UNIVERSITY OF NAIROBI
HOUSING RESEARCH AND DEVELOPMENT UNIT

FOUNDATIONS FOR LOW COST STRUCTURES IN POOR SOIL CONDITIONS

Author: Peter Erkelens

Dates: November 1980
(Printed in September 1981)

Housing Research and Development Unit
Director - T.S. Chana
P.O. Box 30197, Nairobi, Tel. 27441 ext. 212

Internal report on the performance of trenchfill foundations. Background information

The report 'Foundations for Low-Cost Houses' was published in February 1976 by the Housing Research and Development Unit and written by Mr. J. Eygelaar. That report described a cheap method for low cost foundations, using a trench-fill foundation system. In a number of suitable soils a foundation can be constructed by digging a trench, and filling it with stones (bigger stones on the bottom of the trench and smaller ones on the top of the trench) and then applying a blinding layer of 30 mm of cement mortar. Three years after the publishing that report in 1976, it was felt necessary to examine the application of the trench-filled method and to investigate whether, in the light of changed costs, this system still has its advantages.
Several interviews were recorded, which included an official of the (Ministry of Housing) a structural engineer from a consultant firm, and the architect, quantity surveyor, contractor and structural engineer of a major Sites and Services project in Nairobi.

Conclusions:-

All the interviews and literature revealed reservations about the trench-fill system with loosly compacted stones.

1. Trench-fill systems may save in materials costs, but not in labour costs. Firstly, the system requires skilled labour especially trained for the job and, secondly, the compaction requires more supervision.

2. Trench-fill foundations are not the best type of foundations in most cases from the technical point of view. Once the structure is ready, it is not known how the foundations will behave if:

   (a) the soil is settling;
   (b) the rain-water is pouring into the trench; and
   (c) the surrounding soil is eroding away, and therefore removing the horizontal counterforce.

3. In our view the trenchfill system is unsuitable for self-help projects because it is very susceptible to mistakes in the execution stage and is apt to cause eventual collapse of a structure. Unless there is adequate and proper supervision and control during the construction stage.

4. The report on trench-fill foundations should be amended to propose filling with cement mortar instead of filling with sand, in conjunction with this change, costing has to be revised. The amended report, must emphasize the aspect of proper supervision.

5. According to a cost comparison made in appendix 1 and 2 it turns out that a trench-fill foundation with cement mortar filling is not cheaper than the foundation made of concrete strips with concrete blocks.

The interviews:

The questions which were posed were mainly derived from the statements as they were made in the referred report of 1976.

1. Can considerable savings be obtained by replacing the conventional concrete strip plus the greater part of the masonry work in the foundation trench-filling?

2. Can savings in material be obtained?

3. Can savings in (skilled) labour be obtained?

4. Is this type of foundation very suitable for self-help builders?

5. Is the way of finishing the hardcore with a cement screed of 30 mm, with a mixture of 1:6, adequate?

6. Can the trench-filled with hard core only be used for drainage of surface water if the soil has poor draining qualities?

7. How much quality control is required to ensure proper compaction of the stone-filling to avoid undue settlement while loaded?

N.B. The numbers attached to these questions were repeated in the interviews.

I Interview with Mr. A.J. Marshall (ex-chief Housing Officer in the Ministry of Housing and Social Services).

A. Responses to questions in interview

A1. In a letter of 7th April, 1976 Mr. Marshall referred to experiences in Kariobangi Timber project in which he states that the system of integrating the concrete-slab in footing and not going any deeper than the undisturbed soil has proven to be the cheapest of all foundations. However new calculations by Mr. Eygelaar proved this system was more expensive, hence was rejected.

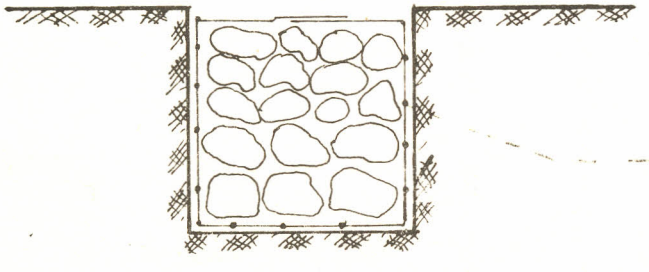
A4. Mr. Marshall did not agree that this system is suitable for self-help builders as the quality control is very important.

A5. The way of finishing the hard-core filling is inadequate. He referred to a Harambee school in Wajir which was constructed with trench-fill foundations. When the site flooded, the foundations were submerged and lost bearing capacity. Negative soil pressure caused the school building to collapse resulting in several casualties. Therefore the use of trench for drainage is a very dangerous issue. If the stones in the trenches are only compacted and not cemented to each other (which is the case here) water will soak the soil and may reduce the bearing capacity of the surrounding soil.

B. Suggestions for improvements of system.

Mr. Marshall suggested the following improvements:-

i. Place chickenwire in the trenches first, fill this with stones, and then bind the chickenwire together on top (see sketch).



Although this solution has its advantages, it has to be tested. If however the sides of the trench are weak, this chickenwire may provide some strength (sideways) to the stone-filling. (system of Gabions). The principle is that rust will deteriorate the wire but this will be replaced by vegetation which will provide stability. However it is unlikely that vegetation will grow here.

On the other hand, the chickenwire prevents stones from settling into the sides of the trench which ordinarilly would improve the bearing capacity. The additional cost factor must also be considered.

ii. The second suggestion was : To prevent the trench from getting soaked by the application of an 'apron'. A pavement on top of the trench-fill can divert the surface water and the rain-water from the roof to other places. This pavement, however, would increase the overall cost. Moreover, the concrete used for the pavement could better be used for a foundation or for mixing with the stones in the trench.

II <u>Interviews with Mr. Dupre of Mutiso-Menezes International, Architects and Town Planners, and Mr Woodrow of I.B. Patel and Mangat, Structural Engineers</u>.

Mutiso Menezes International (MMI) has adopted this system for foundations for Dandora Areas 2 & 3 and Areas 4 & 5 as an alternative to the conventional strip foundations. According to the Bills of Quantities of the Dandora Project Areas 2 & 3 it was priced but as an alternative. The bill gave a single price for both excavation and rockfill listed together.

A1. Mr. Woodrow said that experiments with concrete strip foundations by the City Council of Nairobi have shown that these are economical up to depths of 1.00-1.50m.

A5. According to the Dandora specification the trench-fill has also a cement blinding at the bottom of the trench of 5 cm.

A7. MMI, in Mr. Dupre's opinion, thought that the trench-fill method could be adopted but with strict control over compaction.

III. Interview with Mr. Kanti, a representative of the the maincontractor Twiga Construction Company at the Dandora Areas 2 & 3.

General : The trench-fill system was not applied in the Dandora project because the bottom consists of rock covered with murram and sometimes with a thin layer of black cotton soil, which would have to be removed. Trench-fill with stones was therefore not economical because the depth would have to be at least 40 cm.
The trench-fill system may be applicable to red soils where digging is required for meeting the harder sublayers.

A3. For conventional foundation systems the masons are well trained, while training for the new trench-fill system would be required and thus delays could have occurred in the execution of the project.

A5. The concrete used in a slab is 1:3:6. The mixing for the cement-blinding is the usual 1:4 but it could be 1:6.

A6. The final product cannot be predicted. It varies with the soil, the size of the stones, the thickness of the cement screen and the depth of the trench.

A7. The trench-fill requires extra supervision.
The compaction of the stones requires good workmanship.
The quality of this product is very susceptible to mistakes. The savings in materials are more than compensated by the extra costs for supervision.
In general the contractor has reservations about this system.

IV. Observations from Literature.

Robert K. Dancy, ITDG. A MANUAL ON BUILDING CONSTRUCTION.

(Page 63) Footings must be impervious to moisture. in the sense that moisture will never disintegrate them.

"In Fig. 104 a too common footing is shown. A little consideration shows why it is very bad. In the wet season, water will soften the earth and the whole weight of the building on such points of stone as are shown will send these stones down into that soft earth. Just a very little of that sort of thing will crack a house dangerously.

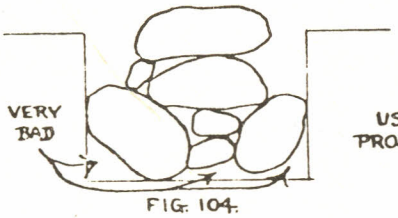


FIG. 104.

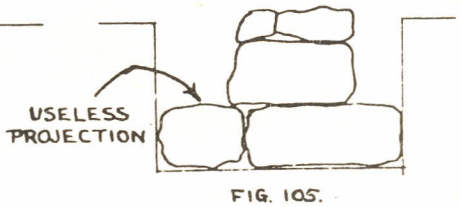
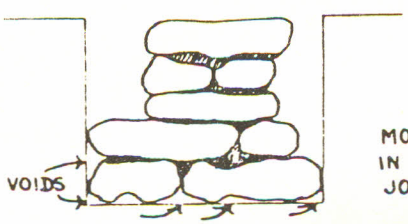
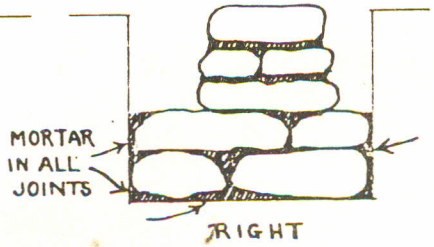


FIG. 105.

Why walls will not stand up.



WRONG
FIG. 106.

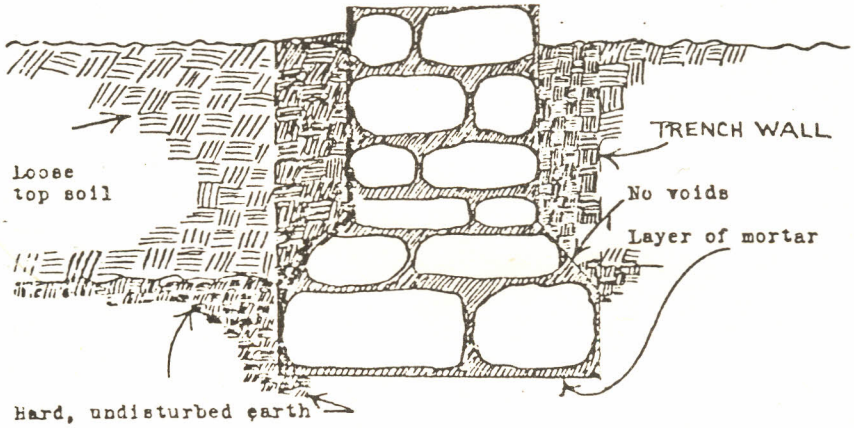


RIGHT
FIG. 107.

As long as cement mortar is used to point the surface joints of all footings and foundation walls, mud mortar may be used in the interior joints. But if there is danger of excessive moisture in the footing trench after the building is erected, then it will be safer to use cement mortar in all joints. Sand and cement mortar is more effective if one half part of lime is put in for every part of cement".

The following picture has more details:-

and shows an acceptable solution, although this also may require high level of craftsmanship. The cost analysis shows that in remote places, where stones are abundant, this may be a cheap solution.

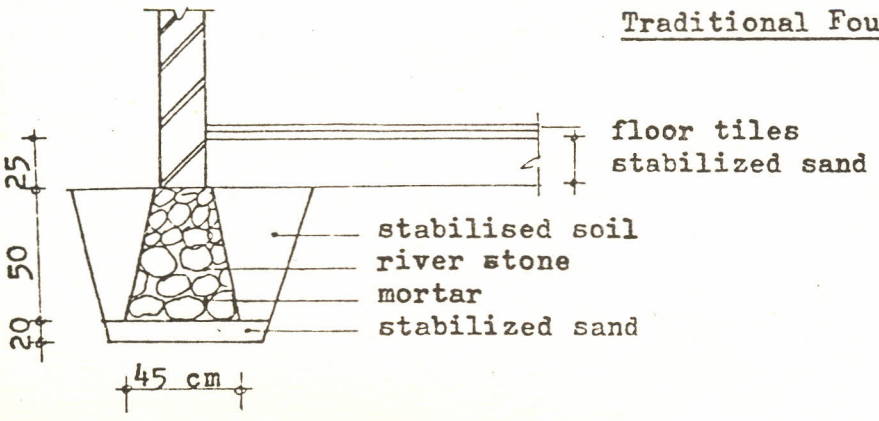


V. Magazine : Masalch Bangunan Volume 23. No. 1 March, 1978 p. 11.

This magazine describes three building projects. "Once the excavation is ready, the brick layers can start. The foundation work is still made according to a long tradition, introduced by the Dutch. However, the foundation is executed in a wrong manner: no mortar is used for the the bottom part. In this way the contractor tries to save money.

The Dutch system as such, stones with voids filled up with mortar, is not a bad system, but as soon as mortar is left out, the foundation is not safe. The system is open to abuse."

Traditional Foundation.

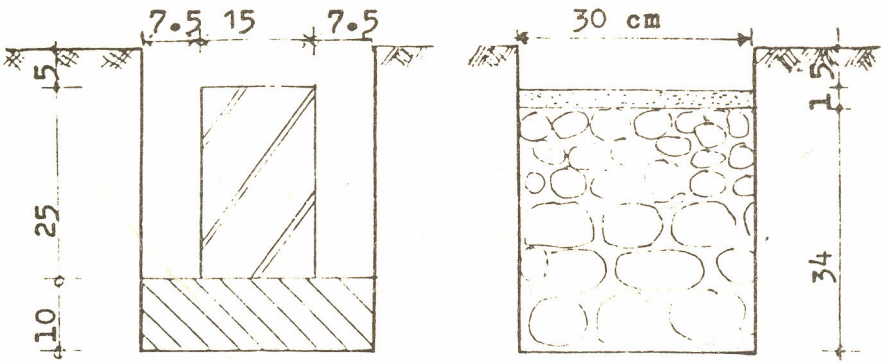


Appendix 1

Cost comparison Concrete Strip Foundation Trench Fill Foundation.

(June - July 1980).

Width 300 mm depth 400 mm. Both to have the same level of masonry, 5 cm. below surface.



Concrete strip foundation. Trench fill foundation.

Concrete Strip Foundation. C.S. 300-400.

	Quant.	Unit	self help mats only		contractor built	
			shs/unit	shs total	shs/unit	shs total
Excavation 0.4 m	0.120	CM	-	-	28/-	3/36
concrete 1:3:6	0.030	CM	312/-	9/35	520/-	15/60
masonry work	0.25	SM	43/-	10/75	81/-	20/25
total cost self help per L.M.				20/10		
total cost contract built per L.M.						39/21

Trench Fill Foundation T.F. 300-400.

	Quant.	Unit.	self help mats. only		contractor built	
			shs/unit	shs total	shs/unit	shs total
excavation	0.120	CM	-	-	28/-	3/36
hardcore filling	0.102	CM	37/-	3/77	62/-	6/32
blinding stones 1 cm	0.3	SM	5/-	1/50	5/-	1/50
total cost self help per L.M.				5/27		
total cost contractor built per L.M.						11/18

Appendix 2

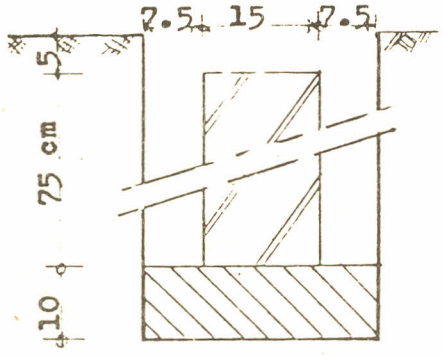
Cost comparison Concrete Strip Foundation/Improved Trench Foundation (June - July 1980)

The same depth will be used as in appendix 1.
The improvement of the trench fill foundation is the use of cement mortar as a filler between the stones in stead of sand.
The same drawings as in appendix 1 apply.

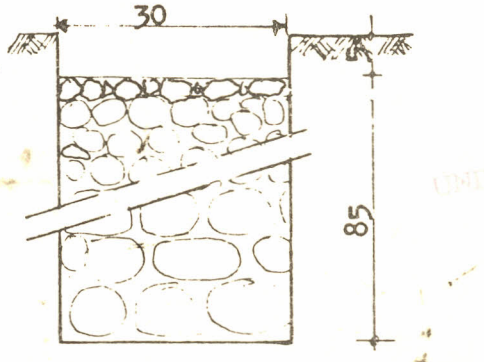
Improved Trench Fill Foundation : T.F. 300-400.

	quant.	unit	self help mats only		contractor built	
			shs/unit	shs/total	shs/unit	shs. total
excavation	0.120	CM	-	-	28/-	3/36
masonry work of hardcore 0.30 m thickness	0.35	SM	80/-	28/-	134/-	46/90
total cost self help per L.M.				28/-		
total cost contractor built per L.M.						50/26

Cost comparison at quarter depth 900 mm.



Concrete strip foundation



Improved trench fill foundation

Concrete Strip Foundation C.S. 300-900.

	quant.	unit	self help mats only		contractor built	
			shs/unit	shs/total	shs/unit	shs total
excavation	0.27	CM	-	-	28/-	7/55
concrete 1:3:6	0.03	CM	312/-	9/36	520/-	15/60
masonry work	0.75	SM	43/-	32/25	81/-	60/75
total cost self help per L.M.				41/61		
total cost contractor built per L.M.						83/90

Improved Trench Fill Foundation : T.F. 300 - 900.

	quant.	unit	self help mats only		contractor built	
			shs./unit	shs total	shs/unit	shs total
excavation	0.27	CM	-	-	28/-	7/55
masonry work of hardcore 0.30 m thickness	0.85	SM	80/-	68/-	134/-	114/-
total cost self help per L.M.				68/-		
total cost contractor per L.M.						121/55