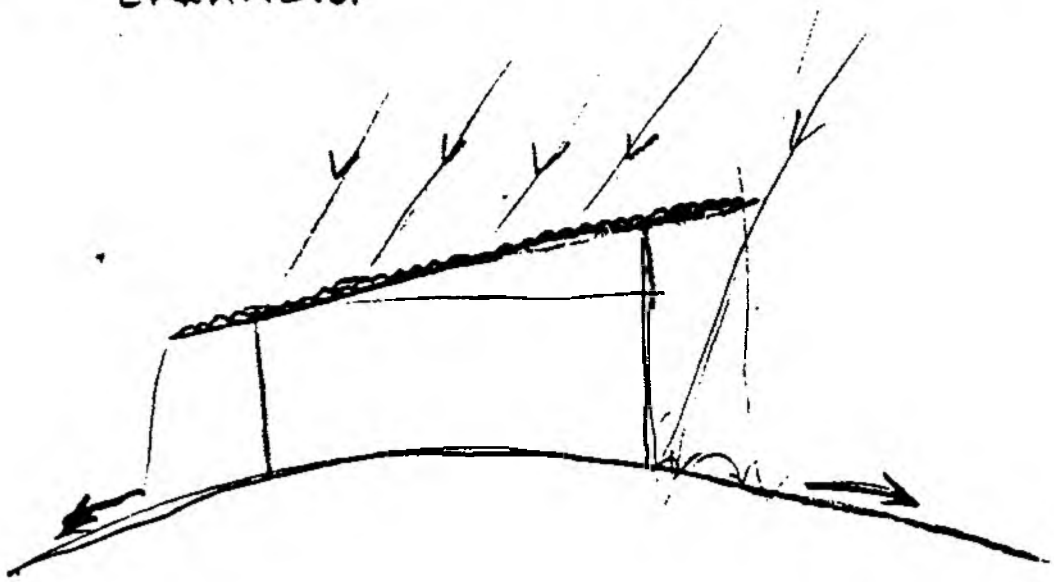
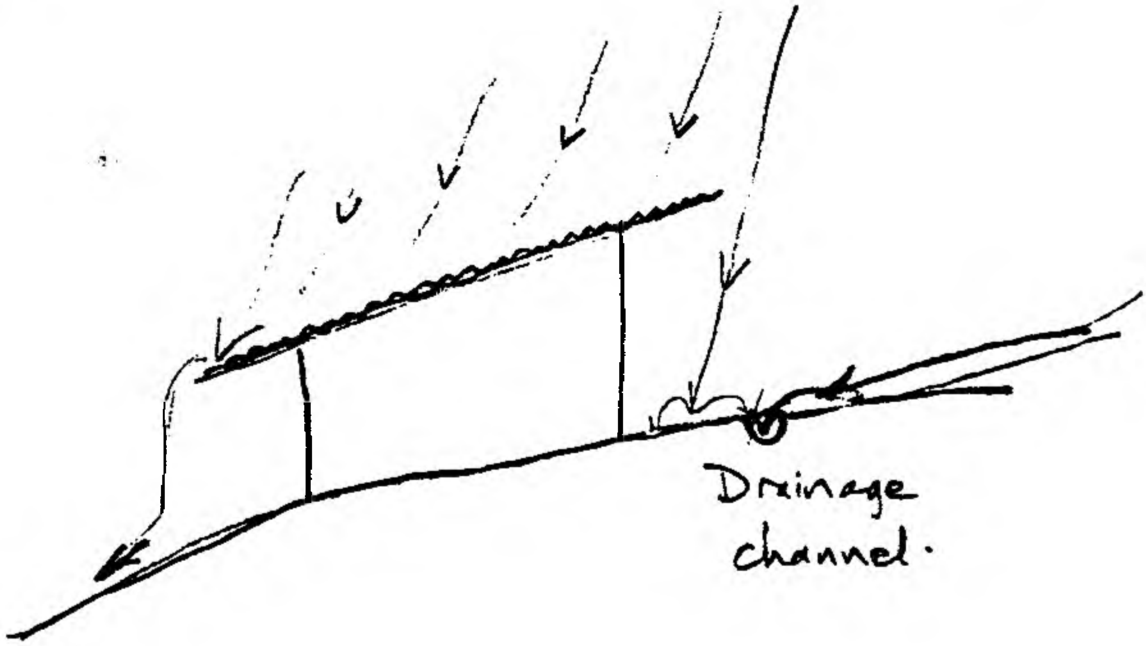


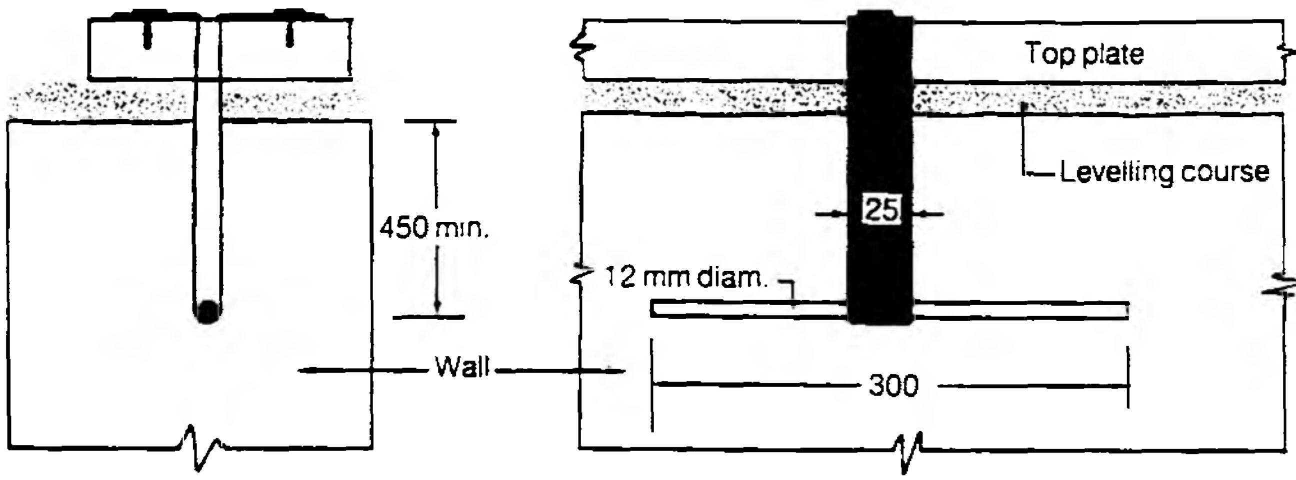
Fig 2. Sloping roof to ensure water run off. Note also extended eaves and arched door.

Fig 3. Siting on raised ground and drainage channels.

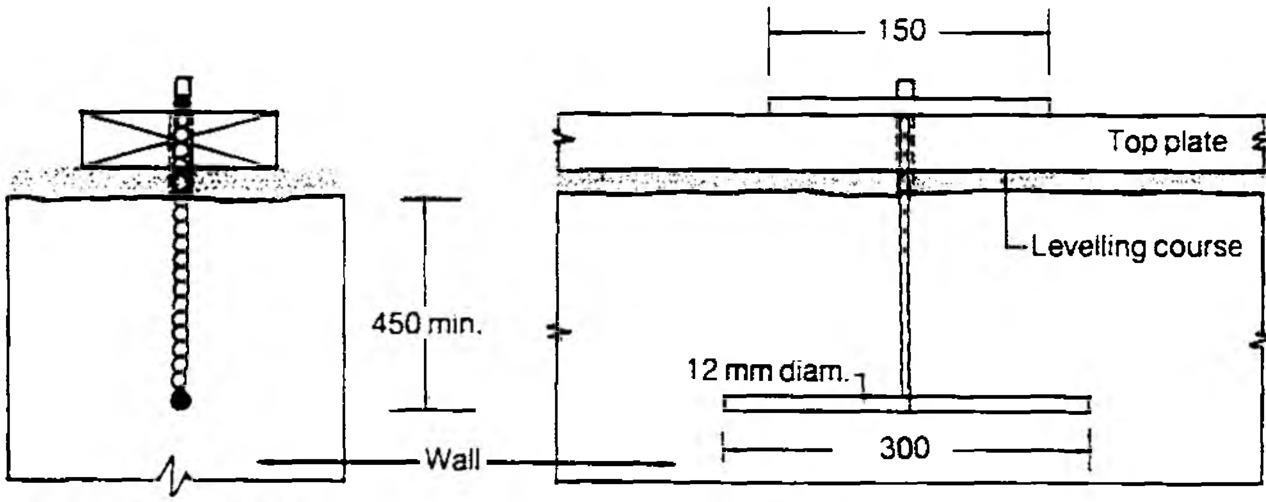




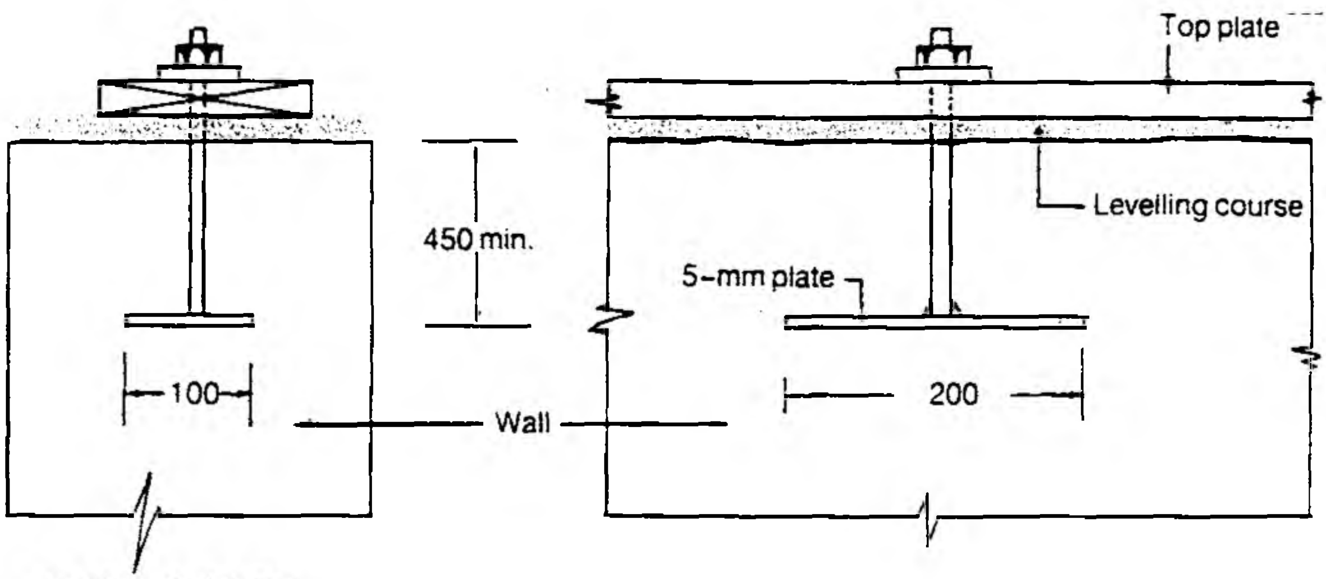
All dimensions in mm



(a) Galvanised steel strap



(b) No. 8 gauge wire



(c) Threaded bolts

~~Fig. 1.4~~—Methods of securing the top plate

From MIDDLETON, G.F (1987)