DEPARTMENT OF ENVIRONMENT

BUILDING RESEARCH ESTABLISHMENT

NOTE NO N(C) 2/89

REPORT OF VISIT TO THE SUDAN ON 1-7 DECEMBER 1988

by David J T Webb PhD C Eng MIMechE MIMatM

SUMMARY

The principal reason for the visit to Khartoum, Sudan was to observe the after effects of the flooding that occurred in the Khartoum and Omdurman areas making some 2 million people homeless and causing widespread devastation of homes, and disruption of health education and communication services. Some 80% of the existing school buildings have been destroyed or seriously damaged.

A new type of school building made from stabilised soil blocks had been partly constructed at El Hag Yousif when it was subjected to almost 25 cms of flood water, both externally and internally, without suffering erosion damage.

Recommendations have been suggested to help with the post flooding re-building programme.

February 1989
BRE 72/1/7
CO 737

BRS 34/89

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Acknowledgement to Associated Press Ltd, Khartoum, Sudan, Wednesday 10 August 1988.

Scene of devastation caused by torrential rains during 4/5 August 1988 coupled with widespread flooding from the River Nile and associated rivers.

An aerial view taken from a helicopter shows the immediate destruction of houses with roads completely disappearing under up to two metres of water and remaining houses appearing like islands in a river.

CONTENTS

1. INTRODUCTION

During August/September 1988, Sudan experienced two separate but related events:- first, three weeks of unprecedented high levels of rainfall including 200 mm on the 4/5 August 1988 centered over the Khartoum and Omdurman areas; and second, high levels of flooding of the River Nile and other rivers, including sheet flooding down wadis which had been dry for decades.

The floods took several weeks to dissipate in the flat areas which have impermeable black cotton soils. About 200,000 homes were destroyed or extensively damaged, and some 2 million people have been left homeless. Agricultural areas along the Nile River basin around Khartoum have been devastated, and essential services such as health, educational establishments, and internal and international communications have suffered. For example, in the Khartoum area, about 80% of the existing schools have been destroyed or seriously damaged. (Figures 1,2,3 and 4).

However, BRE learned that a demonstration school building, constructed of stabilised soil blockwork had not suffered damage.

The Arab Fund for Social and Economic Development (Afesd) in conjunction with UNESCO, is funding a school building pilot project in the El Hag Yousif area of North Khartoum. The project is being organised by the National Council for Research, Sudan (NCR) and the Building and Road Research Institute (BRRI) of the University of Khartoum. The project was started early in 1988, and will consist of 12 classrooms within 4 main buildings, an administrative building and a security building. Both the walls and the floor of the school buildings are to be constructed from stabilised soil blocks.

One classroom element of 60 square metres was being roofed with 1m x 1m sand/cement/Kenaf fibre sheets when the rains occurred. About 25 cm of water was left standing inside the school, and about 30 cm lying against the outer walls. After the flooding had subsided no erosion or damage had occurred to the stabilised soil blocks either to the walls or the floor surface.

ODA had funded the supply of two BREPAK machines to the Sudan in 1983. One machine was sent to Juba, in Southern Sudan where it was used on a mobile school building programme operated by Voluntary Services overseas, and the second machine was used by NCR in Khartoum on research activities.

I had visited Khartoum for two days early in December 1982 (1), and held discussions with senior staff at NCR. Prof A Agib, then the director of NCR, now the Commissioner/Consultant of NCR to the Sudan Minister of Housing and Public Works, explained that before a pilot demonstration project could be started NCR intended to set up a basic research project at NCR on soil stabilisation with the construction of sample walling.

Mr El Fadil Ali Adam, an architect with NCR, spent three years (1979-1982) with the Overseas Division of BRE working on the BREPAK stabilised soil research project and returned home mid 1982 after being awarded his M Phil.

In September 1988 Mr El Fadil began a PhD course at the University of Wales, studying the thermal properties of earthern constructed dwellings. Dr P J Jones, Mr El Fadil's course supervisor at the University, contacted the Overseas Division of BRE requesting assistance with the thermal project, and this also provided an opportunity to learn of the progress of the stabilised soil project in Sudan.

2. DEMONSTRATION SCHOOL BUILDING AT EL HAG YOUSIF - DESIGN

El Hag Yousif is a suburb area to the North East of Khartoum and consists mainly of earthern constructed buildings with about 10 per cent constructed from fired clay bricks.

The traditional Sudanese classroom, 9m by 6m, is usually constructed from fired clay bricks with mud as the mortar between the bricks, Figure 13, with internal mud rendering which has been whitened as shown in Figure 14.

Flood waters caused extensive damage to these school buildings because of their shallow foundations and the mud mortar being washed away from the joints in the bricks, however the fired clay bricks were not affected by the water. Figure 13 shows the site of a traditional school building which collapsed and tents supplied by the UK are now being used as temporary school classrooms. Figure 14 also illustrates the galvanised steel sheeting used for the roof structure which makes the inside of the building very hot indeed.

Each traditional Sudanese school classroom of 54 square metres costs LS40,000.

BRRI was charged by Afesd to design a school building complex and Dr Ahmed El Beshir Aw Adalla, Director of BRRI and Mr El Fadil Ali Adam were made responsible for this work.

The sub soil is black cotton soil and special foundations were constructed as shown in Figure 5.

The layout of the new style classrooms are shown on Figures 6 and 7, the plan being to have an open classroom with all round access for the teacher and, by having intermediate columns, the span of the roof supporting members could be at a minimum size.

Figures 8, 9, 10, 11 and 12 illustrate this new type of school building.

Figure 12 illustrates a step in the roof structure, to allow extra light into the classroom over the area of the blackboard. The floor is constructed from stabilised soil building blocks.

During my visit, the atmosphere inside this demonstration classroom remained quite cool although outside the temperature was around 100°F.

BRRI showed me a detailed costing of the demonstration school building of 60 square metres which when completed will have cost LS 25,000 showing a cost saving of about 40%.

3. DEMONSTRATION SCHOOL BUILDING - CONSTRUCTION

The only person experienced in the production and use of stabilised soil building blocks was Mr El Fadil Ali Adam who as mentioned previously spent 3 years at BRS during the early stages of the soil stabilisation research project.

The director of BRRI listed several problems that had occurred on site during the early stages of this particular project.

1. Lack of a formal training course to instruct local operatives and technicians into the art of stabilised soil block production.

2. High labour turnover on site caused by the lack of continuous funding.

3. Inadequate site supervision and quality control because two young civil engineering graduates lacked the on site experience to control a project of this magnitude.

4. Transport and materials supply and preparation needed to be improved.

In spite of these difficulties, it was generally agreed with the staff at both NCR and BRRI that a satisfactory pilot school classroom had been constructed. Walls consisted of stabilised soil blocks with 6% cement by weight laid in a 1:8 cement/sand mortar and the internal columns were made from a soil mix with 10 per cent cement.

The floor consisted of stabilised soil blocks laid on a 1:6 cement/sand mortar bed.

Some concern was expressed over the strength of the blocks and I undertook to conduct a soil test on the El Hag Yousif soil at BRE. The test results are given under Appendix 3 which illustrates that 6 per cent cement is adequate for all the building provided that quality control is introduced on site. This aspect would be an essential part of any training programme.

To illustrate the strength of blocks on site I arranged a simple rupture test which is illustrated on Figure 15. This shows that 20 blocks are piled on top of one another to check the strength of the lower test block, in fact a further 5 blocks were added with no distress to the test block.

4. MEETING AT BRITISH EMBASSY

A useful discussion was held at the British Embassy with Mr E C N Taylor, First Secretary Aid and Mr D Malcom, Second Secretary Aid. Both these officers were concerned about the efficient use of UK aid to assist with the Emergency Post-Flood Reconstruction Programme.

I mentioned that prior to my departure from the UK I had visited the Eastern Africa department of ODA to look through a report prepared by a Multi Donor Mission which visited Sudan during 4-20 October 88.

This mission, headed by the World Bank, had prepared a 183 page report entitled "Sudan - Emergency Flood Reconstruction Programme" (2) which details the extensive problems now facing the Sudan Government following the flooding in August 88. It highlights the fact that communications and essential services such as health and educational establishments should be repaired or replaced as a matter of urgency.

We discussed the progress of the pilot school project and felt that it could be improved by setting up a formal training course for the personnel involved with new Brepak machines and equipment.

Mr Taylor felt that opposition may be generated by the fired clay brick industry against introducing a new method of building block manufacture to which I replied that fired clay bricks are more expensive. Subsequently Mr Taylor posed this question to Dr Ahmed El Beshir Aw Abdalla, Director of BRRI when they met at the Sharja Conference Centre where I delivered a lecture, on the work of the Overseas Division of BRE, to about 40 professionals from BRRI and NCR.

Several ideas were discussed at this meeting and Mr Taylor suggested that we should involve both Sudan Ministries and Non Governmental Organisations (NGO) in implementing the role of stabilised soil construction in the reconstruction programme.

I undertook to submit proposals and possible costings for the implementation of the soil stabilisation project in the Sudan. (See recommendations, section 6).

After returning home, I received a formal request from Mr Taylor supporting some of the recommendations discussed at our meetings. (See Appendix 4).

5. GERMAN RED CROSS

The Sudan Red Cross, an NGO organisation, is being funded by the German Red Cross to construct some low cost Health Posts and School buildings in various locations in Khartoum and Omdurman.

I had a meeting with Mr Martin Faller, German Red Cross Delegate for the Sudan, to discuss their proposed work in the flood affected areas of Sudan.

Mr Faller has already prepared a feasibility report "Reconstruction of School Buildings affected by Rain and Flood" (3). This study gives a summary of affected schools in all regions by education level as shown in the following table,

Education level	Partly affected	Total damage	Both
Primary	733	595	1328
Intermediate	300	201	501
Secondary	73	57	130
Total	1106	853	1959

The study states that it is impossible to predict the future state of the remaining buildings that have been damaged and they consider that any school affected more than 80 per cent is beyond repair. The sub soil has not yet fully dried out after the flooding and there are daily reports of more school buildings collapsing.

The study reports that the total damage has meant that about 236,500 pupils are now without any formal school buildings.

Mr Faller mentioned that he had seen the pilot school classroom, built from stabilised soil blocks, at El Hag Yousif and that he will be making recommendations to the HQ of the German Red Cross in Bonn to finance the supply of two Brepak soil block making machines together with a clay crushing machine.

This particular move would bring together a Sudan NGO and the Sudan Ministries of Health and Education.

In the event of the German Red Cross funding some Brepak equipment, Mr Faller has asked if their field operators could attend a Brepak training course that I am proposing to run at BRRI.

6. RECOMMENDATIONS

Mr Taylor suggested that the British Embassy or NCR could approach SUDAN CALL to bring together Sudanese NGO's that are involved with the Post Flood reconstruction programme. One such example is the Sudan Red Cross.

These NGO's could be supplied with Brepak machines and a clay crushing and sieving machine from BRRI for a pilot project.

Each NGO should be linked to a Sudan Ministry for the proposed pilot project, as shown in the figure below, and each NGO should appoint 3 technicians to attend a formal Brepak training course at BRRI in Khartoum.

RELATIONSHIP BETWEEN PARTICIPANTS

```
                               SUDAN CALL
                +----+         Pilot Projects        SUDAN MINISTRIES
                |ODA |    +------------------+       +------------+
                +----+    |NGO               +---+INFORMATION |
                |BRE |   /|Community Centres |     +------------+
                +-+--+    +------------------+
EQUIPMENT         |     /
AND TRAINERS   +---+-+ /  +------------------+       +-------+
               |NCR  |/   |NGO               +---+HEALTH |
               |and  |/   |Health posts and  |       +-------+
+-----------+  +-----+--|clinics           |
|University +--+BRRI |\   +------------------+
|of Khartoum|  +--+--+ \
+-----------+     |     \+------------------+        +----------+
                  |      \|NGO               +---+EDUCATION |
         +------+---+    \|Schools           |       +----------+
         |TECHNICAL |     +------------------+
         |TRAINING  |
         +----------+
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Both NCR and BRRI should also nominate 3 technicians to attend the proposed training course. These technicians, after training, would be responsible for liaising with each of the three NGOs.

Equipment provided under the UK aid programme should ideally consist of 10 Brepak machines and 4 clay crushing and sieving machines. BRE would be responsible for supervising the training of the operatives and the setting up of one or two of the pilot project sites. i.e. One Brepak machine and one clay crushing machine retained at BRRI for future soil stabilisation research and possible training courses, the rest of the equipment distributed as suggested earlier.

7. COSTINGS

(a) Equipment and shipping

10 No. Multibloc Brepak machines complete with spare hydraulic seal kit for hydraulic hand pump and spare hydraulic hose at £1559.00 ex works	=	15,590.00
10 Manual block clamp lifters at £31.00	=	310.00
		15,900.00
Less 5%	=	795.00
		15,195.00
10 Steel baseboards @ £100 each		1,000.00
4 Enerpac hand pumps Model SPR87030 (To be held as spares by BRRI)		350.00
4 Pendulum-powered clay crushing and sieving machines at £860.00 ex works		3,400.00
Ancillary equipment for each machine including linear shrinkage mould, timber insert moulds, watering can and hydraulic mould oil		220.00
Consolidating, packing and preparing for shipment		5800.00
Documentation and UK Inland Freight to Shipper		850.00
Shipment from UK to Port Sudan (16 crates having a total weight of about 3400 kg.		900.00
TOTAL		£27,665.00

(Some savings could be made by the manufacture of the Brepak steel baseboards in the Sudan.)

(b) Training course

The training course would be conducted over a period of 2 weeks by two staff members of BRE. One man week would be spent in preparation time.

Staff time at BRE

5 days Dr D J T Webb (SPTO)	@ 320.00 per day	=	1,600.00
10 days Mr J Noonan (PTO)	@ 221.00 per day	=	2,210.00
7 days Craftsman	@ 110.00 per day	=	770.00

Visit to Sudan by BRE staff

SPTO for 8 days		
Return Air Fare	=	977.00
Subsistence estimated at £90 per day	=	720.00
Salary plus overheads (6 day week)	=	2,240.00
PTO for 18 days		
Return Air Fare	=	977.00
Subsistence estimated at £90 per day	=	1,620.00
Salary plus overheads (6 day week)	=	3,536.00
		14,650.00
Allowances to cover local transport in Sudan, Bought in materials for training course and part assistance to the salary of students		1,550.00
Total		£16,200.00

Summarising the costings as follows

a - Equipment procurement and shipping	£27,665.00
b - Back up support from BRE to arrange a training programme	£16,200.00
Total	£43,865.00
(say approx)	£44,000.00

If this total is agreed by the Sudan desk at ODA it would take about 4 months to arrange so giving BRE the opportunity of fitting it into the current work programme.

This suggested time scale would be sufficient to arrange the back up support needed both from NCR, BRRI and the British Embassy in Khartoum.

To ensure a successful rebuilding programme in the flood affected area it may be necessary to plan for two future monitoring visits by BRE staff; the first visit to take place after about 6 months covering an 8 day period and costing about £4000.

If this progress is satisfactory, recommendations could be made to introduce the powered block making machine at present under development at BRE. This machine will require a pilot proving trial and the second follow up visit after about 12 months could provide the ideal opportunity.

Note that the powered block making machine should be capable of making about 200 stabilised soil building blocks each hour compared with about 40 per hour from the Brepak machine. Costings for the second visit have not been considered at this stage.

REFERENCES

1 - Visit report to the Sudan N(C) 16/83

2 - World Bank report - Sudan - Emergency Flood Reconstruction Programme

3 - German Red Cross report - Reconstruction of School Buildings in the Flood Affected areas of Sudan

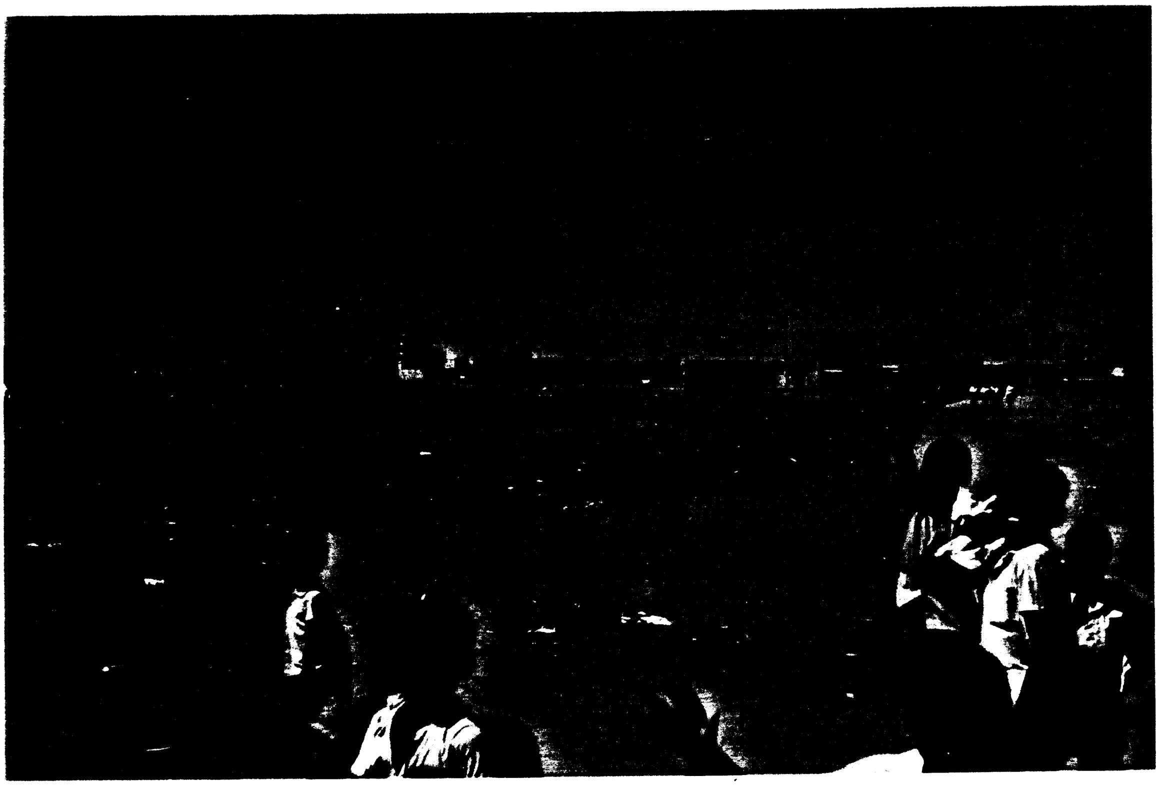

Figure 1 - Area once occupied by houses

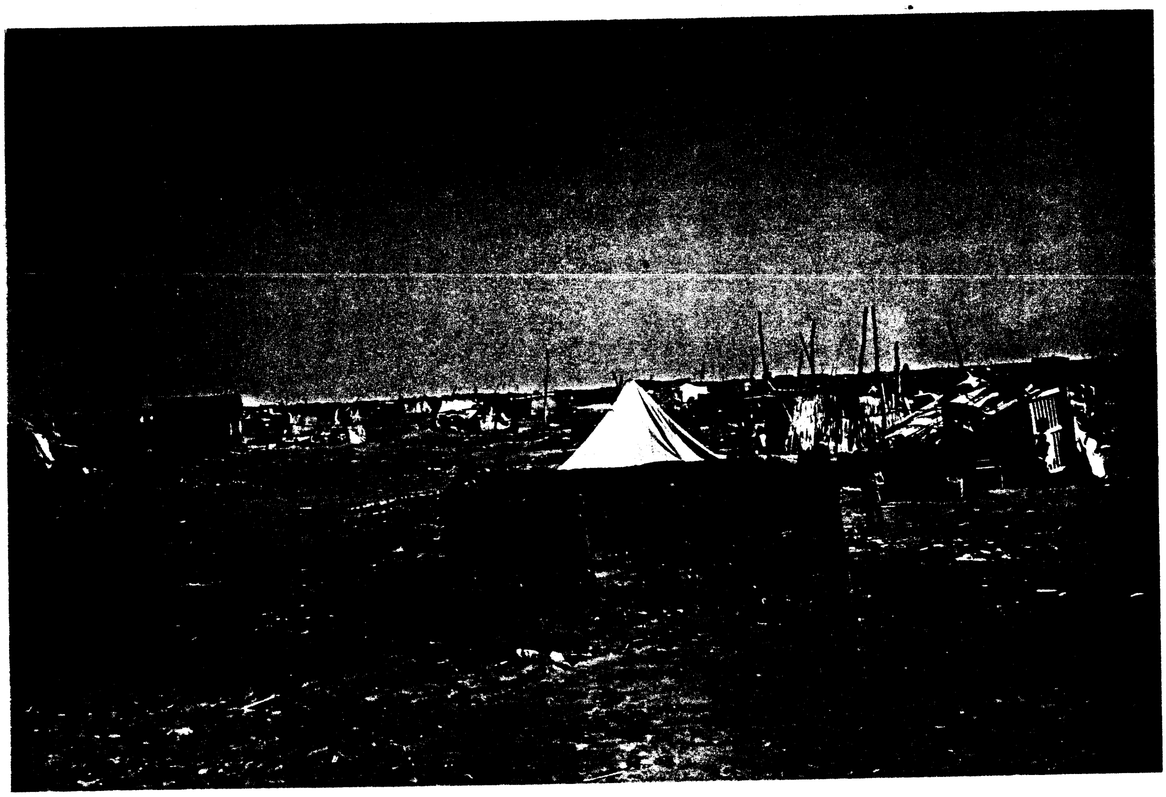

Figure 2 - Rebuilding work

Figure 3 - Area of devastation

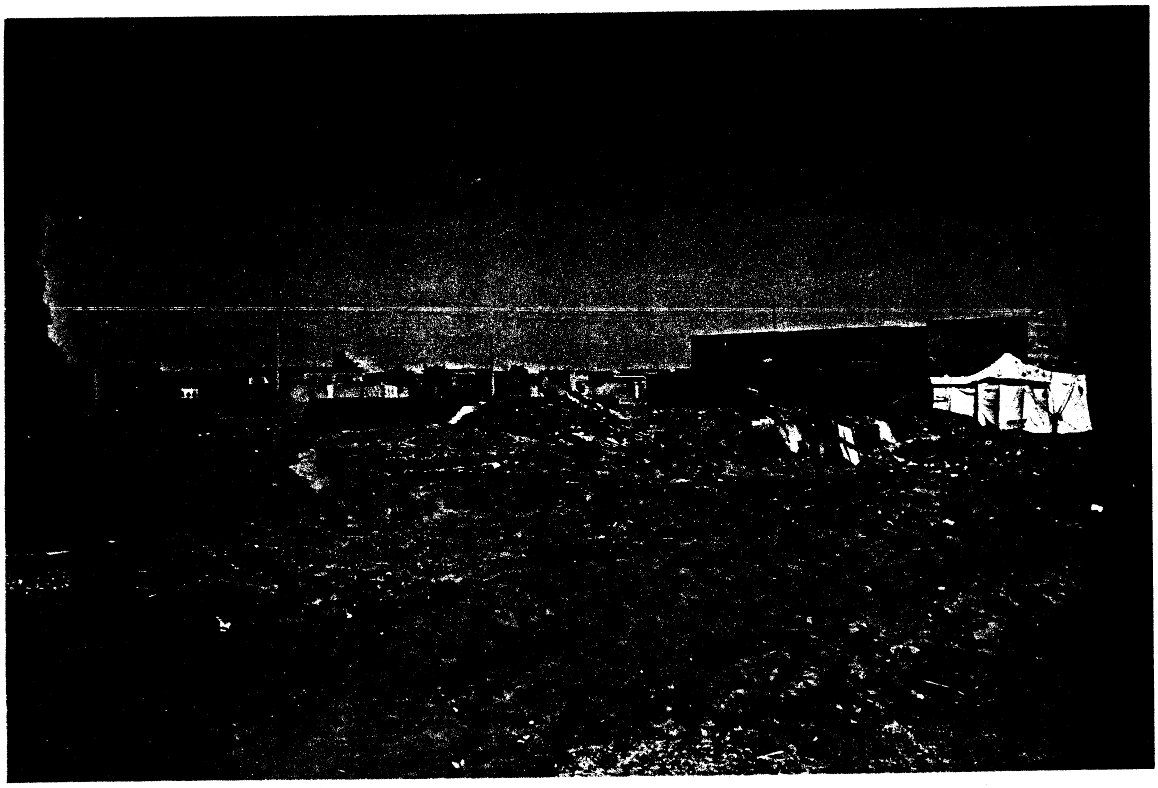

Figure 4 - Walling remains - tent from consignment from UK

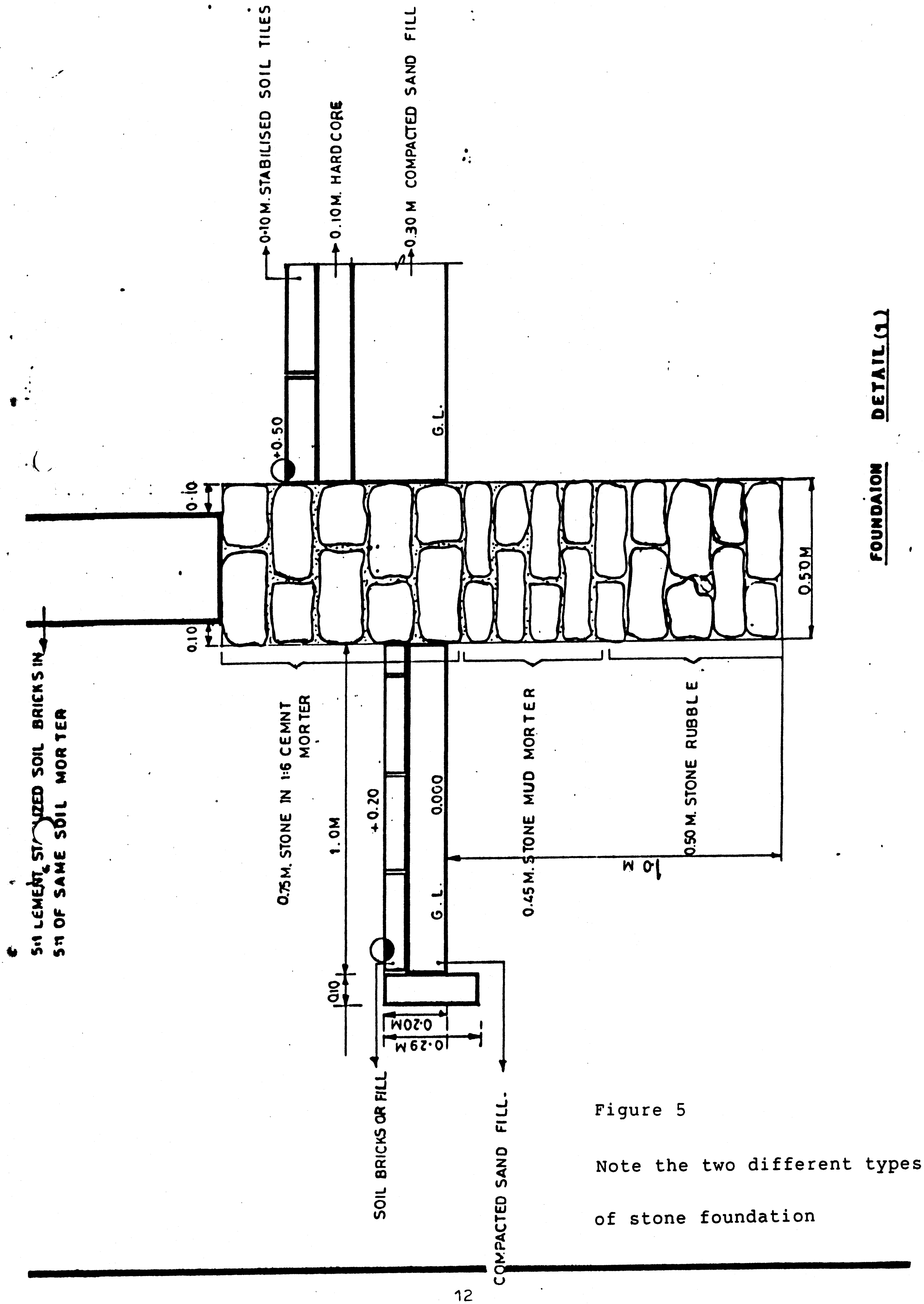

Figure 5

Note the two different types of stone foundation

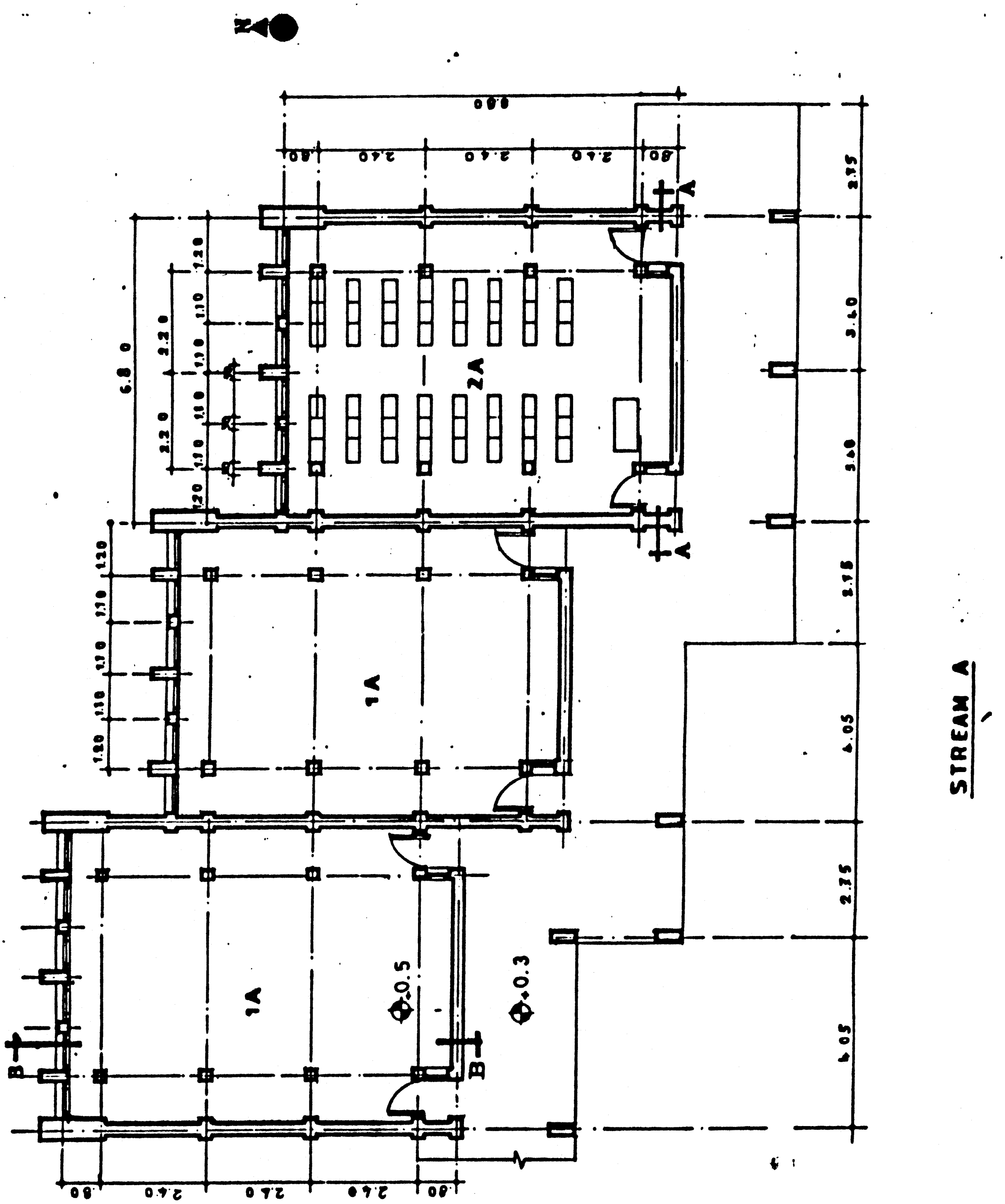

Figure 6 - Layout of junior classroom

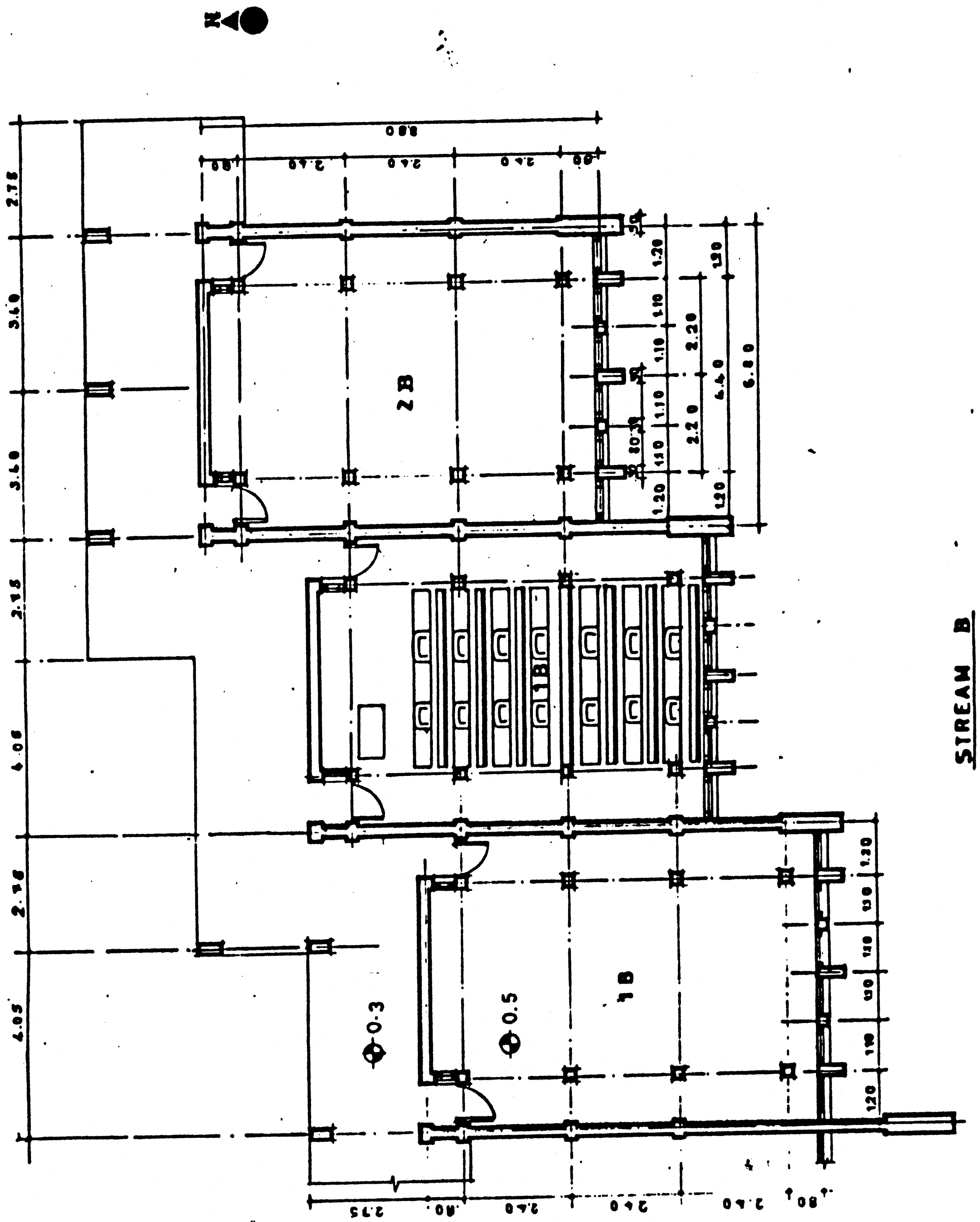

Figure 7 - Layout of senior classroom

Figure 8 - Entrance to classroom

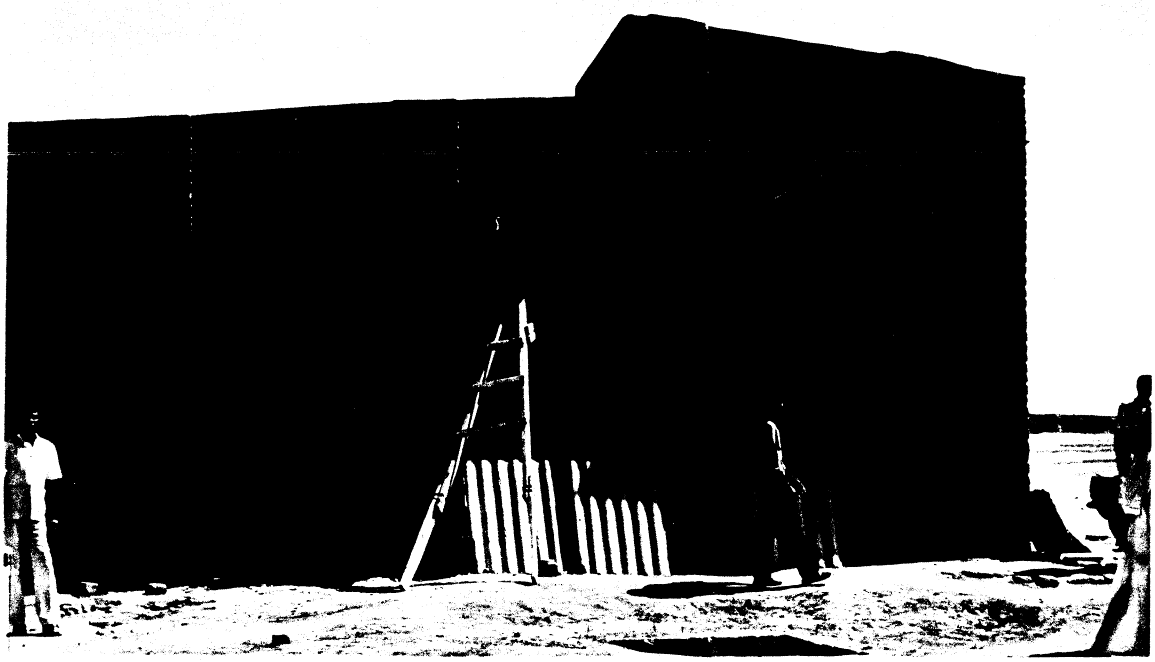

Figure 9 - Side elevation - note roof sheets

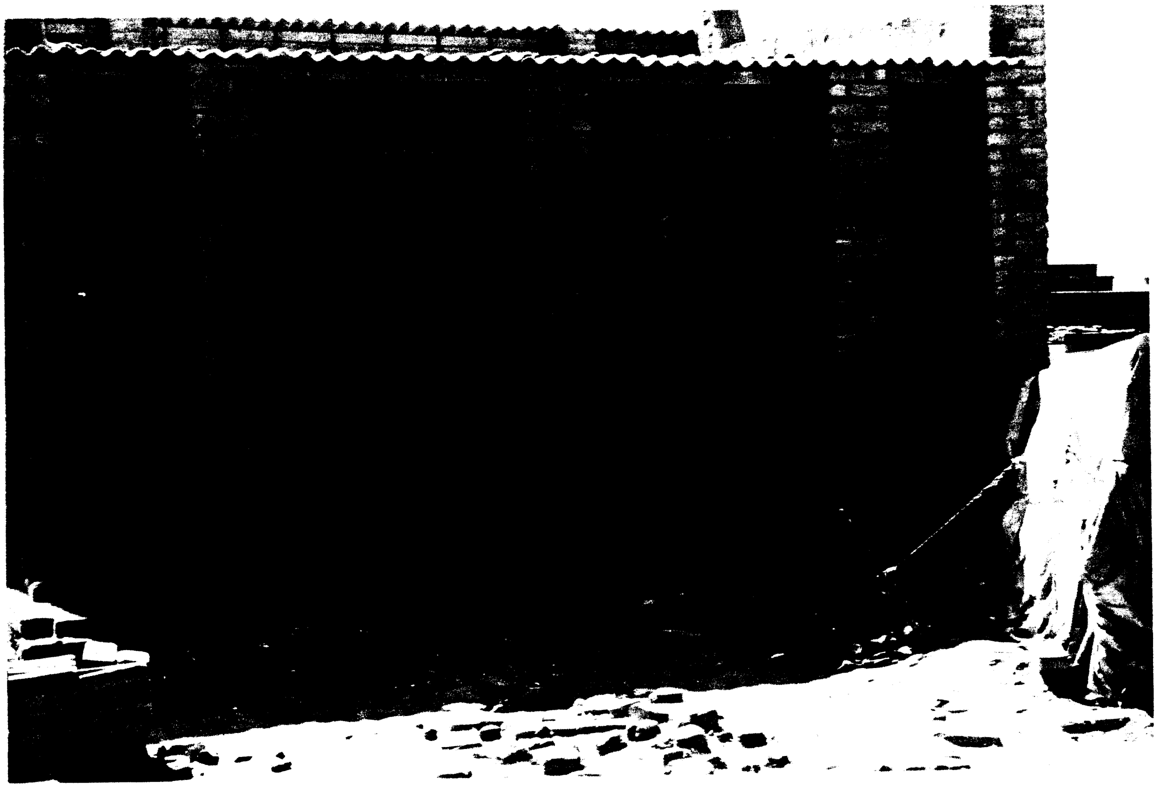

Figure 10 - End elevation

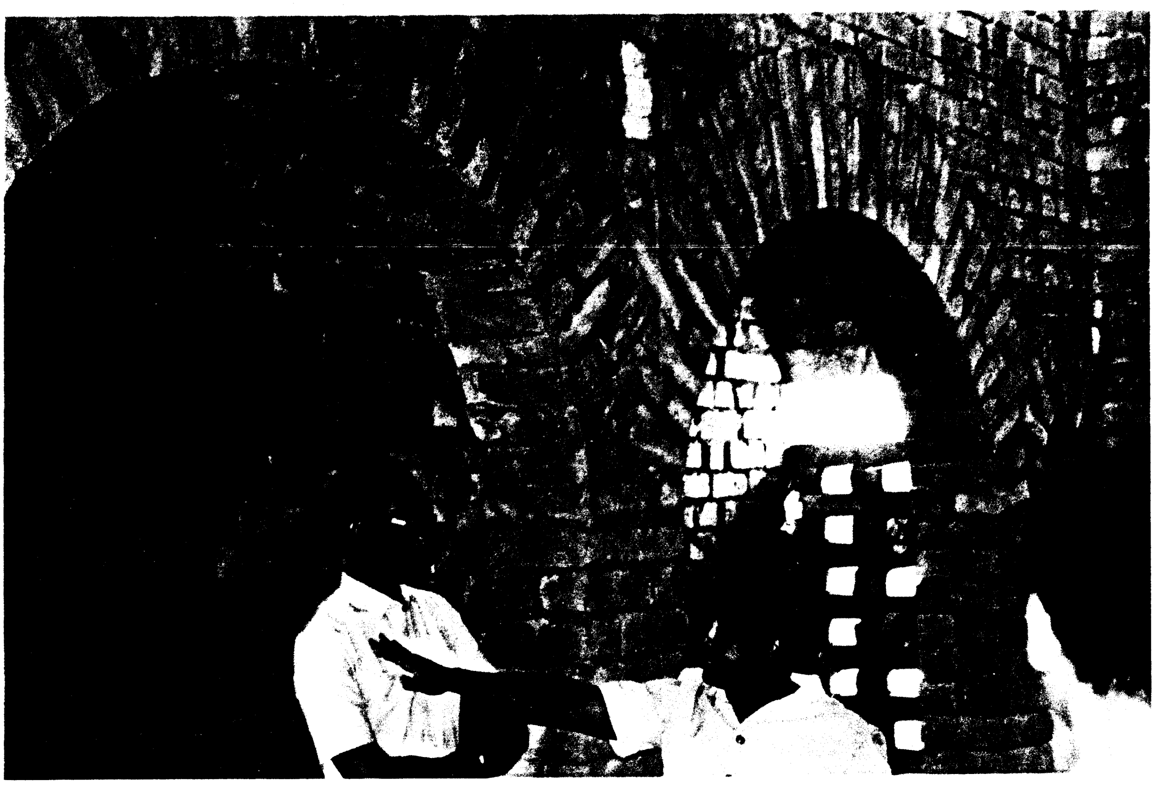

Figure 11 - Internal view - showing column and arches

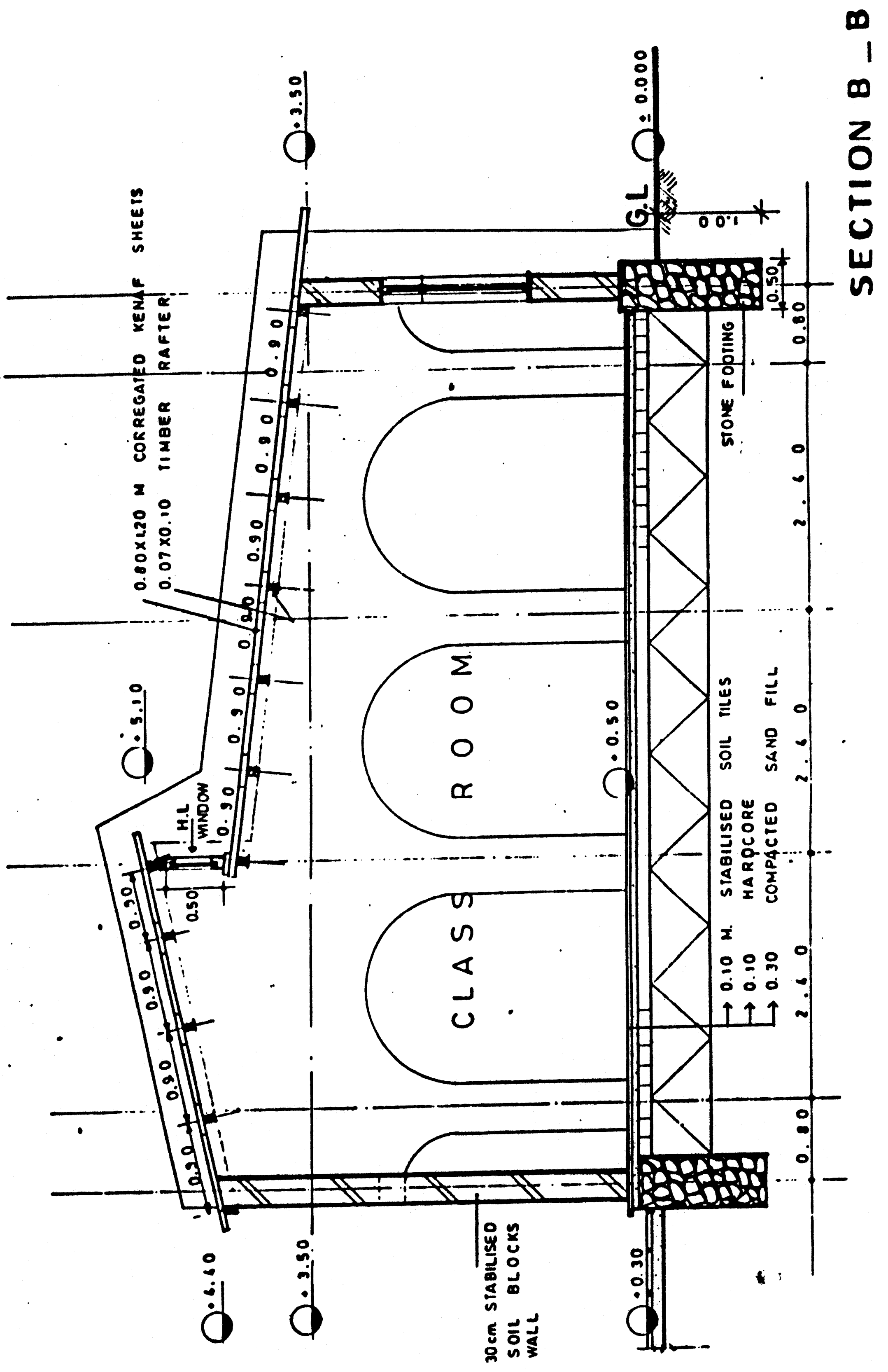

Figure 12 - Side elevation indicating step in roof for extra light into the classroom

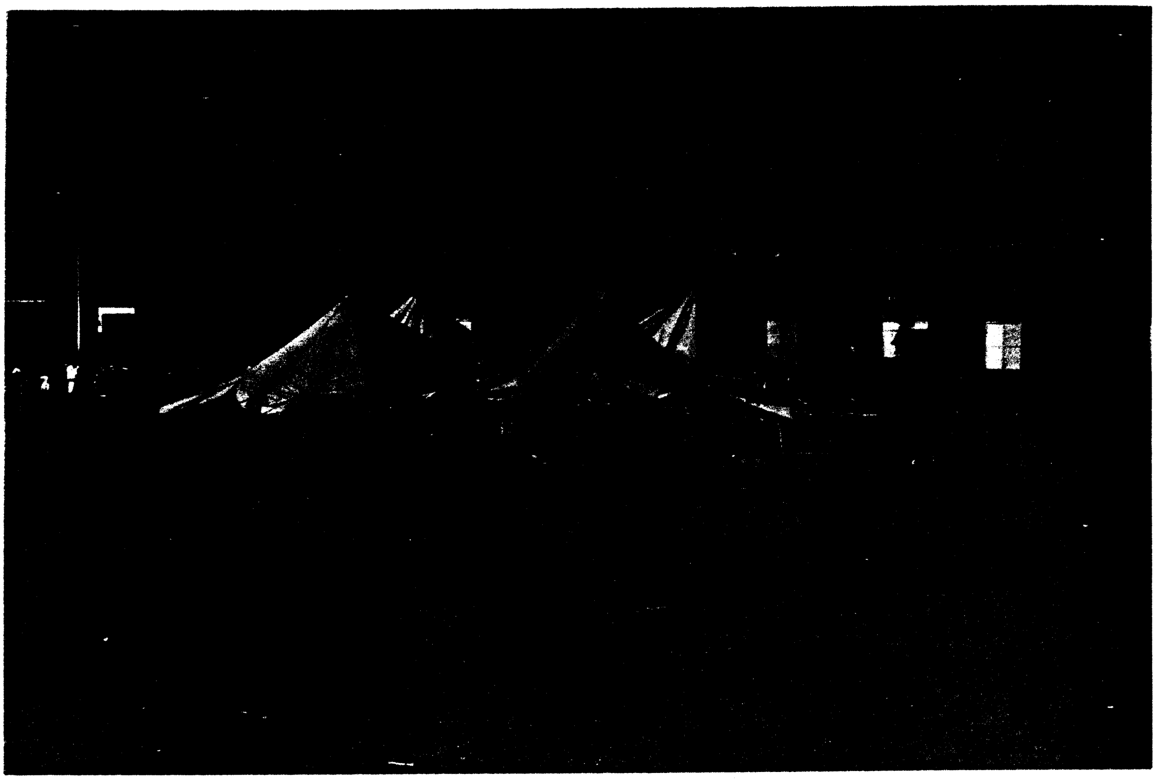

Figure 13 - Traditional classroom with temporary classroom in foreground

Figure 14 - Inside a traditional classroom - note the structural cracks

Figure 15 - Simple rupture test on a stabilised soil block

APPENDIX 1. DIARY OF VISIT

Thursday 1 December	- pm	- depart from Heathrow
Friday 2 December	- pm	- arrive Khartoum
Saturday 3 December	- am	- Discussions at NCR
	- pm	- Discussions at BRRI
Sunday 4 December	- am	- waiting at Khartoum Airport
	- am/pm	- Discussions at BRRI
Monday 5 December	- am	- Meeting at British Embassy
	- am/pm	- Visit El Hag Yousif site
Tuesday 6 December	- am	- Meeting at BRRI
	- am/pm	- Present lecture at Sharja Hall
		- Final meetings at NCR and BRRI
Wednesday 7 December		- Leave Khartoum, arrive Heathrow

APPENDIX 2 - PEOPLE MET DURING VISIT

Mr E Taylor - 1st Sec Aid, British Embassy, Khartoum
Mr D Malcom - 2nd Sec Aid, British Embassy, Khartoum

Prof A A Agib - Consultant for National Council for Research (NCR)

Dr Ahmed El Beshir Aw Adalla - Director, Building and Road Research Institutes

Dr Mohammed Achmed Osman - Head, Building Materials Division, BRRI, University of Khartoum

Dr Ahmed Abbas - Mech Engineering Department, University of Khartoum

Mr Ahmed Obeid - Acting Director, CSTR (NCR)

Mr Abdul Bagi Mohammed - Architect, NCR

* Dr Abdel Karim Mohammed Zeiu - Lecturer in Soil Mechanics, University of Khartoum (BRRI)

Mr Martin Faller - Delegate for German Red Cross, Bonn, West Germany

* Note: Mr Zeiu attended the BRE based "Building Course for Overseas Students" held in 1984.

APPENDIX 3 - EL HAG YOUSIF SOIL SAMPLE

4.75 kg soil sample was brought back from the El Hag Yousif site for analysis at BRE.

Soil tests were conducted as follows:

(i) A linear shrinkage test was conducted using a mould 600 mm long by 40 x 40 mm cross section. The soil sample took about 6 days to dry out and achieved a linear shrinkage of 28 mm (4.67 per cent shrinkage).

This test indicates that 6 per cent cement is needed for efficient soil stabilisation.

(ii) Specimen cylinders of 50 mm diameter by about 100 mm length were made using laboratory test apparatus that employs a similar compacting pressure (10 N/mm2) to that of the Brepak machine. Two mixes were used for these test samples; one with 4 per cent cement and the other with 10 per cent cement stabiliser.

After manufacture, the specimen cylinders were atmospherically cured for 27 days and one specimen was totally immersed in clean water for 24 hours prior to crushing both specimens in a compression test machine.

Specimen test results - P.T.O. to next page.

SPECIMEN TEST RESULTS

Test A - Soil mix with 4 per cent cement

Specimen A1

Cast density	=	2270 kg/m3
Dry density at 28 days	=	2060 kg/m3
Equivalent cube strength	=	5.65 N/mm2

Specimen A2

Dry weight at 27 days	=	426g
Wet weight at 28 days	=	466g
Water absorption	=	40g (9.4 per cent)
Wet equivalent cube strength	=	2.51 N/mm2

Test B - Soil mix with 6 per cent cement

Specimen B1

Cast density	=	2210 kg/m3
Dry density at 28 days	=	2125 kg/m3
Equivalent cube strength	=	8.92 N/mm2

Specimen B2

Dry weight at 27 days	=	415g
Wet weight at 28 days	=	439g
Water absorption	=	24g (5.8 per cent)
Wet equivalent cube strength	=	3.53 N\mm2

The above tests illustrate that good quality stabilised soil building blocks can be made in a Brepak machine when using 6 per cent cement stabilisation.

Using this quantity of cement, adequate strength blocks can be made which do not need any surface protection against the elements.

Note - On site at El Hag Yousif, 7 per cent cement has been used so that if better site quality control could be introduced, 6 per cent cement therefore is recommended which will result in further cost savings.

Appendix 4

Our Ref: TAS 093/16

BRITISH EMBASSY
KHARTOUM

7 December 1988

P. Roberts Esq,
BDDEA
NAIROBI

Dear Peter

SUDAN : BUILDING RESEARCH ESTABLISHMENT

1. I have been so impressed with the potential of BRE's work on low-cost buildings in Sudan that I have asked Dr. David Webb of its Overseas Division to prepare a feasibility study for a possible small project to encourage the extension initially into the poorer areas of Khartoum, of the techniques that have already been satisfactorily experimentely tested here. I am sure you are aware of the technology involved. It consists of adding small amounts of materials eg. cement to the existing expansive clays and then compressing the mixture into building blocks. BRE have invented a simmple machine for acheiving the correct degree of compaction. The bricks produced are sun cured and impervious to water.

2. BRE have, in collaboration with the Sudanese Building and Roads Research Institute (BRRI) at the University of Khartoum, constructed on an experimental basis, a school house for the Ministry of Education in the Haj Yousif district of Khartoum. During the floods, there was 20cm of water inside the building. Thanks to the construction materials, there was no long term damage. In contrast, other conventionaly built structures made of wood - fired Nile brick - collapsed following ingress of water.

3. The experimental building has shown that it is more durable then conventional couterparts. This is a major benefit. But there are others. Significantly it is 40 per cent chearper to construct. It is environmentaly sounder, not requiring the use of fuel wood in the brick manufacturing process. It also produces a much cooler internal temperature. Finally, it is safer on health grounds, as the walls do not crack and cannot, therefore harbour disease vectors.

continued : 4. The

4. The feasibility study that Dr. Webb and I have discussed involves BRE in the provision of equipment (BREPAC machines and clay crushers - at a total of about £30,000) and in-country training by BRE personnel (I am not sure of costs here). BRRI would be the recipient organisation which would run a series of small projects to build clinics, school houses and community centres in and around Khartoum. BRRI's role would be to train trainers who would then set about the construction programme using the equipment provided. The trainees would come from local self-help groups ideally in areas where NGOs are already working. BRRI would therefore provide technical assistance to these groups, who would be responsible for meeting all other costs.

5. I have spoken to the BRRI management about these proposals in the broadest terms, emphasising that there is no commitment from us for the use of aid funds. I do think, however, that BRRI is institiitionally strong enough to be able to run this programme and that design will be satisfactory given the supervisory role of Dr Webb and his colleagues at BRE. I understand from BRRI that there is already a climate of opinion in the industry that brick manufacture must move away from a fuel wood dependent manufacturing process so I suspect that the time is ripe for some seed capital to transfer this new technology as it is likely to be taken up. I feel very strongly that this is an initiative worthy of ODA support, at its simplest because it should help to reduce demand for timber in this already heavily de-forested country. I hope, therefore, it will have your approval in principle for aid funding. I am not certain which pocket of money should be used and hence am copying this letter to Terry Pike for advice on Engineering Division's ability to pay for this work.

Yours ever,
Ecnoin

E.C.N. TAYLOR
First Secretary (Aid)

cc Ms M Cund EAfD ODA
Dr David Webb, BRE, Watford
T Pike Eng Div ODA