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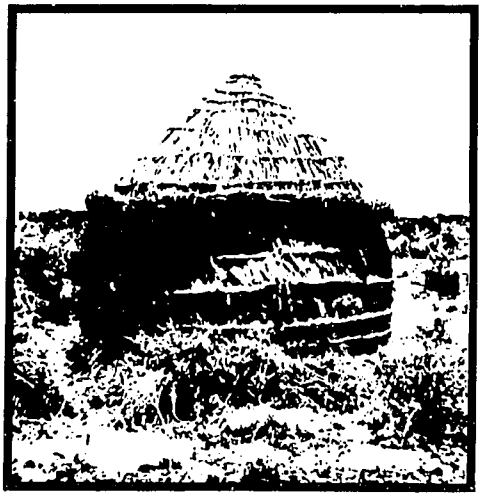

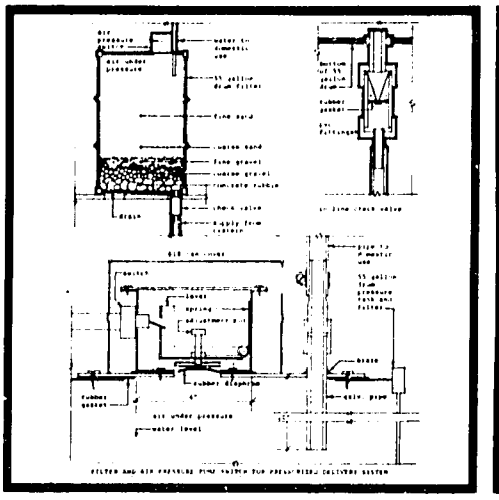

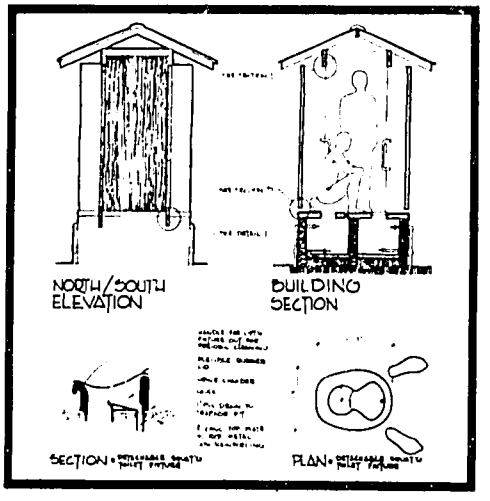

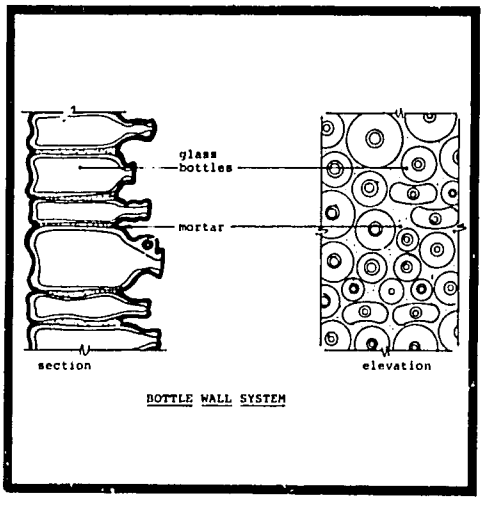

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INVESTIGATION OF ALTERNATIVE ROOFING SYSTEMS
AVAILABLE FOR USE IN THE
KURTUNWAARE PILOT HOUSING PROJECT

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Publication #4: Construction Training Manual for the Pilot Housing Project, Kutunwaare, Somalia, 1981

Publication #6: Design of Alternative Housing Units for the Kurtunwaare Pilot Housing Project, 1981

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INTRODUCTION

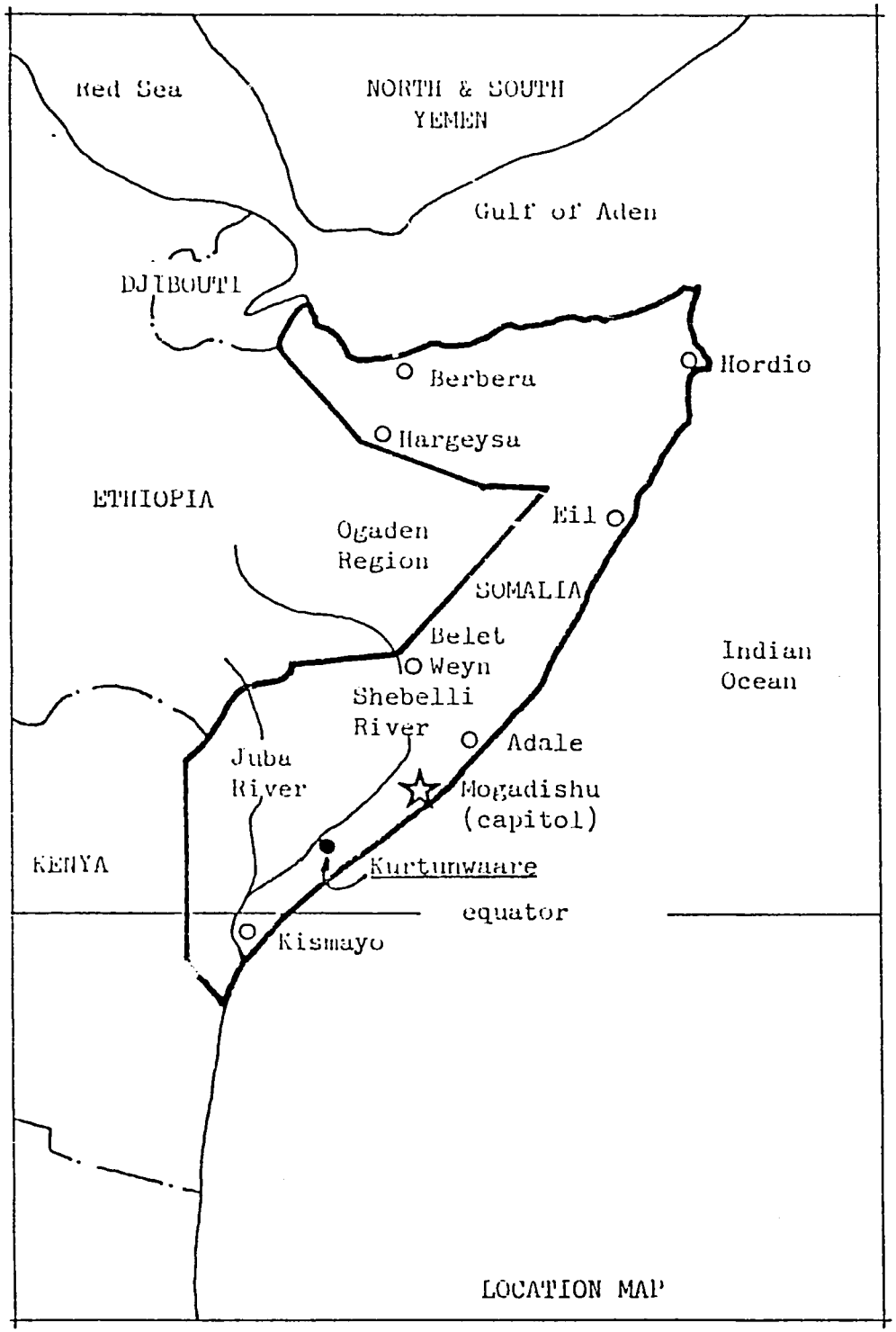
I. Project Background

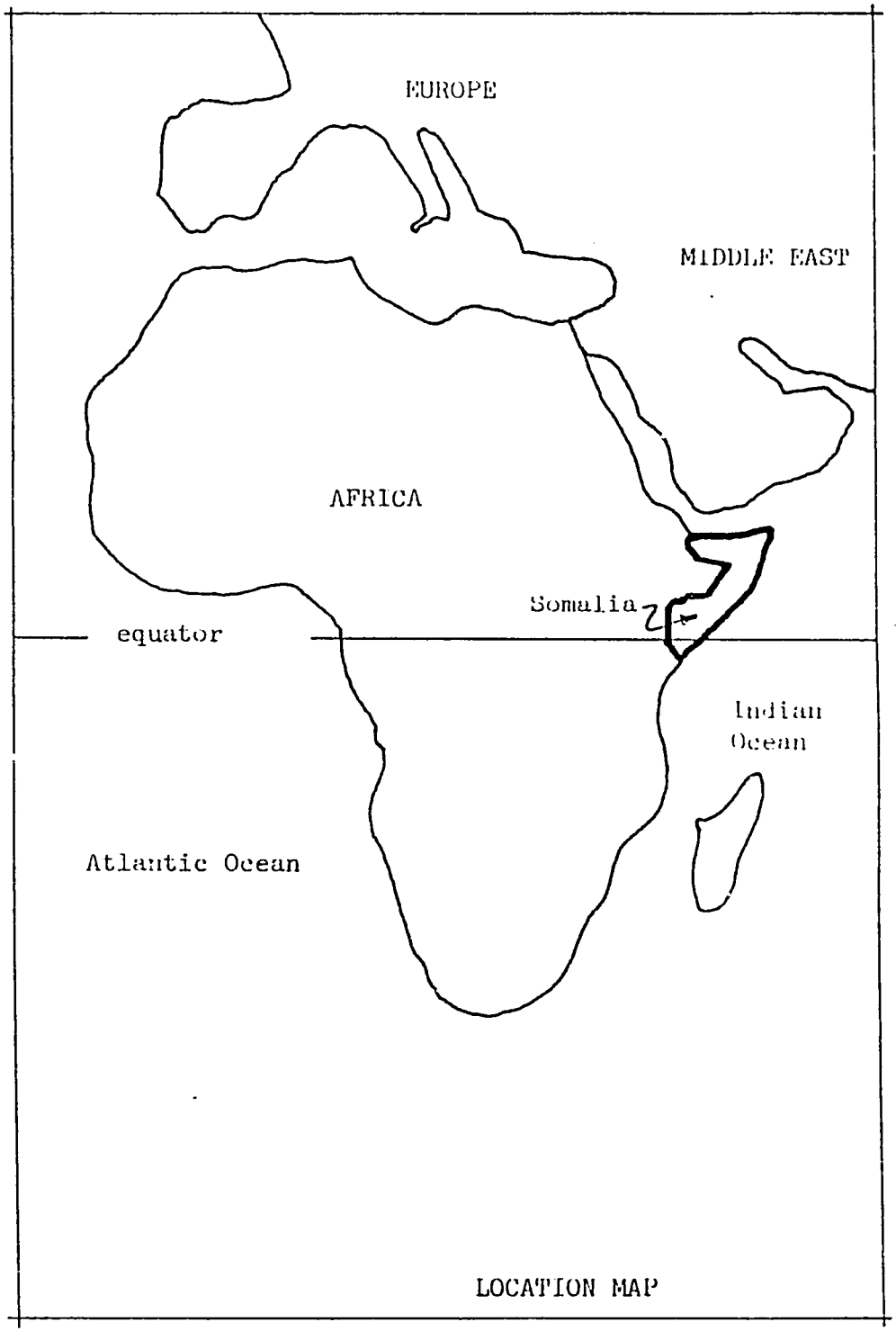
Somalia is one of the many nations affected by the devastating drought that has ravaged Africa since 1973. Although it has diminished in force, the effects of the drought are still evident today. In December 1980, the riverbeds of Somalia's two rivers were prematurely dry. There was no relief in sight for months.

The worst part of the drought came to a close in 1975, but by this time there had been a staggering loss of life and property. Of the many thousands of nomads who did manage to survive, most had lost all their livestock, and with it, their only means of livelihood. In response to this disaster, the Somali government established twenty-one (21) temporary relief camps. They were set up in areas most affected by the drought, in the interior and along the Somali-Ethiopian border. Although most of these camps remain today due to continuing drought and war, they were looked upon at the time as temporary measures to be dismantled at the end of the drought. Because of their location and temporary nature, they were ill-prepared to provide the nomads with a means of re-establishing their livelihood.

The Somali government has a long-term policy of development that calls for the re-culturalization of nomads to a sedentary way of life. In part, the government's goal is to divert the efforts of some of the nomads from the raising of livestock to the development of other areas of the country's economic base such as agriculture and fishing. These goals combined with the plight of the nomads in the temporary relief camps provided the Somali government with the opportunity to implement the resettlement of the nomads.

Aided by the U.S.S.R., the Somali government's newly formed Settlement Development Agency (SDA) set up six permanent villages. Three villages were to have an economic base in agriculture. Three more were to have an economic base in fishing. The fishing villages were established along the Indian Ocean and the agricultural villages were located along the Shebelli and Juba Rivers. The establishment of these villages offered the nomads an opportunity to rebuild their lives based on an alternative sedentary life style. It offered the Somali government the opportunity to redirect the efforts of almost 100,000 nomads to the development of the country's economic base in their agriculture and fishing industries. It was hoped that these efforts would result first in village self-sufficiency for the production of food followed ultimately by the production of a surplus of food that could be exported or sold in the country.


Red Sea
NORTH & SOUTH YEMEN
Gulf of Aden
DJIBOUTI
Berbera
Hordio
Hargeysa
ETHIOPIA
Ogaden Region
Eil
SOMALIA
Belet Weyn
Indian Ocean
Shebelli River
Adale
Juba River
Mogadishu (capitol)
KENYA
Kurtunwaare
equator
Kismayo
LOCATION MAP


EUROPE
MIDDLE EAST
AFRICA
Somalia
equator
Indian Ocean
Atlantic Ocean
LOCATION MAP

Kurtunwaare was one of the three agricultural villages set up by the SDA. It was founded with 4000 families or approximately 26,000 people. The primary crops produced by the village are rice and corn which are grown on cropland irrigated with water from the Shebelli River or on rain-fed fields.

The work required to operate the farming village is provided by the settlers who, in return for their services, are given a food ration, clothing, education, health care, 2 shillings (13¢) a day, and housing. Since its founding, great effort has been invested in the development of the village. To date, most of this effort has been directed at farming and its infrastructure, followed by health, education, social, and governmental facilities. Unfortunately, there has been little opportunity to improve the housing and its infrastructure leaving this area of village development less complete.

When the village was founded, traditional nomadic agals were temporarily set up. These structures are dome shaped houses that range from 5 to 8 feet in diameter, are covered with animal skins, and have a mud floor. Most of these were quickly replaced by the construction of munduuls. The munduul is a more "permanent" structure traditionally used by Somali farmers. It is round in plan, ranges in diameter from 8 to 14 feet, has a cone-shaped thatched roof, a dirt floor, and wattle (stick) walls often plastered with a mixture of mud and animal dung. These houses have a short life with respect to the environmental damage caused by gathering enough materials for their construction. The materials come from the sparse and already endangered vegetation that is slowly giving way to desertification. Many of these houses have deteriorated to a point where they do not offer adequate protection from the elements.

The physical infrastructure for the housing consists of minimal sanitation and water facilities. Site drainage for the houses is virtually non-existent. The sanitation system consists of open pit latrines scattered throughout the village. This is a major problem when it rains since dangerous contamination from the latrines is easily spread through the village by the deluges of water during the rainy season. Water facilities consist of several main wells from which water is carried by village inhabitants to their houses.

The Somali government and the SDA believe that the Kurtunwaare settlers must be convinced that their new life style is an improvement over a nomadic life. Indeed, many settlers have left the village to attempt to re-establish their livestock

herds. The present population of Kurtunwaare is 16,000, of which approximately 70% are women and children. The government feels that housing conditions in the village have made a significant contribution to the exodus of its inhabitants. These problems were addressed by a joint USAID/SDA project aimed at the development and testing of an appropriate housing project for Kurtunwaare.

II. Project Description

There is an obvious need for appropriate housing and its infrastructure in Kurtunwaare based on the existing physical conditions in the village. This is reinforced by the need to convince the settlers that the village is moving forward towards an improvement in living conditions and a greater degree of permanency. In the beginning, in order to establish a firm footing, much of the development effort in Kurtunwaare was directed at agricultural projects. It normally takes many years for agricultural projects to show successful results. This makes it difficult for the resettled nomads, who lack an inherent understanding of agricultural processes, to see this aspect of village development as having a direct bearing on the improvement of their living conditions. A housing project can be completed in a shorter time and everyone can easily understand the benefits and use.

The major goals of the design of the project were as follows:

- Maximize the use of local materials.
- Produce a house of longer lasting, more permanent materials.
- Minimize use of materials that would have a negative environmental impact.
- Design a house suited to the needs of the settlers.
- Provide an improved system of sanitation, drainage, and water supply.
- Construct the project using local village labor and a Somali supervisory staff.

Once a preliminary design was done, a pilot project consisting of up to 400 houses was to be built. This project was to have resulted in the final site layout and house unit design. Once completed, the first phase of the project was to lead to the construction of the final 4000 houses needed for the village.

The preliminary design of the house unit as built in the pilot project and physical site infrastructure can be summarized[1] as follows:

House Construction System

Concrete grade beam foundations
Masonry walls of hand made cinva-ram brick with cement mortar
Wood frame roof structures
Thatched roof membrane modified with tar paper

House Plan

To be further developed and modified during the pilot project construction phase.

Infrastructure

Water standpipe with cistern for every 25 houses
Composting toilet for each house
Adequate site drainage

In addition, a Crafts Training School was to be established in order to train the local settlers in the skills required to build the project. The training school was to train the skilled laborers for the project and include a component for leadership training. The school was eventually to be staffed by Somalis, as were other staff positions in the project. The school was established by a technical assistance team from the Experimental Low Cost Construction Unit of the School of Architecture of Florida A&M University.

III. The Roofing System

Project officials from both the Settlement Development Agency and the Agency for International Development expressed concern about the selection of the makuti thatch roofing system for the project housing units. Makuti is a locally manufactured thatch shingle fabricated from coconut palm leaves which are harvested approximately twenty kilometers from Kurtunwaare. Project officials felt that other roofing systems exist that could be more appropriate than the thatch. Concerns expressed by project officials and other sources can be summarized as follows:

1) Flammability of the thatch - Based on past experience, thatch is considered to be dangerously flammable. This danger is dramatically increased in higher density housing such as is the case in Kurtunwaare.

2) Infestation potential - Thatch provides a very attractive habitat for a host of insects and animals The principal pest is termites.

3) Life span - The expected life of the thatch is only 20% of the estimated life of the rest of the unit.

4) Visual image - Project officials feel that the re-settled nomads would be more attracted to a more modern and urban image than is expressed by thatch.

5) Desertification - The ecosystem of the region surrounding Kurtunwaare is very fragile. Harvesting of thatch for roofing is safe only so long as the harvest does not exceed the carrying capacity of the local palm groves. This capacity has not been studied or evaluated and as the replacement interval for makuti is only four years there could be potential for a long-term problem.

Such concerns prompted a desire by project officials for a study of alternative roofing systems. Although separate funding could not be obtained for this investigation, the work was performed by the Experimental Low Cost Construction Unit supported partially from sub-contract overhead and partially by the School of Architecture at Florida A&M University.

It should be kept in mind that this report is an overview and not an exhaustive evaluation of roofing options. In addition to the assumptions explained below, it should be noted that only limited physical testing was done in support of this study. Should the Kurtunwaare project be extended, a more detailed investigation would be in order including on-site testing of alternative roof types.

The investigation documented in this report is based on the following assumptions:

Any roof system selected should be compatible with the policies of the Somali government and USAID.

The focus of the final comparative evaluation is on the roof membrane itself, not the structure. Two structural systems were chosen that are compatible with all roof membranes evaluated.

Roof systems evaluated are limited to off-shelf systems, reasonably modified off-shelf systems, or systems developed to the extent that they require only a small amount of additional developmental work before they could be used. Systems that represent only "paper ideas" were not extensively evaluated.

All systems should be environmentally sound in terms of local Somali drought and desertification problems.

All systems must be compatible with the 4.88m x 8.85m (16' x 29') house selected from the pilot project prototypes by SDA and USAID representatives. This eliminates systems that might be usable with a shorter span.

The labor required to erect any of the roof systems should be of a simple, straight-forward nature requiring minimum use of complex machinery.

Any system that did not meet the above requirements was not fully evaluated. Some of the limitations of the above assumptions are as follows. Due to the policy of USAID, all materials not obtained in Somalia must be purchased in the United States, (with some exceptions). This places significant restraints on minimizing the cost of materials as a result of increased shipping costs and the possibility of more competitive material costs that could be found more locally in that part of the world. It has been assumed here that any materials not available in Somalia (other than cement) were to be purchased within the United States and shipped to Somalia.

One of the major cost components of all of the roof systems considered was the structural system. In order to focus on the roofing membrane, it is assumed in this report that the roof structural systems be limited to heavy or light timber trusses depending on the weight of the membrane. This is not meant to imply that no other structural system should be investigated, but simply to equalize the effect of that variable. It is in fact strongly recommended that the structural system be rigorously evaluated along with the roof membrane, however, this is something that can be done to further reduce the cost of the roof once a limited range of roof membranes are selected.

IV. Comprehensive List Of Available Roofing Materials

The following list of potential roofing materials and components was developed by the Special Advisory Committee on New Technology Solutions to Roofing Problems in Developing Countries and presented in an article written by Warren R. Nellis of the National Academy of Sciences, Building Research Advisory Board.[2]

1) Roofing Materials
   - Paper Formed
   - Metal sheets formed
     - Iron(galvanized and painted)
     - Aluminium
   - Plastic
     - Sheet
     - Foamed
     - Formed
     - Fibers (artificial thatch)
   - Bituminous
     - Formed
     - Built up
     - Shingles
   - Cement asbestos
     - Formed
     - Shingles
   - Wood/wood products
     - Shingles/Tiles
     - Plywood
     - Particle board
   - Vegetable
     - Grass
     - Cones
     - Reeds
     - Bamboo
       - Thatch
       - Woven

Concrete
  Plain/reinforced
  Ferrocement
  Lightweight
    Foamed
    Lightweight aggregates
Clay Products
  Formed
    Tiles
    Sheets
Fabrics
Animal products
Minerals
  Slate
  Stone
  Gypsum
Earth materials
  Stabilized
  Non-stabilized
  Foamed

2) Binders
Portland cement
Other Hydraulic-setting cements
From blast furnace slag
  Fly ash
  Calcinated clay
  Limestone
  Magnesium oxychloride sulfate
  Gypsum
  Lime
Sulphur (elemental)
Asphalts (pitches)
Coal tar derived
Petroleum derived
Tall oil pitch (coatings)
Natural asphalt
Vegetation derivatives
Pitches
  Tall oil pitch
  Cottonseed pitch
Resins
  Cashew nut shell liquid
  Soya bean oil residue
  Lignins
  Starches
    Grains
    Root Crops
Sugars
  Molasses
Slurry of banana stalks & leaves
Gums
Oils(drying, with & without catalyst)
  Linseed
  Cashew nut shell liquid
Rubber
Natural Latex
Protein
  Casein
  Animal and fish blood
  Legume protein
  Bone/Hoof glue(animal glue)
  Tannery waste
Animal grease
Silicates
  Sodium silicate (water glass)
Resins (Enormous potential at local level - can get produce from agriculture faster than if an industry must be established.)
Thermosetting plastics
  Unsaturated polyesters
Urethanes
Urea-formaldehyde
Thermoplastics
  Polyolefins
Earths
  Clays
Shellac
Glass
  Blast furnace slag

3) Reinforcement
Metal
  Rod
  Fiber
  Mesh
  Woven
  Expanded
Mineral fibers
  Asbestos wallostonite
  Amphibole
  Chrysotile (long fiber)
  Rock wool (slag)
  Glass fibers
Vegetable waste
  Rice hulls
  Bagasae
  Cottonseed
  Peanut and other seed hulls
Textile fiber wastes (cotton, jute, sisal, etc.)
Coconut husks
Straw

4) Fibers/Aggregate
   - Inorganic
     - Sand
     - Earth
     - Expanded (bloated)clays
     - Verniculite
     - Expanded shale
     - Expanded perlite
     - Expanded slag and glass
     - Sintered fly ash
     - Rock
     - Shell
     - Pozzolans
     - Diatomaceous earth
     - Clays
     - Waste glass
     - Air (in foams)
   - Organic
     - Vegetation (processed and waste)
     - Bark
     - Wood (sawdust, chips)
     - Cork
   - Carbonized and expanded vegetation
     - Husks
     - Cereal grains
     - Hulks
     - Plant products in general
     - Paper
     - Charcoal
     - Processed garbage
     - Coconut pith
       - Nut shells
     - Animal products
       - Hair
       - Feathers
   - Synthetic materials
     - Waste cans and other metals
     - Rubber (tires)
     - Plastic foam (styrene, etc.)
     - Plastic fibers

5) Coatings
   - Materials
     - Sulphur (elemental)
     - Polymers/paints
       - Metallic
       - Silicones
     - Cashew nut shell liquid
     - Bituminous
     - Organic wastes
     - Mineral particulates
     - White wash
     - Galvanizing

V. Roofing Systems Considered In This Report

From the preceding list, from other sources including the personal experience of members of the Experimental Low-Cost Construction Unit while working in Somalia and in consideration of the basic assumptions and limitations of this paper, the following list of roofing systems was considered for use in Kurtunwaare:

- Makuti
  - Traditional
  - Modified with Tar Paper
  - Preservative Impregnated
  - Fire Retardant Impregnated
  - Sulphur Impregnated
- Thatch
  - Reed
  - Grass
- Clay
  - Local Fired Clay Tiles
  - Local Fired Brick Vaults or Low Domes
- Cement
  - Zed Tiles
  - Corrugated Fiber Reinforced
  - Corrugated Asbestos Cement
  - Ferrocement Vault
  - Reinforced Concrete Slab
- Metal
  - Corrugated Aluminum Sheets
  - Corrugated Galvanized Iron Sheets
- Sulphur
  - Sulphur Impregnated Corrugated Cardboard
  - Sulphur Impregnated Fabric

VI. Roofing Systems Fully Evaluated In This Report

The roofing systems that were finally decided upon for inclusion in the full evaluation are as follows:

- Makuti
  - Traditional Makuti
  - Modified with Tar Paper
    - Variations on Thickness
    - Variations on Purlins Spacing
  - Preservative and Fire Retardant Treated
- Local Fired Clay Tiles
- Corrugated Fiber Cement Tiles
- Corrugated Galvanized Iron Sheets
- Corrugated Aluminum Sheets
- Corrugated Asbestos Cement Tiles
- Sulphur Impregnated Corrugated Cardboard
- Reinforced Concrete Slab

The systems that were not fully evaluated are:

Sulphur Impregnated Makuti
Reed and Grass Thatch
Local Fired Brick Vaults or Low Domes
Zed Tiles
Ferrocement Vault

Sulphur impregnated makuti was eliminated because it would need too much further developmental work to confidently offer it as a viable alternative. In theory it should work, therefore it is listed here with the recommendation that it be further investigated as a potential method of increasing the life of makuti. Reed and grass thatch were eliminated because of the possible negative impact on Somalia's fragile environment. Desertification is already a serious problem in Somalia. It was felt that use of local materials that could be improperly harvested, leading to additional damage to local vegetation and ultimately increased desertification, should not be recommended. The last three on the list were not further pursued because of the relatively long span requirements of the present house prototype. However, should the span be reduced from 4.88m (16') to around 3.66m (12') these systems might become more attractive. The relatively long span would require the use of too much material, making the systems uneconomical. In the case of the brick vault or arch, the 4.88m (16') span is simply beyond the structural capabilities of that system.

VII. Footnotes

1) A more detailed account of the actual project as designed by USAID and as it was proposed to be carried out by Louis Berger International Inc. along with Florida A&M University, School of Architecture, Experimental Low-Cost Construction Unit may be found respectively in the following two documents:

USAID, Somalia Project Paper, Kurtunwaare Settlement Project Number 649-0130, USAID, Washington, D.C., Request for Proposals, 1978.

Louis Berger International Inc. and Florida A&M University, School of Architecture, Experimental Low-Cost Construction Unit, Technical Assistance for the Kurtunwaare Settlement Project, Low Cost Minimum Shelter Construction Program, Technical Proposal, Louis Berger International Inc., 100 Halsted Street, East Orange, New Jersey, USA, 1979.

2) Nellis, W. R., Roofing for Developing Countries, Masalah Bangunan, Vol. 19, Number 2, 1974.

MAKUTI ROOFING SYSTEMS

I. Summary

All of the Makuti roofing systems considered in this report are modifications of the traditional system. In the attempt to develop alternative variations on the traditional system, the following approaches present themselves:

- Changes in the roof pitch.
- Variations in the thickness or plys of the makuti shingles.
- Changes in the spacing of the purlins.
- Addition of a backup membrane (such as roofing felt) under the makuti.*
- Modification of the makuti itself by impregnation with other materials.

These approaches will be discussed further in the Preliminary Conclusions and Recommendations section of this report. From them came the following alternative Makuti roof systems:

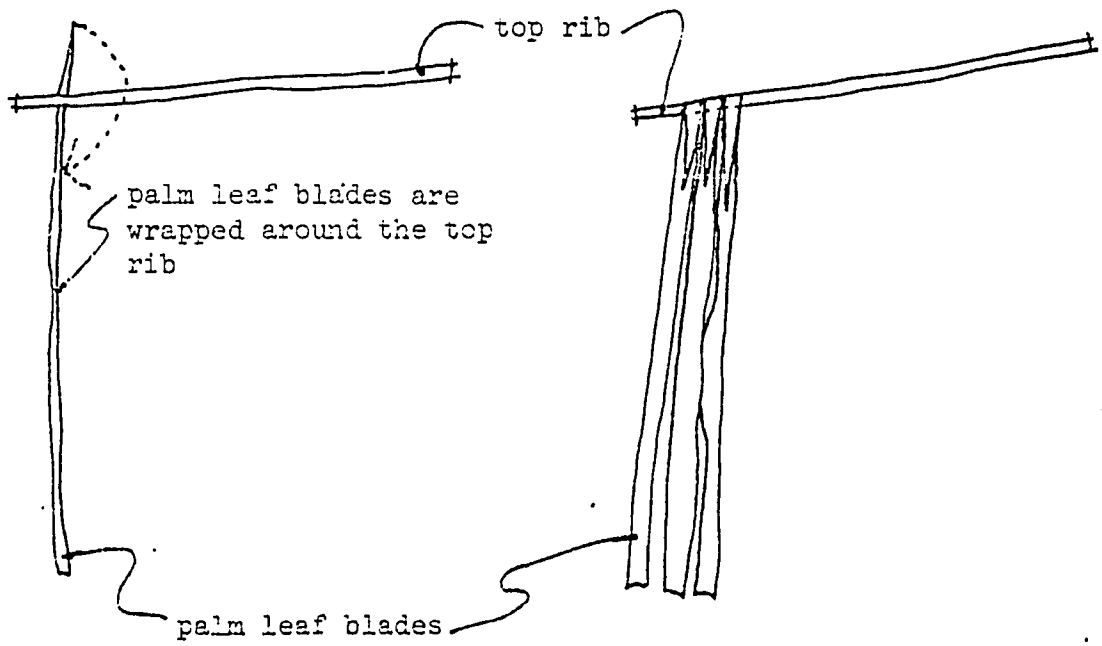
Traditional makuti
Makuti Modified with Tar Paper
  Variations on Makuti thickness
  Variations on Purlin spacing
Preservative and Fire Retardant treated Makuti

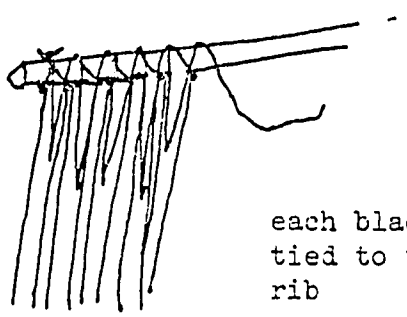
* This system was initially chosen and used for the pilot project roof system.

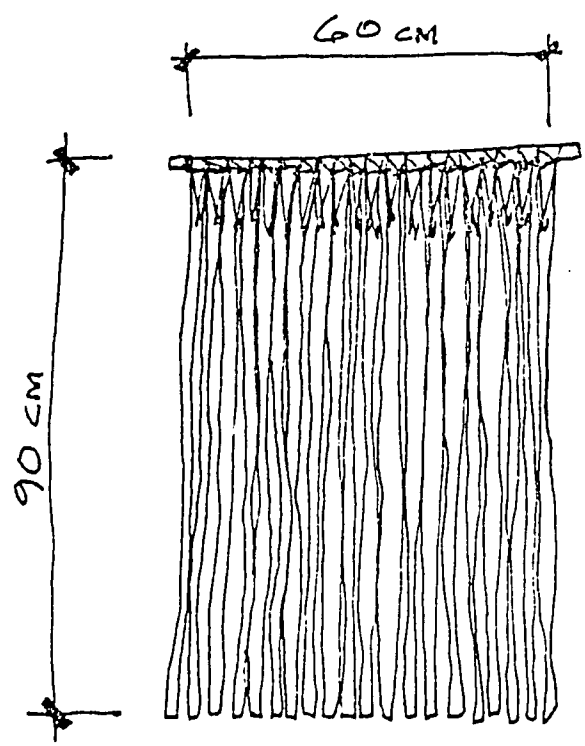
II. Traditional Makuti Roof Membrane

Makuti is the local name for a type of thatch that is made from coconut palm leaves. It is unique among the different types of thatch in that it is made into a shingle-like mat that, in the Kurtunwaare area, is 60cm by 90cm in size. The mat consists of a top rib and palm leaf blades that are wrapped around the rib and then tied to it. The rib is cut from the palm leaf stalk and is approximately 1cm to 2cm in diameter, though not necessarily round in shape. The Somalis that make the makuti mats or shingles, first harvest the palm leaves for which they pay local farmers 2 shillings. The leaves are transported to their village where they are allowed to dry. Once sufficiently dry, the leaf blades are stripped off the stalk. Most of the stalks, which range in length from 2.5m to 3.5m, are then set aside to be sold later for use as purlins. Some of the stalks are split into 1cm to 2cm diameter strips which are then cut to length, approximately 60cm, for use as the top rib of the makuti mat. With the leaf top ribs prepared, the individual leaf blades are attached. This is done by wrapping one end of each leaf

blade around the top rib and then tying it to the rib with a local natural fiber in a woven pattern. These mats or shingles are bundled together into groups of ten to be sold by the roadside for 4.5 shillings a bundle. The coconut stalk purlins are sold in bundles of eight for 8 shillings. These prices represent the prevailing rate as of December, 1980. See illustrations:







finished makuti mat or shingle

A makuti roof consists of the makuti membrane, coconut stalk purlins and a supporting structure consisting of trusses or rafters made from lumber or rough wooden poles. Once the structural framework is in place, the purlins are tied or nailed to the rafters or trusses at a spacing of 15cm.[1] With the purlins in place, the makuti is tied to the purlins. This is usually done with a twine made from local natural fibers.

Most traditional makuti roofs are installed immediately after the makuti is purchased so that storage is not a problem. However, with larger scale projects comes the need to store makuti for longer periods of time. This is because makuti is especially prone to attacks from termites. In and around Kurtunwaare, the termite problem is quite severe. It is not suprising to find makuti infested with termites within a day or two if stored directly on the ground. Most of the makuti purchased for the project was used immediately or at least within a week. For periods of up to a week it was found that one of the completed houses with a concrete floor was satisfactory for makuti storage. For longer periods of storage, it would be necessary to spray the ground in the immediate area thoroughly with termite poisons.

III. Makuti Modified With Tar Paper

The roofing system that was selected for use in the pilot housing project was a modified traditional makuti (thatch) roof. The major difference between this and a traditional makuti roof system was the layer of 30 pound roofing felt (tar paper) located underneath each row of makuti shingles. The principal differences between the two roof systems are as follows:

- Tar paper backup
- Increased purlin spacing (20cm o.c.)
- Double or triple layer makuti shingles
- Theory of water repellance and life span
- Use of metal tie wire and nails

At each row or purlin, tar paper cut to a width of 46cm (18") was rolled out over the last row to the length of the roof. With the tar paper in position the makuti shingles were then laid down and wired through the tar paper to the purlins. The purlins were spaced 20cm apart which allows the tar paper to lap over the layer below in such a way that a 2 ply tar paper roof results. The tar paper is completely covered by the 90cm long makuti shingles. The makuti shingles were applied in two different ways. At first in Xubins* A-1 and half of A-3, the makuti was applied using shingles of three layers of makuti mats.

* A Xubin is a grouping of 10 houses.

Later, for the rest of the roofs, a shingle consisting of two makuti mats was used. Type 1, the three layer shingle, resulted in 12 plys of makuti and 2 plys of tar paper. Type 2, the two layer shingle, resulted in 8 plys of makuti and 2 plys of tar paper (See chart page 19).

The theory of water repellance and life span differs also. With the traditional makuti system, water is repelled by the blades of the mats which provide thousands of channels upon which the rain water can run. In theory, there is always a lower blade onto which a drop of water may fall to be lead away and down off the roof. However, as the roof begins to age, the blades rot or through other erosive forces begin to diminish in number until there are areas thin enough for water to penetrate. With a traditional makuti roof, this happens within 4 years.[1] The tar paper modified roof actually consists of two different kinds of roofs in one. First, there is a layer of makuti roofing which works as described above. Second, there is the tar paper roof which works as a roof in itself. The tar paper is protected from the elements by the Makuti layer and also acts as a back up system for the thatch. In theory, the life span of the tar paper modified makuti roof should exceed the four year life of the traditional roof since as the makuti breaks down the tar paper is there to stop water penetration for several more years. Thus, it is assumed that a makuti roof modified with tar paper would last about six years. Other factors that influence the life of a makuti roof are the roof pitch (slope) and the number of plys of makuti. Roofs with a greater slope and/or more layers of makuti mats will have a correspondingly longer life span.[2] However, this must be carefully considered in relation to the fact that both increases in the roof slope and makuti thickness result in a higher first cost.

In addition to the above mentioned makuti roof systems a third system was generated in order to reduce the cost of the roof material. This system uses the same makuti and tar paper construction. The difference is the spacing of the purlins which are nailed to the trusses 30cm apart. This alternative is proposed in hopes of material savings of purlins, makuti, and tar paper. It is assumed that since the effect of the greater purlin spacing is the reduction of makuti and tar paper plys the life will be somewhat reduced. In this case, it is assumed that the life span will be reduced by one year compared to the Type 2 makuti roof discussed above. This is because of the 1 ply tar paper and 6 ply makuti.

IV. Preservative and Fire Retardant Treated Makuti

Palm thatch, through impregnation can be made more resistant to decay, fire, and erosive processes thus leading to an increased life span. Impregnation can be done in a number

of ways with many different kinds of materials. Some of the impregnations considered for use with the makuti are as follows:

Preservative and Fire Retardant - Makuti is soaked in the following chemical solution: 3 parts boric acid, 1 part copper sulphate, 5 parts zinc chloride, 6 parts sodium bichromate, and 100 parts water.[3] It is claimed that this could increase the life from 4 years up to 12 to 15 years.

Fire Retardant - Makuti is dipped in the following solution and then resprayed each year. The mixture consists of 28 pounds of sulphate ammonia, 14 pounds of carbonate ammonia (lump), 7 pounds of borax (lump), 7 pounds of boracic acid, 14 pounds of alum, and 50 gallons of water.[4] Recommended by the British Home Office, this treatment would improve only the fire resistance of the makuti with little effect on its life span thereby increasing its cost.

Sulphur - Although no known research has been done on this technique it is theoretically possible to impregnate makuti in a bath of molden sulphur. Sulphur impregnation should significantly increase life span and water resistance, eliminate infestation and reduce fire danger. The impregnated shingles would be heavier than the natural makuti. This process predicated on an inexpensive supply of sulphur and fuel.

Other materials could be used for improving the life of makuti through impregnation processes. However, only the first approach listed above was considered for full evaluation in this report. Use of a fire retardant alone would increase the first and yearly cost of the roof while improving it only a little. Sulphur impregnation, while it might hold promise, has not been tested at all and should not be considered until after a time when it has been tested.

Alternative Makuti Roof System - Summary Chart

The following chart summarizes the variations of makuti roof systems that are fully evaluated in this report. See also the narrative description in this section and the comparative description charts, page 38, for a more complete description.

Roof Type	MAKUTI MEMBRANE		Purlin Spacing	Tar Paper Plys
	Mat Layers	Plys		
Traditional	1	6	15	0
Tar Paper Modified As Built Type 1	3	12	20	2
Tar Paper Modified As Built Type 2	2	8	20	2
Tar Paper Modified Type 3	2	6	30	1
Preservative Treated Type 4	1	6	15	0

VI. Footnotes

1) Eygelaar, J., and Kaszner, O., Makuti Roofing For Farmer's Housing, Housing Research and Development Unit, University of Nairobi, Kenya, 1978, p. 5.

2) Ibid., p. 6.

3) Purushotham, A. and Rana, K.S., Treatment Against Decay and Fire Of Grasses and Palmyra Leaves Used for Thatch Roofs, Ideas and Methods Exchange, No. 14, Item II, Department of Housing and Urban Development, Office of International Affairs, Washington, D.C., 1954, pp 1-2.

4) Callaway, T.R., Thatching, unpublished manuscript, 1964, p. 164.

ALTERNATIVE ROOFING SYSTEMS

Summary

In addition to the variations of makuti roof systems discussed in the preceding section, other alternative roof systems were considered. These roof systems are:

- Local Fired Clay Tiles
- Corrugated Fiber Cement Tiles
- Corrugated Galvanized Iron Sheets
- Corrugated Aluminum Sheets
- Corrugated Asbestos Cement Tiles
- Sulphur Impregnated Corrugated Cardboard Shingles
- Reinforced Concrete Slab

II. Local Fired Clay Tiles

The fired clay tile roof system is one that is presently capable of being manufactured in Kurtunwaare. It uses local clay that is first mined and then transported to the site where clay bricks and roofing tiles are manufactured. The clay is mixed with water, molded in a flat metal form, and then laid on a small ridge of sand to dry and create the final low curve shape. Once the tiles have dried sufficiently, they are placed in a simple kiln where they are fired using wood for fuel. The firing takes several days and a great deal of wood. One firing requires 2.5 cubic meters which produces about 2000 tiles (enough for one house) that are 32cm long and average 15cm in width. It takes up to a month to gather the necessary fuel. The system was developed and production set up by Mr. Michael Knowles who was working at the time for UNDP on this and a number of other projects in Kurtunwaare and other areas of Somalia.

III. I.T. Workshop, Corrugated Fiber Cement Tiles

This system is in many ways identical to asbestos cement tiles except that it is manufactured on-site using only one imported material (cement) in small quantities. It seems to represent a compromise between use of indiginous and imported materials and labor. The tile is made from cement; sand; local natural fibers such as sisal, banana, bagasse, coconut, etc.; and water. It is manufactured using a process in which the mix is prepared by hand in a mortar boat, and then the panels are formed on a simple table jig. Each panel is then allowed to cure before it is installed on the building. A panel covers approximately one square meter when in place and should have a life span equivalent to any of the standard imported roof tiles such as asbestos cement, or metal roofing sheets. However, the lifespan at this time can only be empirically estimated based on the

performance of the tile since early ones were first installed in 1977.[1] The roofing tile evaluated in this report and its manufacturing system were developed by John Parry of the Intermediate Technology Workshop, United Kingdom.

IV. Corrugated Galvanized Iron, Aluminum, and Asbestos Cement Tiles

These three roofing systems are standard off-shelf, high performance roof systems that must be imported and require little manpower to install. They are especially appropriate where the cost of labor is high relative to the cost of materials. They require foreign currency to purchase, whether they are purchased from the United States or countries more geographically convenient. They all offer a life of at least 15 years with little or no maintenance. In addition to this, they tend to be viewed as prestigious building materials. One of the major disadvantages of galvanized iron is that it absorbs heat from the sun which is consequently radiated to the inside of the house causing a great deal of discomfort to occupants. This effect can be nearly completely controlled by its color and the amount of ventilation under the roof, or by installation of a ceiling. If galvanized iron is painted white, enough heat is reflected by the color to almost eliminate the radiation of heat to interior spaces.[2] This would be highly recommended for both galvanized iron and aluminum and would improve the performance of asbestos cement. It would of course cost more, however an unpainted metal roof in the Somali climate would produce unbearable discomfort to the occupants.

V. Sulphur Impregnated Corrugated Cardboard Shingles

Based on recent work done at Florida A&M University, Experimental Low-Cost Construction Unit on sulphur impregnated corrugated cardboard used as low-cost roofing material, the sulphur cardboard shingle is proposed as a possible roof material for Kurtunwaare. A corrugated paperboard plant is in operation at Kisimayo, Somalia where paper stock is imported and made into corrugated paperboard that is then used to make shipping boxes for Somalia's banana exports. Under the assumption that this paperboard combined with imported plasticized sulphur could be used to make shingles this system was fully evaluated. Shingles could be manufactured and cut to size in Kisimayo and then shipped by sea to Merca or Mogadishu and then to Kurtunwaare. Once in Kurtunwaare they would be impregnated with sulphur by allowing them to soak for approximately three hours in molten sulphur. This would be done by using wood or charcoal in carefully controlled fires to heat the sulphur. The type of fuel used and method of use would have to be carefully investigated before this system could be recommended

for use. Other than this, the technology is fairly well developed. The life span of sulphur impregnated cardboard shingles is uncertain, however the material, based on early empirical evidence, seems like it should be fairly long lived. In this case it was assumed that it will last for 15 years before replacement would be required.

VI. Reinforced Concrete Slab

This system is a conventional reinforced concrete flat slab. It is to be reinforced with number 3 steel bars spaced 8 inches on center each way. Due to the span of 4.88m (16'), a 5½" thick slab would be used with a slope of approximately 2 percent to allow drainage.

VII. Footnotes

1) Intermediate Technology Development Group, Low Cost Handmade Roof Sheets of Strong Fiber Reinforce Cement, I.T. Workshop Publication, Warley, UK, no date, pp. 2-3.

2) Givoni, B. and Hoffman, M. E., Effect of Roof Design on Indoor Climate in Hot Arid Zones, Build International, No. 6, UK, 1973, p. 534.

STRUCTURAL SYSTEMS

I. Summary

There are two basic types of structural framing systems (illustrated on the following pages) used in the evaluation of the alternative roof systems. They are both truss/frames. The first of these two is light framing for roofs that are light weight. The second is a heavier framing for roofs considered to be heavy weight. The basic difference is that a heavily framed system consists of almost twice as many trusses (15 as compared to 8) as the light framing system. This results in the use of almost twice as much lumber. Both systems are tied together at the peak with a continuous ridge beam. The only part of the structural system that varies from roof to roof is the purlins. In some cases, the material used changes. For example, coconut stalk purlins are used for makuti, 1 x 3 wood purlins are used for corrugated iron, and 2 x 4 purlins for cement asbestos. In other cases the spacing of the purlins varies such as with the makuti systems. Both systems are assumed to be made from the same materials used in the pilot project which was number 1 structural grade pressure treated lumber imported from the United States.

A more detailed study would include a different structural system for each roof. This is not done here in order to simplify the comparison and to focus primarily on the roofing membrane itself. Once the range of roofing membranes has been limited then the structural systems can be more fully evaluated and costs reduced.

The roof systems that are considered to be light weight, requiring light framing are as follows:

- All Makuti Roof Systems
- Corrugated Galvanized Iron Sheets
- Corrugated Aluminum Sheets
- Sulphur Impregnated Corrugated Cardboard Shingles

Roof systems considered to be heavy weight requiring heavier framings are:

- Local Fired Clay Tiles
- Corrugated Fiber Cement Tiles
- Corrugated Asbestos Cement Tiles

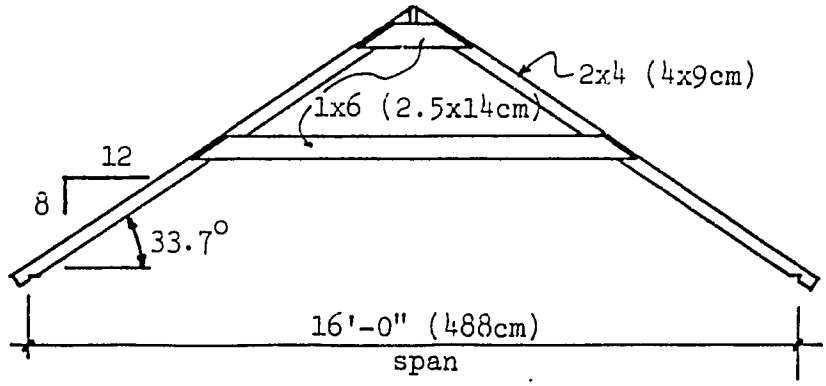
In addition to the above, the reinforced concrete slab system must be identified as belonging in a category of its own in that it provides its own structural system.

II. Structural Systems for Lightweight and Heavyweight Roofs

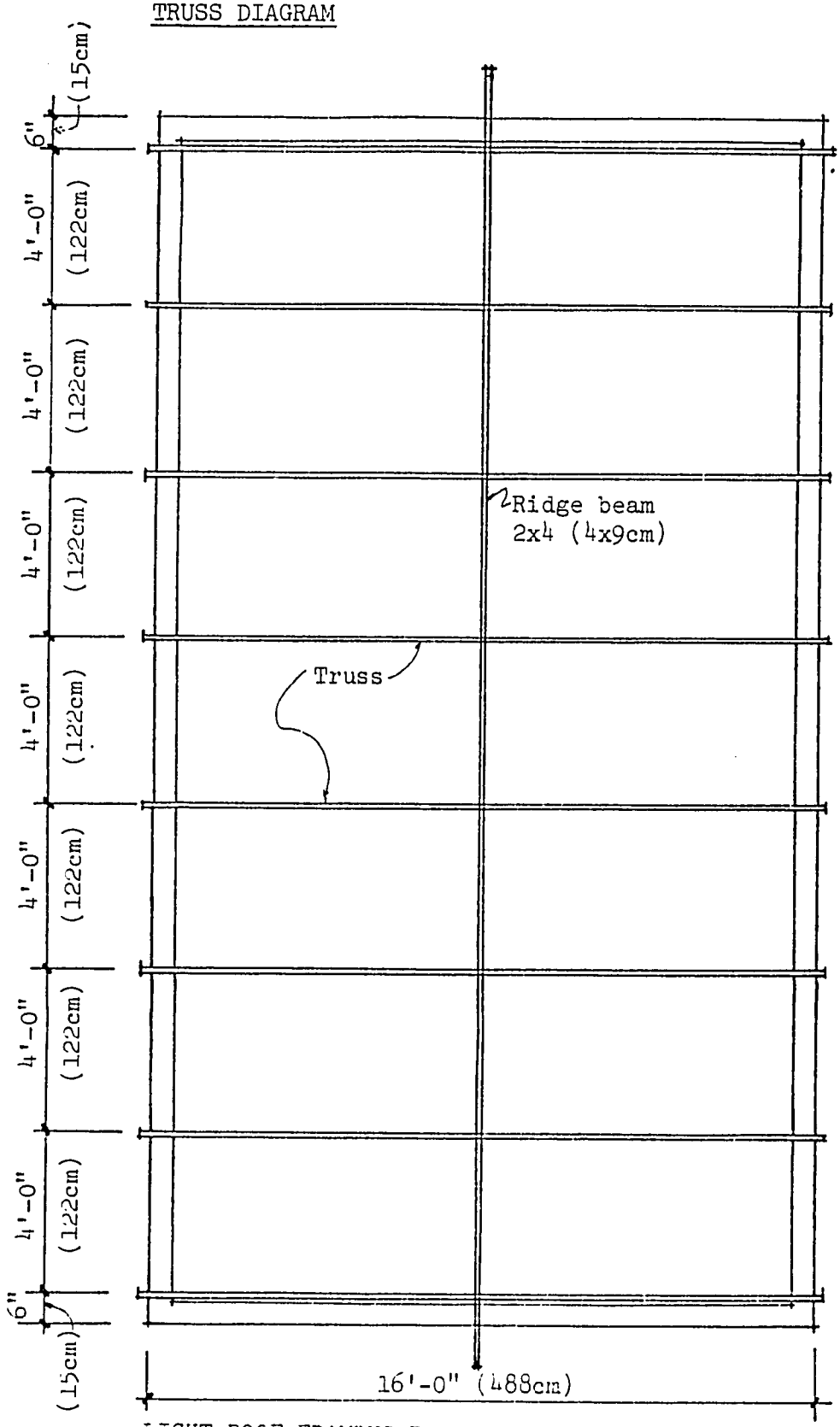
The structural system assumed for use for lightweight roofs consists of 8 wood trusses spaced at 122 cm (4'0") center to center. The trusses consist of a 2 x 4 top chord and 1 x 6

top and collar tie. Trusses are tied together with a 2 x 4 ridge. The grade of lumber used is no. 1 structural grade, pressure treated. The slope is approximately 34° (8/12 pitch). This slope is compatible with all the roof systems evaluated although not always the theoretically optimum. The cost of this roof structure is $95.42 or $1.71 per square meter of roof area. On the following page is a graphical description of the system.

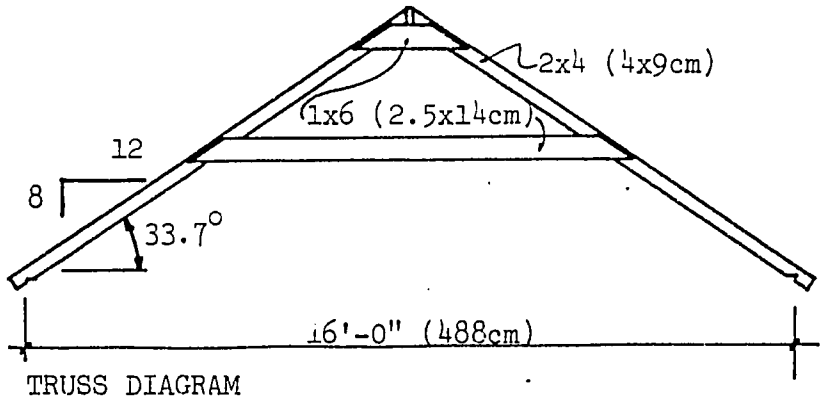
The structural system assumed for use for heavy weight roofs is identical to the one for lightweight roofs except that its trusses are spaced 61 cm (2'0") center to center. The cost of this roof structure is $171.31 or $3.07 per square meter of roof area. See the following page for a graphical description.



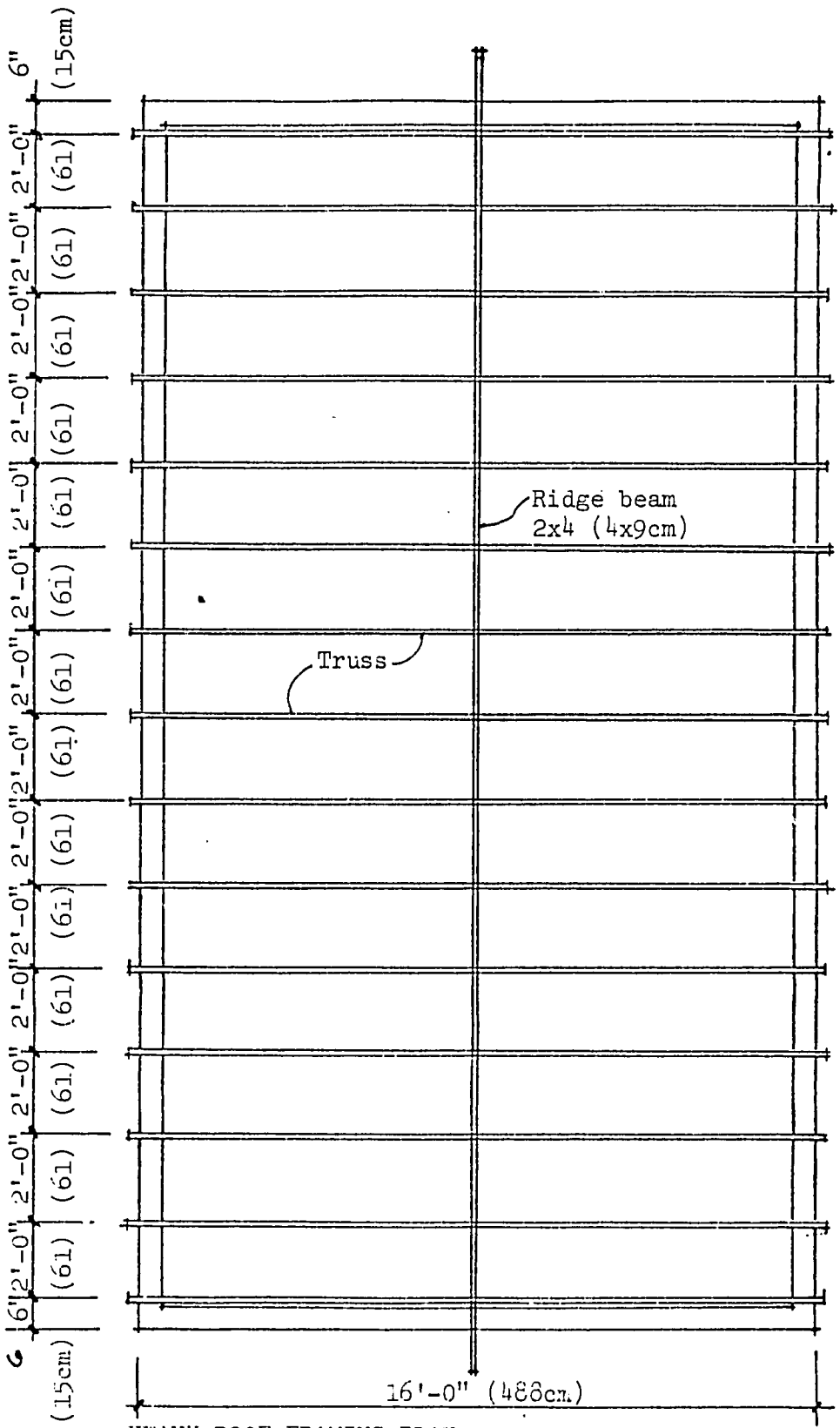
TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



TRUSS DIAGRAM



HEAVY ROOF FRAMING PLAN

COMPARATIVE DESCRIPTION CHARTS

I. Explanation of Comparative Description Charts

The Comparative Description Charts are divided into five major groups of information. They are:

- Physical Description
- Local Environmental Impact
- State of Development
- Economics
- Special Notes

The Physical Description presents a summary description of the basic roof system. This includes a description of the primary membrane, such as makuti, asbestos cement tiles, etc., Subroof, Manufacturing and/or Construction procedure required to construct the roof, and a description of the structural system required for that roof. In addition to this description, physical characteristics of each roof system are described. This includes a narrative description of the system's thermal properties and a rating representing its relative weight, flammability and infestation potential. The last three characteristics are rated on a seven point scale that represents opposite extremes of that particular characteristic. The scale ranges from +3 to a -3, where +3 is the best condition and -3 is the worst condition. The values assigned to each of the characteristics are the subjective evaluation of the authors.

The State of Development assessment is based on the use of the same kind of scale. A roof system that is an "off-the shelf" item such as corrugated metal roofing would rate a +3 since it is completely developed. A roof system that would require more developmental work for use, such as the local clay tiles, is rated lower, in this case a +1. No roof system was included that would require a great deal of additional developmental work since full evaluation of such a roof would be too speculative and therefore misleading.

The summary of Local Environmental Impact is an assessment of the effect a given roof system might have on the local environment. That is the local Kurtunwaare Region, or all of Somalia.

The Economics section includes the following subsections.

- Materials Cost
- Labor Cost
- Total First Cost
- Foreign Currency Requirement
- Cost of Roof/Year
- Maintenance
- Local Economic Impact
- Local Transportation

The Material Cost is presented in United States dollars or Somali shillings depending on the place of purchase. Costs are given per square meter of roof area assuming a 55.8 square meters of roof. All costs are representative of those who's effective date is January 1980. This was done since most of the materials evaluated were purchased at that time. This does not represent the most accurate up-to-date estimate, which was not the purpose of the Economics section of the Comparative Description Charts. The purpose is primarily to present a cost comparison. As can be seen in the final Economic Comparison Chart, the range of first and yearly cost is quite wide. From this a reasonable comparison can be made and the comparative price differences can be presented.

Labor Cost was determined by first estimating the mandays it would take to manufacture and/or construct a given roof system. This was then multiplied by a cost of 2 shillings per manday. It should be noted at this point that the labor cost does not allow for two important factors. First and most importantly, it does not account for costs incurred by the Somali Government by providing food, shelter, medical, health, educational, and governmental services to the settler labor. Secondly, there is a pay scale ranging from 2 to 10 shillings per day that allows those more skilled or with more responsible positions a greater income. If this were applied to construction labor, cost could increase. However, all the settler labor was paid 2 shillings per day during the pilot project. Requests were made for pay increases, but none were ever implemented. Therefore, it was assumed that 2 shillings per day would be representative of labor costs in the future.

The Total First Cost of the roof is calculated by first converting all costs paid for with Somali shillings into United States dollars using an exchange rate of 6.2 shillings to the dollar. The Total Materials Cost and Total Labor Cost is first calculated in dollars and then changed into the cost in Somali shillings again using the 6.2 shillings to the dollar exchange rate. The Foreign Currency Requirement is determined by calculating the percentage of the total first cost that must be paid for with United States dollars.

The Cost of the Roof Per Year is determined using the straight cost of materials, labor, and maintenance. The total cost of the roof for an assumed 15 year life cycle was calculated using estimates presented in the maintainance section of the chart. Once this was determined, the yearly cost of the roof was calculated. It is important to note that it was assumed that no Somali or United States money is borrowed to pay for materials, labor, or maintenance costs, thereby incurring no interest charges. This is important because inclusion of

these factors could radically alter the relative yearly costs. For example, if only United States money were to be borrowed, roof systems made primarily from local Somali materials would be much more attractive.

Local Economic Impact is a narrative summary of the assumed economic impact that might be expected in the private economic sector in and around Kurtunwaare. It does not include a description of multiplier linkages beyond the immediate impact. For example, makuti purchases immediately effect the nearby village where makuti is manufactured. Once this income is distributed among the families in the village, the money is further distributed causing a local economic ripple effect. No assumptions are made as to the specifics of this effect except that they will occur.

An important factor in considering the cost of the roof systems is the cost of Local Transportation required to move materials from the docks of Mogadishu or the location of purchase to Kurtunwaare. This has not been included in the actual cost comparision due to the present unstable fuel situation in Somalia. Estimates for mileage only are given for each material required.

The final portion of the Comparative Description Chart is the Special Notes section. Here notes pertaining to special assumptions or conditions are included to qualify certain assertions in the charts. This section allows for the unique differences of each roof system that may not fall neatly into a rigid format.

II. Cost of Materials

The charts on the following pages show the material prices used in calculating the costs shown in the Comparative Description Charts. Prices in Chart I were obtained from the Afro-American Purchasing Center (AAPC), New York, unless otherwise noted. AAPC purchased most of the materials for the Kurtunwaare Pilot Project. Prices in Chart II were obtained from William G. Moore, Wholesale Suppliers, New York; Gulf States Chemical, Monticello, Florida; or Sulphur Institute Washington, D.C. Prices presented on Chart III were the prevailing prices available during the time of the Kurtunwaare Pilot Project.

MATERIALS COST CHART I
Materials Imported by USAID For the Pilot Housing Project[a]
Prices Effective as of January 24, 1980

MATERIAL	UNIT	PRICE/UNIT	PRICE & SHIPPING/ UNIT[b]
No. 1 Structural Grade, Pressure-Treated Lumber			
2 x 4 x 10	$/1000 Bd. Ft.	$395.00	$592.50
2 x 4 x 12	"	431.00	646.50
2 x 4 x 14	"	431.00	646.50
2 x 4 x 16	"	446.00	669.00
1 x 6 x 12	"	429.00	643.00
Exterior Grade Plywood			
1/2" x 4' x 8'	$/1000 SF	$502.00	$753.00
3/4" x 4' x 8'	"	646.00	969.00
Portland Cement[c]			
94 lb. bag	$/Bag	$ 4.40	$ 4.40
30 lb. Building Felt (Tar Paper) 30" wide, 20.1 SM Rolls	$/Roll	$ 12.90	$ 19.35
Steel Reinforcing Bar			
No. 2 Pencil Rod	$/Long Ton	$588.00	$882.00
No. 3 Deformed Bar	"	511.84	767.76

[a]All costs (except as noted) obtained from Afro-American Purchasing Center, (AAPC), New York. All represent costs with an effective date of January 24, 1980.

[b]Shipping Costs: Except as noted, it has been assumed that the cost of shipping materials to Mogadishu is 50% of the material cost. This factor was recommended by representatives of USAID and AAPC.

[c]The cost of Portland Cement shown here already included the cost of shipping. It was not shipped from the United States, but from an area near Somalia.

MATERIALS COST CHART II
Materials Necessary for Proposed Alternative Roofing System Estimates
Prices effective as of January 1980[f]

MATERIAL	UNIT	PRICE/UNIT	PRICE & SHIPPING/ UNIT
Corrugated Glavanized Iron 18 gage	$/Sheet[a]	$ 8.21	$ 12.32
Corrugated Aluminum	$/Sheet[a]	16.63	24.95
Corrugated Asbestos Cement Tiles	$/Sheet[b]	13.28	19.92
Corrugated Fiber Cement Tiles	$/Sheet[b]	.30[c]	.30[c]
Preservative and Fire Retarding Chemicals			
Boric Acid	$/100 Lbs.	44.65	66.98
Copper Sulphate	"	52.20	78.30
Zinc Chloride	"	85.14	127.71
Sodium Bichromate	"	57.90	86.85
Plasticized Sulphur	$/Ton	120.00[d]	180.00
Corrugated Cardboard	$/1000 SF	30.00[e]	30.00[e]

[a]Sheet sizes are nominally 2' x 10'.

[b]Sheet sizes are nominally 1m x 1m.

[c]Price estimated based on I.T. Workshop information. It is assumed that the major cost is the cement. Sand and fiber costs were assumed to be negligable.

[d]The price of sulphur is fluctuating widely at this time. Sulphur prices are expected to decline in the future.

[e]Although it is assumed that the corrugated cardboard will be manufactured in Somalia, the estimated price in dollars has been used since paper stock is imported. It is assumed that the shipping cost is included since manufacturing is done in Somalia.

[f]All prices represent prices as of January 1980. Prices obtained from United States suppliers representing April 1981 prices have been presented in January 1980 dollars assuming an inflation of 1% per month as recommended by representatives of AAPC.

MATERIALS COST CHART III

Materials Obtained Locally In Somalia For The Pilot Housing Project

MATERIAL	UNIT	PRICE/UNIT
Makuti	SoSh/Bundle[a]	4.5 SoSh
Coconut Stalk (purlins)	SoSh/Bundle[b]	8.0 SoSh
Aggregate 3/4" gravel	SoSh/Load[c]	30.0 SoSh
Lime	SoSh/Load[c]	15.0 SoSh
Sand	———	———[d]

[a]Somali Shillings per Bundle of 10 makuti mats or shingles.

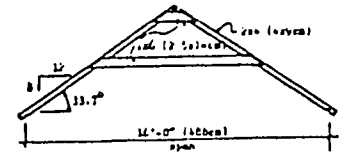
[b]Somali Shillings per Bundle of 8 coconut stalk purlins.

[c]Somali Shillings per 4 cubic meter load.

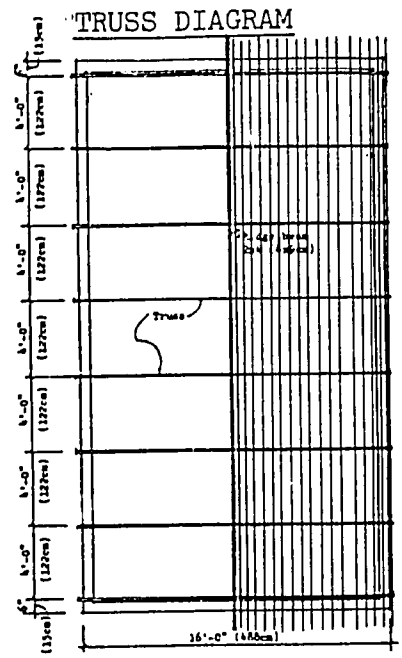
[d]There was no charge for sand if trucks were provided to transport it to Kurtunwaare.

ROOF TYPE Traditional Mackuti

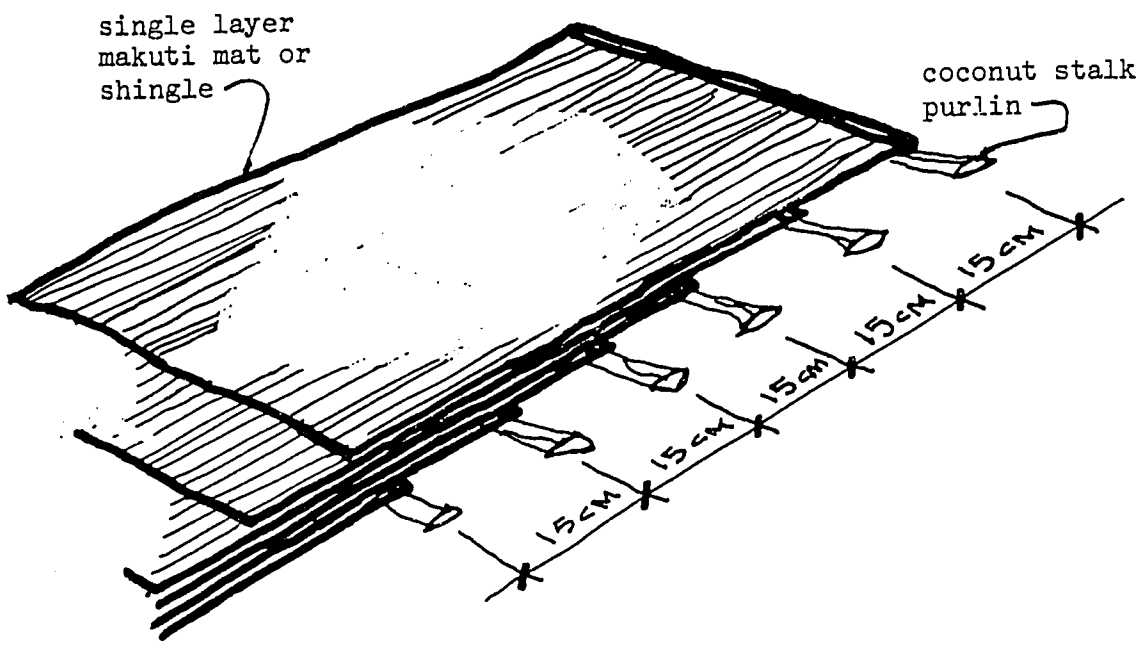
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



ROOF TYPE TRADITIONAL MACKUTI

PHYSICAL DESCRIPTION:

Primary Membrane: 1 layer mackuti mat 15cm vertical lap

Subroof: none

Manufacturing/Construction Procedure: The structure is erected. Ridge beam and coconut stalks are applied. Makuti is lashed in single layer mats to the purlins with tie wire or local natural fiber such as sisal.

Thermal Effects: The makuti mats provide good insulation from daytime heat from the sun.

Description Of Structure: Light Framing. The structure is constructed from #1 structural grade pressure treated 2 x 4 trusses. (see drawings) Purlins are laid on trusses @ 15cm on center.

Weight:	light----		medium-----				heavy
	3	(2[a])	1	0	-1	-2	-3
Flammability:	nonflammable----						flammable
	3	2	1	0	-1	-2	(-3)
Infestation Potential:	none----------						high
	3	2	1	0	-1	-2	(-3)

LOCAL ENVIRONMENTAL IMPACT: The raw material for makuti comes from the coconut palm. Local Somalis who manufacture the mats purchase palm leaves from nearby farmers. If properly harvested, the palm leaves represent a good renewable resource. Since the coconut is to the farmer a cash crop, it is unlikely that the farmers would allow over-harvesting of the palms.

STATE OF DEVELOPMENT:

developed-----						undeveloped
(3)	2	1	0	-1	-2	-3

Local Economic Impact:

Makuti is manufactured locally by private sector Somali's living in a nearby village. Makuti and the coconut stalk purlins (a kind of by-product) are sold on a cash-only, demand basis. Makuti sales were the main economic activity of the village.

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	1.71	2.95
Subroof	--	--
Primary Membrane	--	6.60
Sub Totals:	1.71	9.55

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	7	14	.25
Subroof	--	--	--
Primary Memb.	7	14	.25
Sub Totals:	14	28	.5

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	3.33	20.60

Foreign Currency Requirement: % of first cost: 51 %

Cost of Roof/Year: 15 yr life cycle — $/SM: 25.71; Sh/SM: 150

Local Transportation:

Timber - Mog. to Kwaare. = 150km

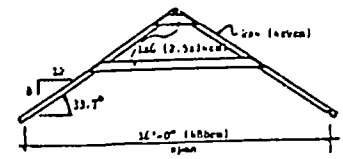
Makuti & purlins - Genali to Kwaare. = 50km

Maintenance: 1) Replace makuti every 4 years.
2) Replace coconut stalk purlins every 8 years.
3) Replace structure every 15 years.

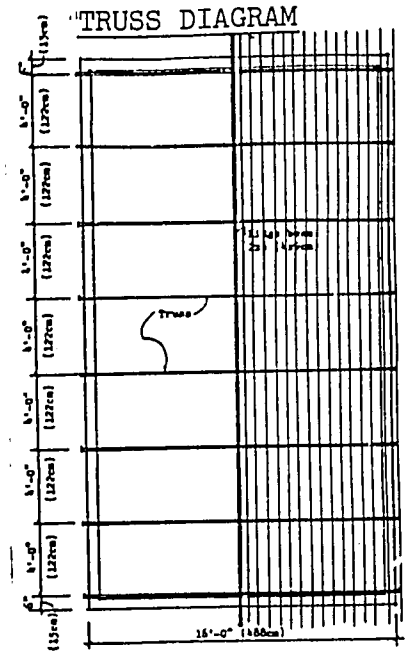
SPECIAL NOTES: a) The weight of makuti increases substantially when wet from rain.

ROOF TYPE (as built type 1) Makuti with Tar Paper

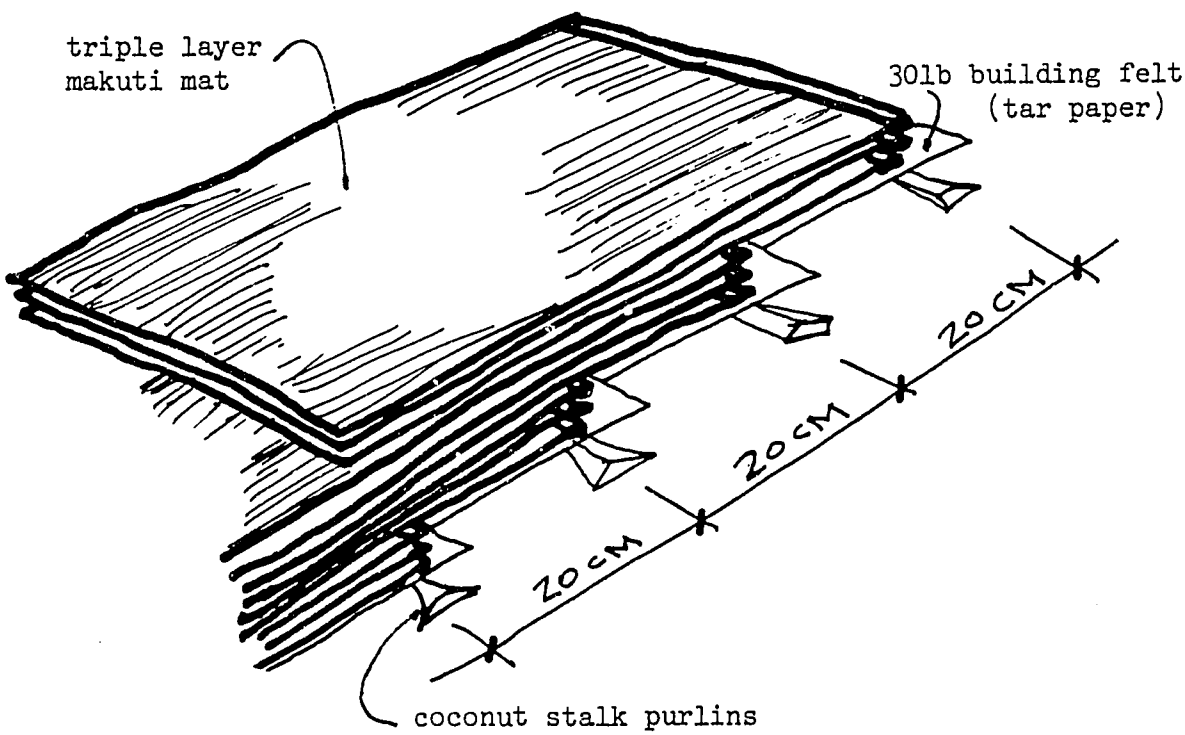
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



ROOF TYPE (as built type 1) MAKUTI WITH TAR PAPER

PHYSICAL DESCRIPTION:

Primary Membrane: 3 layer makuti mats 20 cm vertical lap

Subroof:

Manufacturing/Construction Procedure: Structure is erected. Ridge beam and purlins are nailed in place. A 46cm (18") roll of tar paper is laid out. 3 layer makuti mats are wired through the tar paper to the purlins.

Thermal Effects: The makuti mats provide good insulation from daytime heat from the sun.

Description Of Structure: Light framing. The structure is constructed from #1 structural grade pressure treated 2 x 4 trusses. (see drawings) Purlins are nailed to trusses @ 20cm on center.

Weight:	light----			medium-----			heavy
	3	2 [a]	1	0	-1	-2	-3
Flammability:	nonflammable----						flammable
	3	2	1	0	-1	-2	-3
Infestation Potential:	none----------						high
	3	2	1	0	-1	-2	-3

LOCAL ENVIRONMENTAL IMPACT: The raw material for makuti comes from the coconut palm. Local Somalis who manufacture the mats purchase palm leaves from nearby farmers. If properly harvested, the palm leaves represent a good renewable resource. Since the coconut is a cash crop for the farmer, it is unlikely that the farmers would allow overharvesting.

STATE OF DEVELOPMENT:

developed-----						undeveloped
3	2 [b]	1	0	-1	-2	-3

Local Economic Impact: Makuti is manufactured locally by private sector Somali's living in a nearby village. Makuti and the coconut stalk purlins (a kind of by-product) are sold on a cash only, demand basis. Makuti sales were the main economic activity of the village.

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	1.72	2.15
Subroof [c]	1.45	--
Primary Membrane	--	14.50
Sub Totals:	3.17	16.65

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	7	14	.25
Subroof	--	--	--
Primary Memb.	10	20	.36
Sub Totals:	17	34	.61

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	5.96	36.30

Foreign Currency Requirement: % of first cost: 54 %

Cost of Roof/Year: 15 yr life cycle	$/SM	Sh/SM
	37.12	230

Local Transportation:

Timber & tar paper - Mog. to Kwaare. = 150km

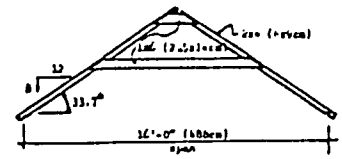
Makuti & purlins - Genali to Kwaare. = 50km

Maintenance:
1) Replace makuti every 7 years.
2) Replace tar paper every 7 years.
3) Replace coconut stalk purlins every 7 years.
4) Replace structure every 15 years.

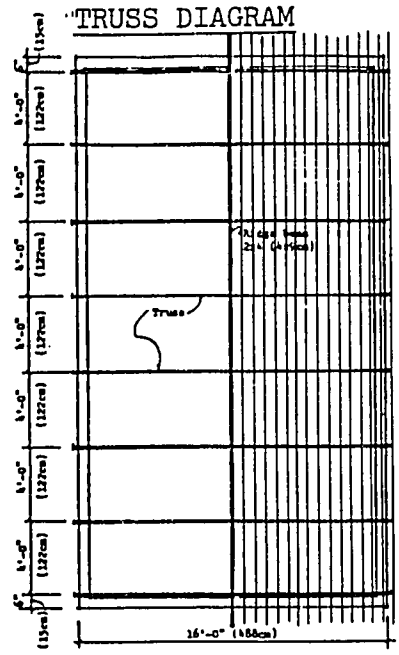
SPECIAL NOTES: a) The weight of the makuti increases substantially when wet from rain. b) Although this system was actually installed as described in Kurtunwaare, careful obeervation of its performance must be made to determine the exact value of adding the tar paper. c) The labor for installation of the subroof and makuti are combined under the Primary Membrane heading. d) Tar paper may be subject to damange as it is unsupported. People climbing on the roof for maintenance can kick holes in it. Also, it gets brittle with age. e) Animals?

ROOF TYPE (as built by type 2) Makuti with Tar Paper

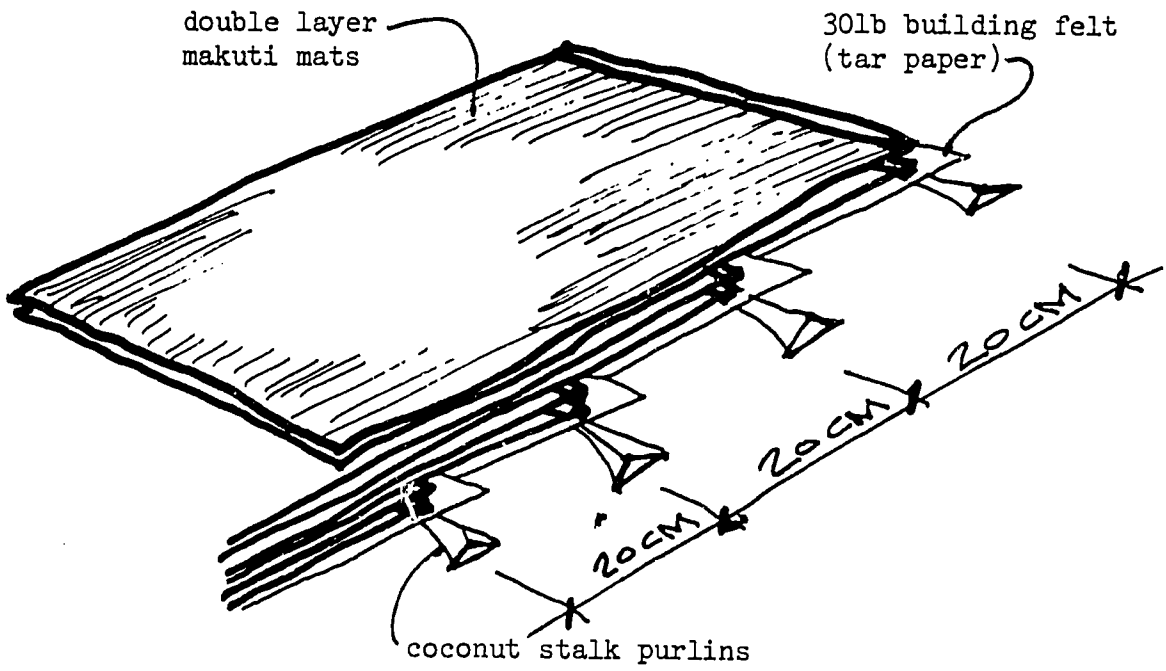
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



ROOF TYPE (as built type 2) MAKUTI WITH TAR PAPER

PHYSICAL DESCRIPTION: 2 layer makuti mats

Primary Membrane: 20cm vertical lap

Subroof: 30# tar paper

Manufacturing/Construction Procedure: Structure is erected. Ridge beam and purlins are nailed in place. A 46cm (18") roll of tar paper is laid out. 2 layer makuti mats are wired through tar paper to purlins.

Thermal Effects: The makuti provides good insulation from daytime heat from the sun.

Description Of Structure: Light Framing. The structure is constructed from #1 structural grade pressure treated 2 x 4 trusses. (see drawings) Purlins are nailed to trusses @ 30cm on center.

Weight:	light----			medium-----			heavy
	3	(2[a])	1	0	-1	-2	-3
Flammability:	nonflammable----						flammable
	3	2	1	0	-1	-2	(-3)
Infestation Potential:	none----------						high
	3	2	1	0	-1	-2	(-3)

LOCAL ENVIRONMENTAL IMPACT: The raw material for makuti comes from the coconut palm. Local Somalis who manufacture the mats purchase palm leaves from nearby farmers. If properly harvested, the palm leaves represent a good renewable resource. Since the coconut is a cash crop for the farmer, it's unlikely that the farmers would allow overharvesting.

STATE OF DEVELOPMENT:

developed-----						undeveloped
3	(2[b])	1	0	-1	-2	-3

Local Economic Impact: The raw material for makuti comes from the coconut palm. Local Somalis who manufacture the mats purchase palm leaves from nearby farmers. If properly harvested, the palm leaves represent a good renewable resource. Since the coconut is a cash crop for the farmer, it's unlikely that the farmers would allow overharvesting.

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	1.72	2.50
Subroof	1.45	--
Primary Membrane	--	9.70
Sub Totals:	3.17	11.80

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	7	14	.25
Subroof[c]	--	--	--
Primary Memb.	10	20	.36
Sub Totals:	17	34	.61

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	5.17	32.00

Foreign Currency Requirement: % of first cost: 61 %

Cost of Roof/Year: 15 yr life cycle	$/SM	Sh/SM
	36.90	228

Local Transportation:

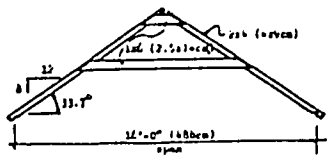
Timber & tar paper - Mog. to Kwaare. = 150km
Makuti & purlins - Genali to Kwaare. = 50km

Maintenance:
1) Replace makuti every 6 years.
2) Replace tar paper every 6 years.
3) Replace coconut stalk purlins every 12 years.
4) Replace structure every 15 years.

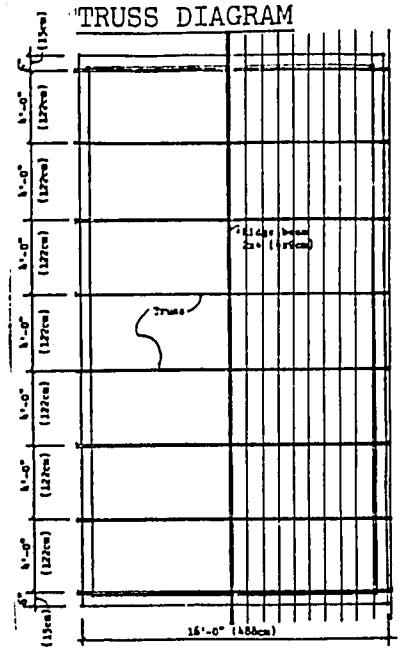
SPECIAL NOTES: a) The weight of the makuti increases substantially when wet from rain.
b) Although this system was actually installed as described in Kurtunwaare, careful observation of its performance must be made to determine the exact value of adding the tar paper.
c) The labor for installation of the subroof and makuti are combined under the Primary Membrane heading.

ROOF TYPE (type 3) Makuti with Tar Paper

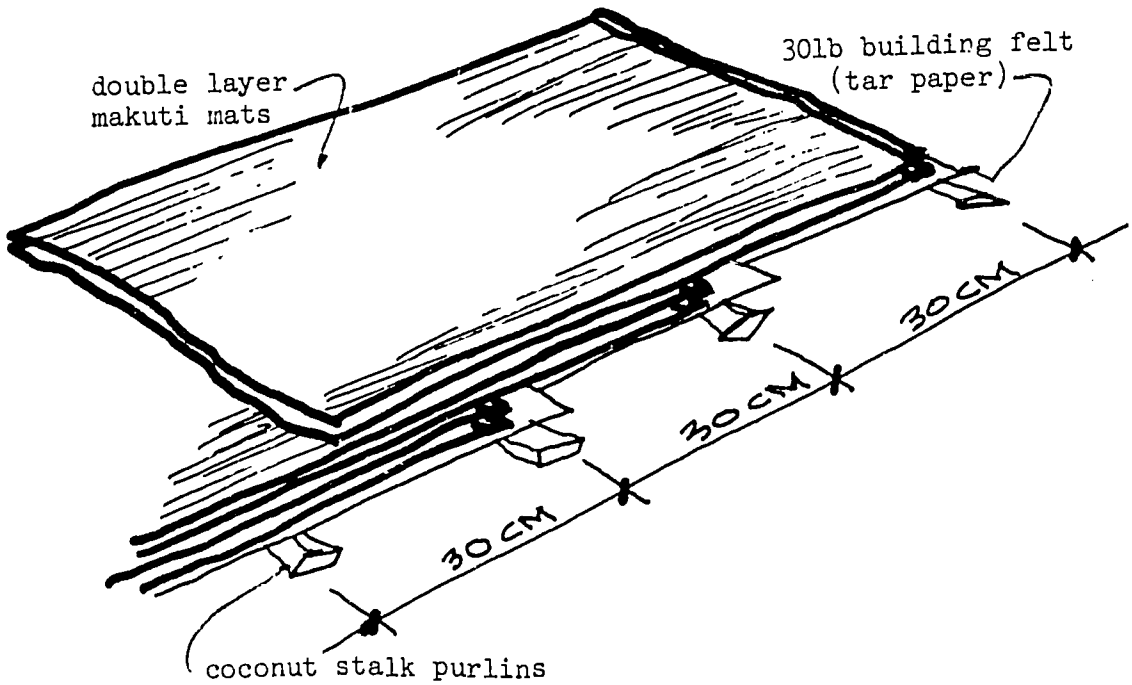
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



ROOF TYPE (type 3) MAKUTI WITH TAR PAPER

PHYSICAL DESCRIPTION:

Primary Membrane: 2 layer makuti mat 30cm vertical lap

Subroof: Tar paper

Manufacturing/Construction Procedure: Structure is erected. Ridge beam and purlins are nailed in place. A 46cm (18") roll of tar paper is laid out. 2 layer makuti mats are wired through the tar paper to the purlins

Thermal Effects: The makuti mats provide insulation from daytime heat from the sun.

Description Of Structure: Light Framing. The structure is constructed from #1 structural grade Pressure treated 2 x 4 trusses. (see drawings) Purlins are nailed to trusses @ 20cm on center.

Weight:	light----		medium-----				heavy
	3	(2[a])	1	0	-1	-2	-3
Flammability:	nonflammable----						flammable
	3	2	1	0	-1	-2	(-3)
Infestation Potential:	none----------						high
	3	2	1	0	-1	-2	(-3)

LOCAL ENVIRONMENTAL IMPACT: The raw material for makuti comes from the coconut palm Loaal Somalis who manufacture the mats purchase palm leaves from nearby farmers. If properly harvested, the palm leaves represent a good renewable resource. Since the coconut is a cash crop for the farmers, it is unlikely that the farmers would allow overharvesting.

STATE OF DEVELOPMENT:

developed-----						undeveloped
3	2	(1)	0	-1	-2	-3

Local Economic Impact: Makuti is manufactured locally by private sector Somali's living in a nearby village. Makuti and the coconut stalk purlins (a kind of by-product) are sold on a cash only, demand basis. Makuti sales were the main economic activity of the village.

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	1.72	2.15
Subroof[b]	.96	--
Primary Membrane	--	6.45
Sub Totals:	2.68	8.60

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	7	14	.25
Subroof	--	--	--
Primary Memb.	7	14	.25
Sub Totals:	14	28	.50

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	4.07	25.20

Foreign Currency Requirement: % of first cost: 65 %

Cost of Roof/Year: 15 yr life cycle — $/SM: ; Sh/SM:

Local Transportation:

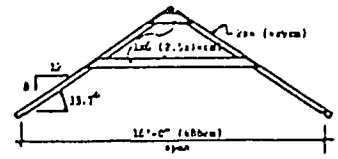
Timber & tar paper - Mog. to Kwaare. = 150km
Makuti & purlins - Genali to Kwaare. = 50km

Maintenance:
1) Replace makuti every 5 years.
2) Replace tar paper every 5 years.
3) Replace coconut stalks every 10 years.
4) Replace structure every 15 years

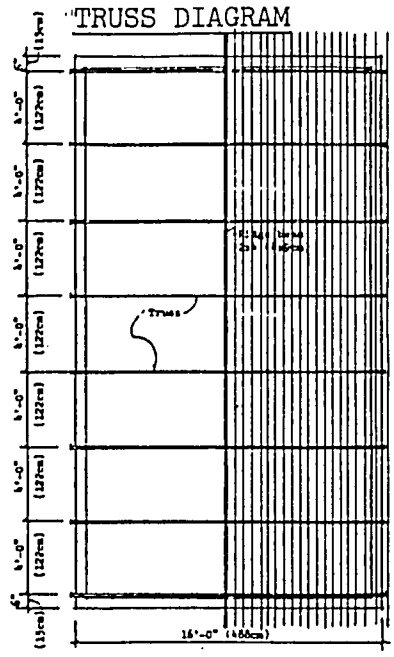
SPECIAL NOTES: a) The weight of the makuti increases substantially when wet from rain.
b) The labor for installation of the subroof and makuti are combined under the Primary Membrane heading.

ROOF TYPE (type 4) Preservative Treated Traditional Makuti

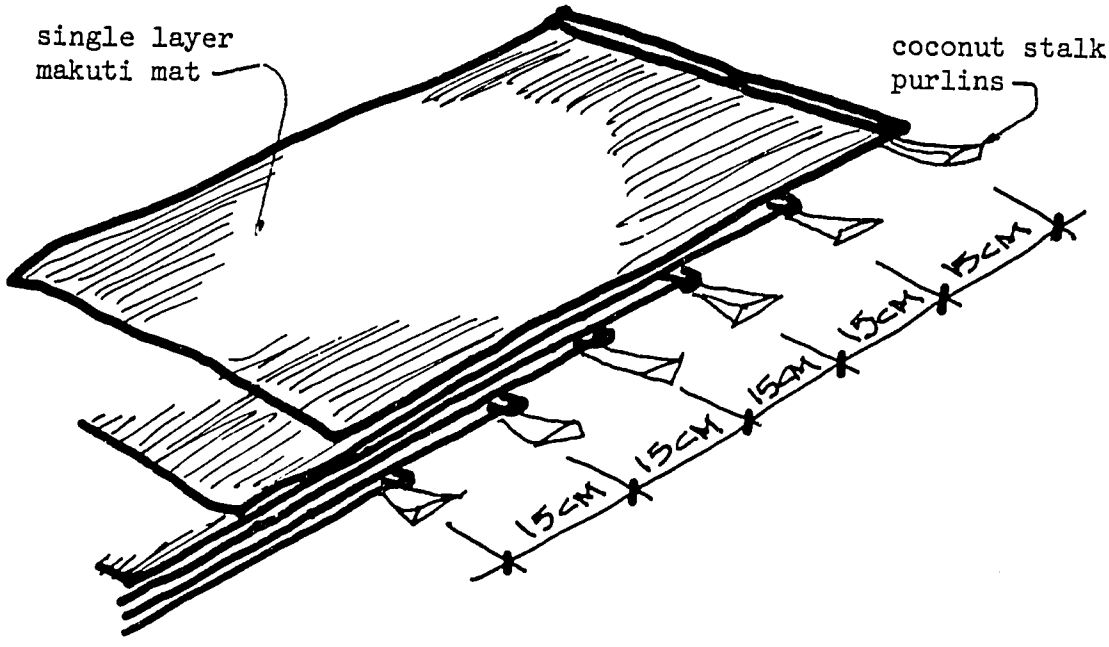
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



ROOF TYPE (type 4) PRESERVATIVE TREATED TRADITIONAL MAKUTI

PHYSICAL DESCRIPTION: Preservative treated[a] 1 layer makuti mats

Primary Membrane: 15cm vertical lap

Subroof: none

Manufacturing/Construction Procedure: The makuti is soaked in preservative solution for 24 hours. The structure, ridge beam, and purlins are erected. The makuti is tied in single layer mats to the purlins with tie wire or local natural fiber such as sisal.

Thermal Effects: Makuti provides good insulation from daytime heat from the sun.

Description Of Structure: Light Framing. The structure is constructed from #1 structural grade pressure treated 2 x 4 trusses. (see drawings) Purlins are nailed to trusses @ 15cm on center.

Weight:	light----		medium-----				heavy
	3	(2b)	1	0	-1	-2	-3
Flammability:	nonflammable----						flammable
	3	2	1	0	-1	(-2)	-3
Infestation Potential:	none----------						high
	3	(2)	1	0	-1	-2	-3

LOCAL ENVIRONMENTAL IMPACT: The raw material for makuti comes from the coconut palm. Local Somalis who manufacture the mats purchase palm leaves from nearby farmers. If properly harvested, the palm leaves represent a good renewable resource. Since the coconut is to the farmer a cash crop, it is unlikely that the farmers would allow overharvesting of the palms.

STATE OF DEVELOPMENT:

	developed-----						undeveloped
	3	2	1	(0)	-1	-2	-3

Local Economic Impact: Makuti is manufactured locally by private sector Somalis living in a nearby village. Makuti and the coconut stalk purlins (a kind of by-product) are sold on a cash-only, demand basis. Makuti sales were the main economic activity of the village.

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	1.71	2.15
Subroof	--	--
Primary Membrane	5.45	6.60
Sub Totals:	7.16	8.75

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	7	14	.25
Subroof	--	--	--
Primary Memb.	12	24	.43
Sub Totals:	19	38	.68

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	8.68	54

Foreign Currency Requirement: % of first cost — 83 %

Cost of Roof/Year: 15 yr life cycle	$/SM	Sh/SM
	32.28	200

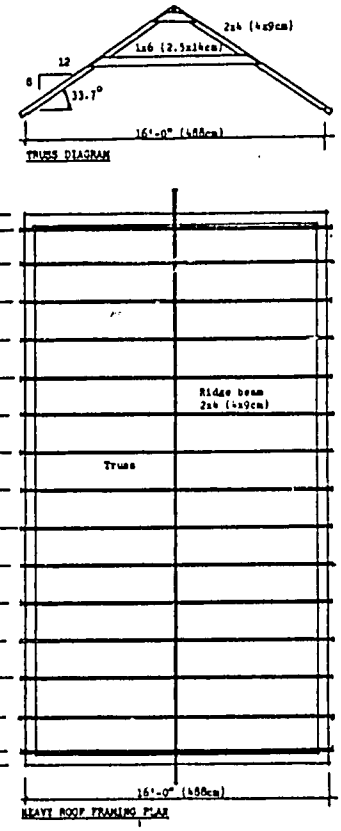
Local Transportation:
Timber & preservative - Mog. to Kwaare. = 150km
Makuti & purlins - Genali to Kwaare. = 50km

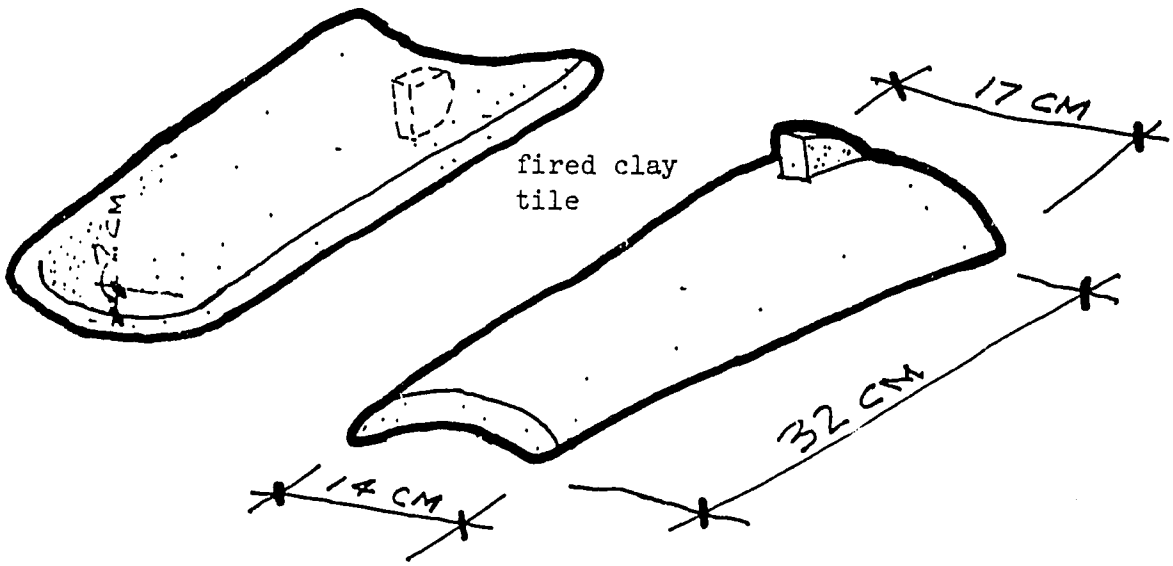
Maintenance: 1) Replace makuti every 15 years.[c]
2) Replace purlins every 15 years.
3) Replace structure every 15 years.

SPECIAL NOTES: a) Preservative refers to the following chemical mixture: 3 parts Boric Acid; 1 part Co per Sulphate, 5 parts Zinc Chloride, 6 parts Sodium Bichromate, 100 parts water. Thatch is soaked for 24 hours.[1] b) The weight of makuti increases substantially when wet from rain. c) The life span estimated for palm thatch ranges from 12 to 15 years when treated with the above mentioned mixture. This is an empirically based estimate.[1]

ROOF TYPE Local Fired Clay Tiles

DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:





ROOF TYPE LOCAL FIRED CLAY TILES

PHYSICAL DESCRIPTION:

Primary Membrane: Fired Clay Tiles

Subroof: none

Manufacturing/Construction Procedure: Tiles are formed, dried, & fired with wood for fuel. The structure is erected with ridge beam & coconut stalk purlins nailed to trusses. Tiles are simply laid in place with no mechanical connection, only their weight will hold them.

Thermal Effects: Tiles will provide some insulation from daytime heat. Openings in roof[d] will provide good ventilation.

Description Of Structure: Heavy Framing. The structure is constructed from #1 structural grade pressure treated 2 x 4 trusses. (see drawings) Coconut stalk purlins are nailed to trusses @ 20cm ctr.

Weight:	light----		medium-----				heavy
	3	2	1	0	-1	(-2)	-3
Flammability:	nonflammable----						flammable
	3	(2[a])	1	0	-1	-2	-3
Infestation Potential:	none----------						high
	3	(2)	1	0	-1	-2	-3

LOCAL ENVIRONMENTAL IMPACT: Clay tiles require firing to achieve their hardened surface and relatively long life. This is presently done using wood for fuel. According to Mr. Mike Knowles, the UNDP developer of the tile, it took 2½ cubic meters per firing batch of 2000 tiles and a month to gather. Use of wood fuel contributes to Somalia's desertification.

STATE OF DEVELOPMENT:

developed-----						undeveloped
3	2	(1[b])	0	-1	-2	-3

Local Economic Impact: Since the clay tiles are manufactured by the settlers of Kwaare., there will be little economic impact on local Somali's in the private sector. Manufacture of the tiles by the villagers requires that local labor be diverted to tile production from farming.

ECONOMICS:

Material Cost:[e]	U.S. $/SM	Somali Sh/SM
Structure	3.07	2.15
Subroof	--	--
Primary Membrane	--	-- [c]
Sub Totals:	3.07	2.15

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	9	18	.30
Subroof	--	--	--
Primary Memb.	45	90	1.60
Sub Totals:	54	108	1.90

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	3.72	23.10

Local Transportation:

Timber - Mog. to Kwaare. ≈ 150km

Wood fuel-surrounding area to Kwaare. = ?

Foreign Currency Requirement: % of first cost — 82 %

Maintenance: 1) Replace tiles every 15 years.[d]
2) Replace coconut stalk purlins every 15 years.
3) Replace structure every 15 years.

Cost of Roof/Year: 15 yr life cycle

	$/SM	Sh/SM
	13.83	85.80

SPECIAL NOTES: a) It is assumed that the tiles are nonflammable but that the structure is. b) The tile production system is fully developed. However, the total roof system requires more developmental work & testing. c) It is assumed that the material cost is practically free. Only labor is required to gather materials. d) It would be advantageous to whitewash the roof every 2-3 years for heat reflectivity, but this is optional. e) IMPORTANT NOTE: The quantity of tiles produced is limited to enough for 1 roof/month until the fuel supply is increased.

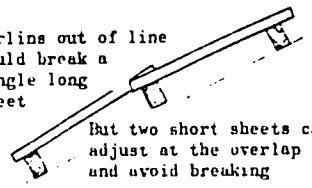
ROOF TYPE I. T. Workshop Corrugated Fiber Cement Tiles

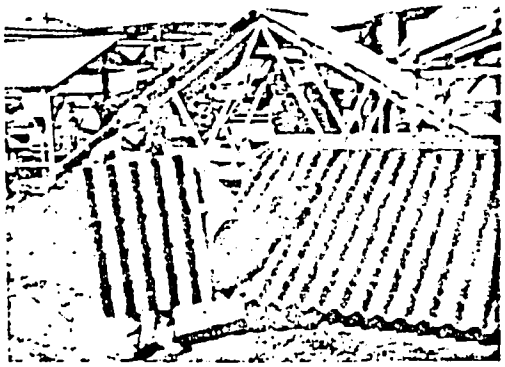
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:

Roof Sheets Work on evolving the best application for the fibre cement roofing technology has resulted in the development of a sheet or panel designed to fit on a variety of roof structures.

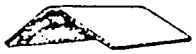
The sheets can be made in two alternate forms; smooth side upwards with a highly reflective top surface, or with the trowelled face upward, so that the strengthening cross ribs provide an attractive tile-like effect.

Most fibre cement sheets are now made in short lengths of one metre to accommodate irregularities which occur in many roof structures.

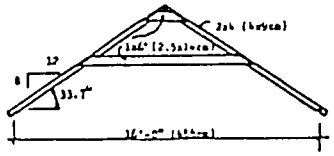




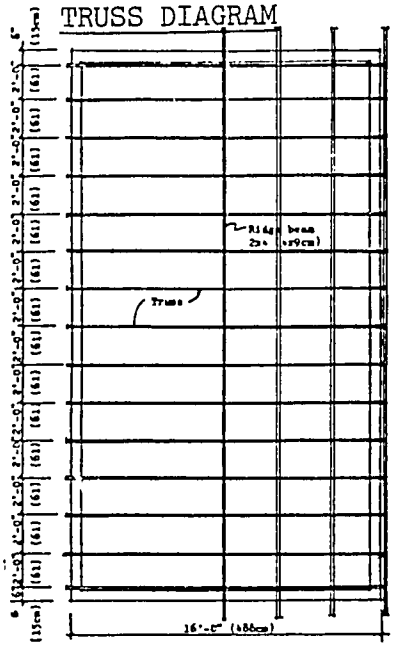
Ridge Tiles A second component which can be made in the same plant is the fibre cement ridge tile. In its simplest form this is just a plain capping which provides a strong ventilating ridge to the roof.



All the products are made to a simple formula of Portland cement, sand, chopped fibre and water. A wide range of artificial and natural fibres can be used to make the FRC products, including sisal, coir and polypropylene.



TRUSS DIAGRAM



HEAVY ROOF FRAMING

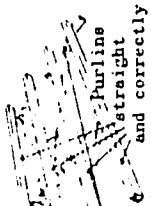
Coolness An advantage with the use of the FRC sheets and ridge tiles is their coolness when compared, for instance, with corrugated iron. In most climates it will not be necessary to install a ceiling under an FRC sheet roof as the sheets provide both insulation and also ventilation between the joints and at the ridge.

Strength The sheets can be made to a specification. Where needed, greater strength can be achieved by increasing their thickness or the depth of the corrugations and cross ribs, or by using a higher cement sand ratio. For normal climates it is considered that a load carrying capability of 100 kg at a point midway between the purlins will be adequate. In hurricane-prone areas it might be necessary to increase this minimum to 150 kg. Typical FRC roof sheets weigh 15 kg per sq.m. (4 lbs per sq.ft.)

Durability As the production process was first developed in 1975, roof sheets made with I.T. Workshop method have only so far been under exposure test since then until the time of preparation of this leaflet in 1980. None of the many thousand sheets put under test or in to practical use on buildings in different countries over the last 3 years has shown any sign of physical deterioration due to age. So durability could be a feature of this new product as well as low initial cost.

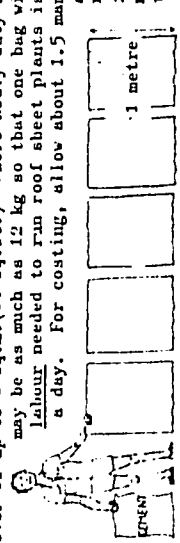
Structures Although up to a third heavier than asbestos, FRC sheets do not demand any difference in roof structures as the main factor determining the design of these is not weight, but wind pressure which could amount to ten times any load put on the roof by the weight of the sheets themselves. Builders should use trusses made on a template to ensure that purlins are accurately positioned. FRC sheets are not flexible and will crack if fixed irregularly.

Fixings The majority of FRC sheets in use are nailed, but where possible the use of hookbolts is preferable providing a more secure fixing. Development work is in progress on a system of built-in fixing ties to further reduce the cost of bought-in components.



Maintenance The sheets are not especially resistant to impact from heavy falling or flying objects and where this occurs repairs will be needed for holes and cracks. This can be done in situ without actually removing the sheet, and it is even possible to undertake the repair from below, thereby avoiding having to climb on the roof. The repair is simple to carry out, the sheet surface around the crack is painted with PVA (white wood glue) and then a patch of fresh fibre cement patted on by hand and left to set.

Economics The most important cost in producing the sheets is cement. For normal applications with good sand it is often possible to produce standard duty sheets with as little as 8 kg of cement. One bag of cement will therefore produce roofing cover of up to 6 sq.m. (64 sq.ft.) Where heavy duty sheets are required, cement used may be as much as 12 kg so that one bag will produce 4 sq.m. (43 sq.ft.) Labour needed to run roof sheet plants is usually 4 men to make 20 items a day. For costing, allow about 1.5 manhours wages per sheet. Sand and fibre are not usually regarded as a significant cost factor. One kg of fibre will normally produce 5 sheets and a ton of sand over 100 sheets.



IN TYPICAL APPLICATIONS ONE BAG OF CEMENT AND ONE MAN'S LABOUR NOW MAKE FIVE ROOF SHEETS IN A DAY

ROOF TYPE I. T. WORKSHOP CORRUGATED FIBER CEMENT TILES

PHYSICAL DESCRIPTION:

Primary Membrane: Corrugated Fiber Cement Tiles

Subroof: none

Manufacturing/Construction Procedure: Cement tiles are fabricated by mixing sand, cement, fiber, & water. They are formed over an asbestos tile form. The structure is erected with 2x4 purlins. ement tiles are nailed or bolted to the purlins.

Thermal Effects: Cement tiles will provide a small amount of daytime insulation. Tiles will radiate a small amount of heat.[b]

Description Of Structure: Heave Framing. The structure is constructed from #1 structural grade pressure treated 2 x 4 trusses. (see drawings) Purlins are 2x4's nailed to trusses @ 1m on center.

Weight:	light----		medium-----				heavy
	3	2	1	0	-1	(-2)	-3
Flammability:	nonflammable----						flammable
	3	(2[a])	1	0	-1	-2	-3
Infestation Potential:	none----------						high
	3	(2)	1	0	-1	-2	-3

LOCAL ENVIRONMENTAL IMPACT: Local sand, appropriate natural fiber (coconut husk or bana fibers), and water are required to manufacture these tiles. Use of these materials would have little environmental impact. Coconut husk and bananna fiber is in abundance in the Kurtunwaare area. They are also renewable resources.

STATE OF DEVELOPMENT:

developed-----						undeveloped
3	(2)	1	0	-1	-2	-3

Local Economic Impact: Since the cement fiber tiles would be manufactured by the settlers of Kurtunwaare, there would be little economic impact on the private sector. Manufacture of tiles in Kwaare would require diversion of some labor from farming to tile production.

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	4.33	--
Subroof	--	--
Primary Membrane	.30	--c
Sub Totals:	4.63	--

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	9	18	.32
Subroof	--	--	--
Primary Memb.	19	38	.68
Sub Totals:	28	56	1.00

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	4.79	30

Foreign Currency Requirement: % of first cost: 97 %

Cost of Roof/Year: 15 yr life cycle[d]	$/SM	Sh/SM
	17.82	110

Local Transportation:

Lumber & cement - Mog. to Kwaare. = 150km

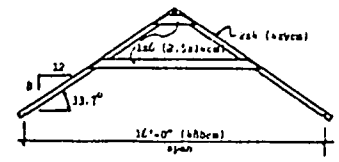
Sand - Merca to Kwaare. = 50km

Maintenance: 1) Replace tiles every 15 years.[b] 2) Replace coconut stalk purlins every 15 years. 3) Replace structure every 15 years.

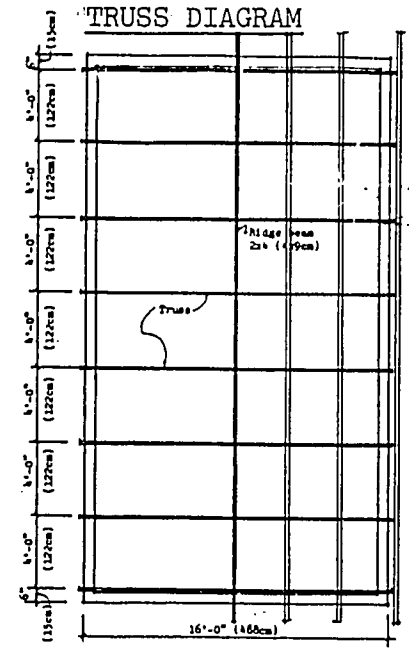
SPECIAL NOTES: a) It is assumed that the tiles are nonflammable but that the structure is. b) Whitewashing the roof every 2-3 years would significantly improve the thermal qualities of the tiles. Most heat would be reflected. c) It is assumed that the materials cost would be practically free. Only labor would be required to gather the materials. d) The developer of this roof system I.T. Workshop, C/O JPM Parry & Assoc., UK, note that the tiles have been in use since 1977 showing no signs of deterioration. The 15 year life is an assumption.

ROOF TYPE Corrugated Galvanized Iron

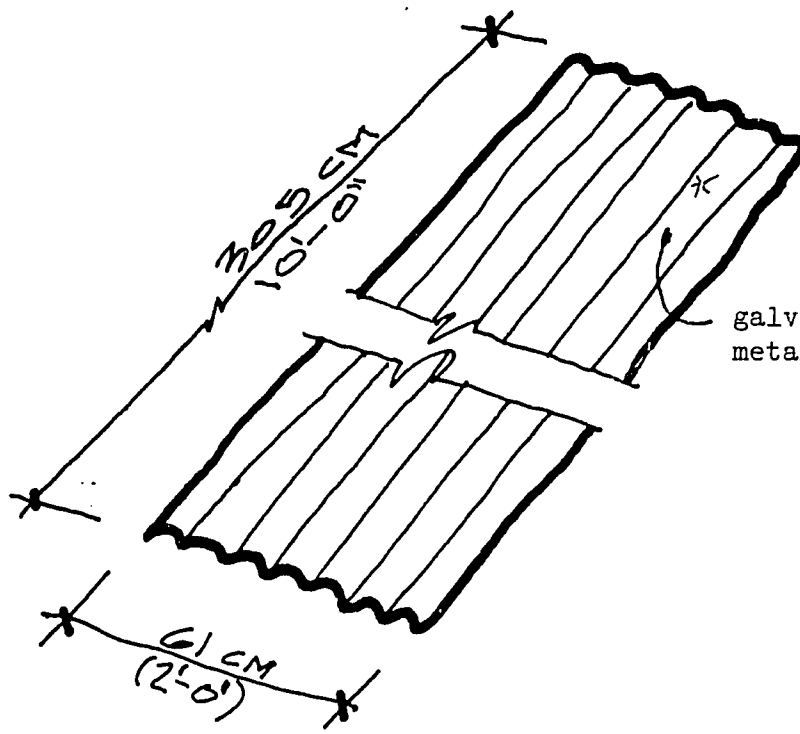
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



galvanized corrugated metal sheet

ROOF TYPE CORRUGATED GALVANIZED IRON

PHYSICAL DESCRIPTION:

Primary Membrane: Corrugated Galvanized Iron

Subroof: none

Manufacturing/Construction Procedure: Structure is erected. Ridge beam and purlins are nailed in place. Corrugated galvanized iron is nailed in place.

Thermal Effects: Corrugated iron has practically no insulative value and radiates the suns heat to the living space. a

Description Of Structure: Light Framing. The structure is constructed from #1 structural grade pressure treated 2x4 trusses. (see drawings) 1x3 purlins are nailed to trusses @ 1m on center.

Weight: light----medium-----heavy
(3) 2 1 0 -1 -2 -3

Flammability: nonflammable----flammable
3 (2) 1 0 -1 -2 -3

Infestation Potential: none----------high
3 (2) 1 0 -1 -2 -3

LOCAL ENVIRONMENTAL IMPACT: None

STATE OF DEVELOPMENT:

developed-----undeveloped
(3) 2 1 0 -1 -2 -3

Local Economic Impact: None. (Unless corrugated iron is purchased locally. In that case it would still be imported since Somalia has no facilities for manufacturing galvanized iron roofing.)

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	2.17	--
Subroof	--	--
Primary Membrane	6.96	--
Sub Totals:	9.13	--

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	4	8	.16
Subroof	--	--	--
Primary Memb.	2	4	.07
Sub Totals:	6	12	.23

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	9.17	57.85

Foreign Currency Requirement: % of first cost: 100 %

Cost of Roof/Year: 15 yr life cycle	$/SM	Sh/SM
	34.11	211

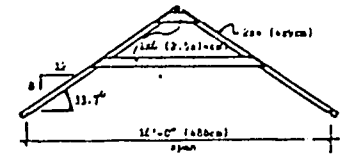
Local Transportation: Timber & corr. iron - Mog. to Kwaare. = 150km

Maintenance: 1) Replace iron every 15 years. 2) Replace structure and purlins every 15 years.

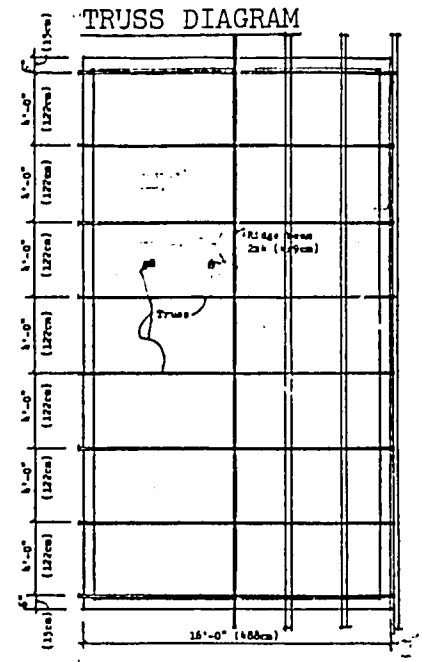
SPECIAL NOTES: a) A substantial amount of discomfort to occupants is caused by the radiation of heat from a galvanized iron roof. The simplest way to minimize this effect is to coat the roof with white paint. Then most of the suns heat is reflected away. Another way to reduce heat radiation to occupants is to install a insulative or well ventilated ceiling.

ROOF TYPE Corrugated Aluminum

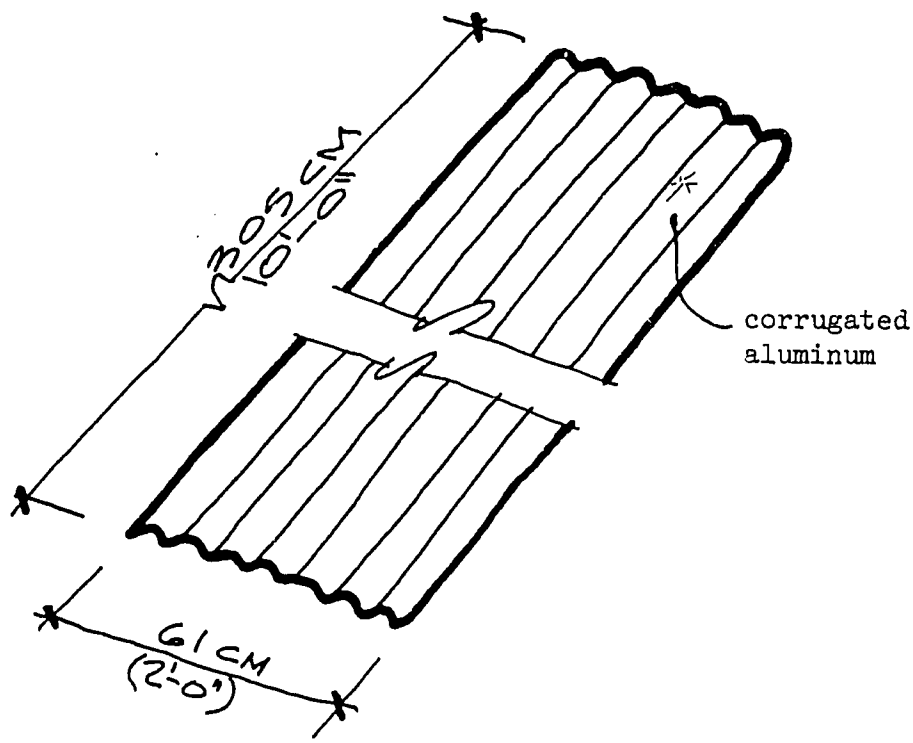
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



ROOF TYPE CORRUGATED ALUMINUM

PHYSICAL DESCRIPTION:

Primary Membrane: Corrugated Aluminum

Subroof: none

Manufacturing/Construction Procedure: Structure is erected. Ridge beam and purlins are nailed in place. Corrugated aluminum roofing is nailed in place.

Thermal Effects: Aluminum roofing has practically no insulative value and radiates the suns heat to the living space. a

Description Of Structure: Light Framing. The structure is constructed from #1 structural grade pressure treated 2x4 trusses. (see drawings) 1x3 purlins are nailed to trusses @ 1m on center.

Weight: light----medium-----heavy
(3) 2 1 0 -1 -2 -3

Flammability: nonflammable----flammable
3 (2) 1 0 -1 -2 -3

Infestation Potential: none----------high
3 (2) 1 0 -1 -2 -3

LOCAL ENVIRONMENTAL IMPACT: None

Local Economic Impact: None

Local Transportation:
Timber & roofing - Mog. to Kwaare. = 150km

Maintenance: 1) Replace roofing every 15 years. 2) Replace structure every 15 years.

STATE OF DEVELOPMENT:

developed-----undeveloped
(3) 2 1 0 -1 -2 -3

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	2.17	--
Subroof	--	--
Primary Membrane	14.09	--
Sub Totals:	16.26	--

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	4	8	.16
Subroof	--	--	--
Primary Memb.	2	4	.07
Sub Totals:	6	12	.23

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	16.30	101

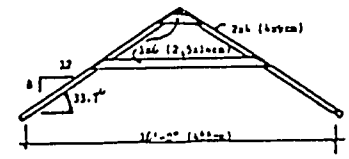
Foreign Currency Requirement: % of first cost: 100 %

Cost of Roof/Year: 15 yr life cycle	$/SM	Sh/SM
	60.64	376

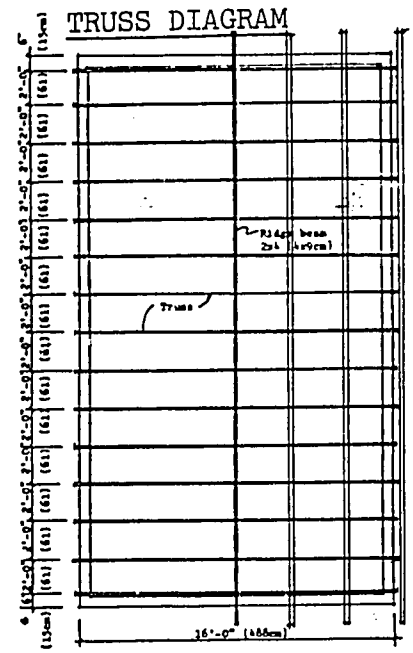
SPECIAL NOTES: a) Aluminum is more reflective than corrugated iron but still radiates enough heat to occupants to cause discomfort. This effect can be practically eliminated by painting the roofing white to reflect the suns heat.

ROOF TYPE Corrugated Asbestos Cement Tiles

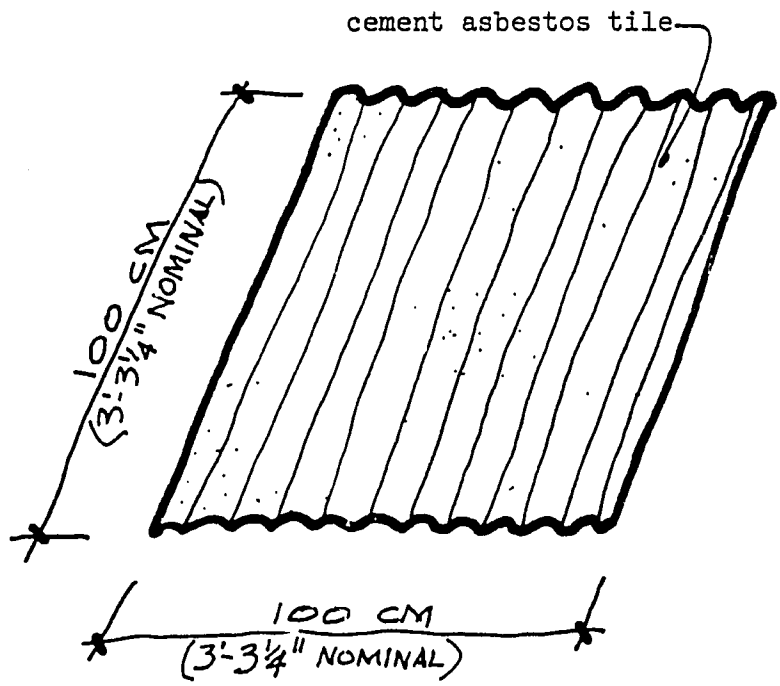
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



HEAVY ROOF FRAMING PLAN



ROOF TYPE CORRUGATED ASBESTOS CEMENT TILES

PHYSICAL DESCRIPTION:

Primary Membrane: Corrugated Asbestos Cement Tiles

Subroof: none

Manufacturing/Construction Procedure: Structure is erected. Ridge beam and purlins are nailed in place on the trusses. Corrugated tiles are nailed or screwed to the trusses with minimum 14cm long nails or screws.

Thermal Effects: Tiles provide some insulation from daytime heat. Tiles are reflective when new and radiate only a little heat. a

Description Of Structure: Heavy Framing. The structure is constructed from #1 structural grade pressure treated 2x4 trusses. (see drawings) Purlins are 2x4's nailed to trusses @ 1m on center.

Weight: light----medium-----heavy
3 2 1 0 -1 (-2) -3

Flammability: nonflammable----flammable
3 (2) 1 0 -1 -2 -3

Infestation Potential: none----------high
3 (2) 1 0 -1 -2 -3

LOCAL ENVIRONMENTAL IMPACT: None

STATE OF DEVELOPMENT:

developed-----undeveloped
(3) 2 1 0 -1 -2 -3

Local Economic Impact: None

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	4.33	--
Subroof	--	--
Primary Membrane	19.92	--
Sub Totals:	24.25	--

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	9	18	.30
Subroof	--	--	--
Primary Memb.	4	8	.16
Sub Totals:	13	26	.46

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	24.32	151

Foreign Currency Requirement: % of first cost: 100%

Cost of Roof/Year: 15 yr life cycle — $/SM: 90.47; Sh/SM: 561

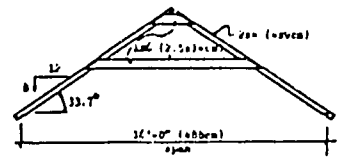
Local Transportation: Timber & roofing - Mog. to Kwaare. = 150km

Maintenance: 1) Replace asbestos every 15 years. 2) Replace structure and purlins every 15 years.

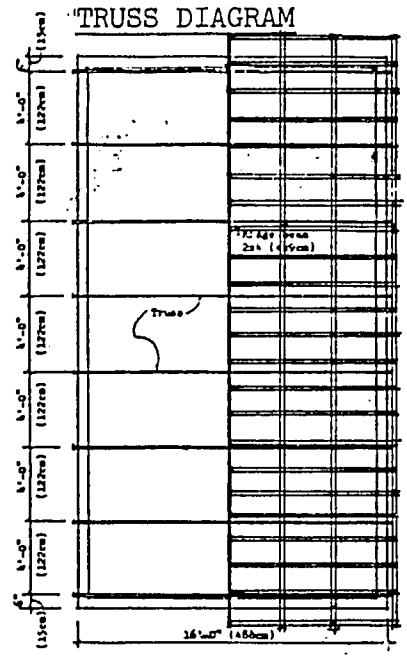
SPECIAL NOTES: a) As asbestos roofing ages, it becomes darker, thereby radiating more heat to house occupants. It is recommended that once this happens, a coat of whitewash be applied every 2-3 years.

ROOF TYPE Sulphur Impregnated Corrugated Cardboard

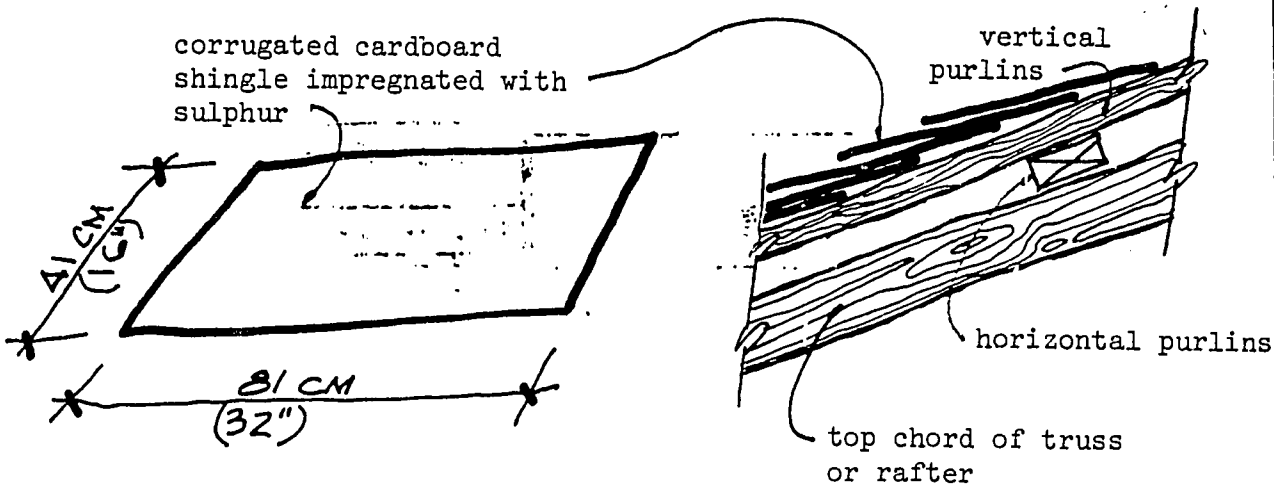
DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:



TRUSS DIAGRAM



LIGHT ROOF FRAMING PLAN



ROOF TYPE: SULPHUR IMPREGNATED CORRUGATED CARDBOARD

PHYSICAL DESCRIPTION:

Primary Membrane: Sulphur Impregnated Corrugated Cardboard

Subroof: none

Manufacturing/Construction Procedure: Corrugated cardboard impregnated with sulphur. Structure is erected. Sperial vertical purlins are installed at 41cm on center. Shingles are nailed to purlins.

Thermal Effects: Provides a small amount of insulation. Roof will radiate some heat. More study needed.

Description Of Structure: Light Framing. The structure is constructed from #1 structural grade pressure treated 2x4 trusses. (see drawings) Purlins are 2x4's nailed to trusses @ 1m on center with vertical 2x2's nailed on top at 41cm on center.

Weight: light----medium-----heavy

3 (2) 1 0 -1 -2 -3

Flammability: nonflammable----flammable

3 2 1 0 (-1) -2 -3

Infestation Potential: none----------high

3 (2) 1 0 -1 -2 -3

LOCAL ENVIRONMENTAL IMPACT: none

STATE OF DEVELOPMENT:

developed-----undeveloped

3 2 1 0 (-1) -2 -3

Local Economic Impact: This system is assumed to be fabricated in Kurtunwaare. There would be little impact on the private sector economy. Fabrication of sulphur shingles in Kurtunwaare would require the diversion of some labor to this task.

ECONOMICS:

Material Cost:	U.S. $/SM	Somali Sh/SM
Structure	4.93	--
Subroof	--	--
Primary Membrane	2.13	--
Sub Totals:	7.06	--

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	10	20	.36
Subroof	--	--	--
Primary Memb.	2	4	.07
Sub Totals:	10	24	.43

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	7.13	44

Foreign Currency Requirement: % of first cost: 100 %

Cost of Roof/Year: 15 yr life cycle	$/SM	Sh/SM
	26.52	164

Local Transportation:

Lumber & sulphur - Mog. to Kwaare. = 150km

Cardgd. shingles - Kisiamo - Mog. by ship

- Mog. to Kwaare. = 150km

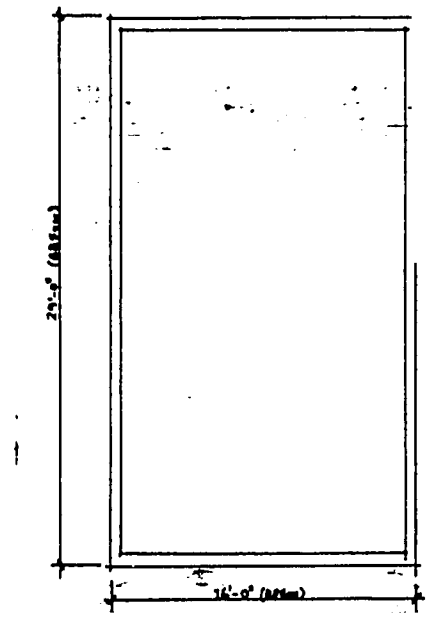
Maintenance: 1) Replace sulphur shingles every 15 years.

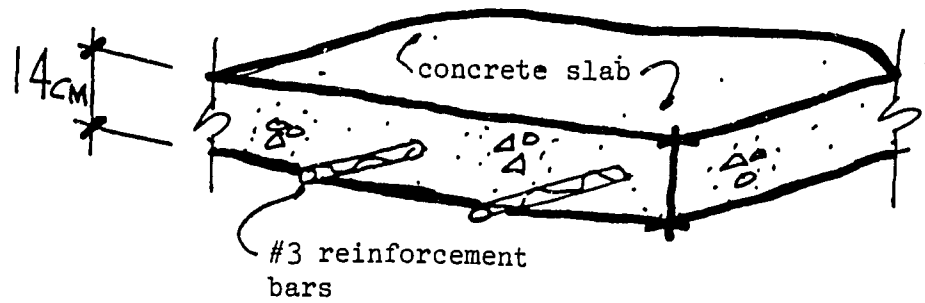
2) Replace purlins & structure every 15 years.

SPECIAL NOTES:

ROOF TYPE Reinforced Concrete Slab

DESCRIPTIVE DRAWINGS AND/OR PHOTOGRAPHS:





ROOF TYPE REINFORCED CONCRETE SLAB

PHYSICAL DESCRIPTION:

Primary Membrane: 5½" Reinforced Concrete Slab

Subroof: none

Manufacturing/Construction Procedure: Flat slab formwork erected. Stell reinforcing placed. #3 bars at 8" on center each way.

Thermal Effects: Will store heat from daytime and radiate it to occupants for 1-2 hours after sunset. [a]

Description Of Structure: Self contained structure

Weight: light----medium-----heavy
3 2 1 0 -1 -2 (-3)

Flammability: nonflammable----flammable
(3) 2 1 0 -1 -2 -3

Infestation Potential: none----------high
(3) 2 1 0 -1 -2 -3

LOCAL ENVIRONMENTAL IMPACT: none

Local Economic Impact: none

Local Transportation:
Cement & steel - Mog. to Kwaare = 150km
Agggregate & sand - Merca to Kwaare = 50km

Maintenance:

STATE OF DEVELOPMENT:

developed-----undeveloped
(3) 2 1 0 -1 -2 -3

ECONOMICS:

Material Cost:[b]	U.S. $/SM	Somali Sh/SM
Structure	--	--
Subroof	--	--
Primary Membrane	11.09	--
Sub Totals:	11.09	--

Labor Cost:	Mandays (MD)	Cost @ 2 Sh/D	Somali Sh/SM
Structure	--	--	--
Subroof	--	--	--
Primary Memb.	18	36	.80
Sub Totals:	18	36	.80

Total First Cost:	U.S. $/SM	Somali Sh/SM
Materials + Labor	11.89	74

Foreign Currency Requirement: % of first cost: 100 %

Cost of Roof/Year: 15 yr life cycle	$/SM	Sh/SM
	34.25	212

SPECIAL NOTES:
a) Should be whitewashed for reflectivity.
b) Cost of form work not included.

OVERALL ECONOMIC COMPARISON CHART

ROOF TYPES	FIRST COST Materials $/SM	Labor $/SM	Totals $/SM	$/ROOF	FOREIGN CURRENCY REQD. (%)	MAINT. COST 15 YR $/ROOF	TOTAL LIFE CYCLE COST 15 YR $/ROOF	$/ROOF/YR
Traditional Makuti	$ 3.25	$0.08	$3.33	$185.81	51%	$199.84	$ 385.65	$25.71
As Built Makuti Type 1	5.86	0.10	5.96	332.57	54%	224.23	556.80	[illegible]7.12
As Built Makuti Type 2	5.07	0.10	5.17	288.49	61%	265.01	553.50	36.90
30 cm Porlin, Makuti Alternate Type 3	4.07	0.08	4.15	231.57	65%	237.78	469.35	31.29
Preservative Treated Makuti-Alternate Type 4	8.57	0.11	8.68	484.34	83%	——[a]	484.20	32.28
Local Fired Clay Tiles	3.41	0.31	3.72	207.58	82%	——[a]	207.58	13.83
I.T. Workshop Corr. Fiber Cement Tiles	4.83	0.17	5.00	279.00	100%	——[a]	279.00	18.60
Corr. Galvanized Iron	9.13	0.04	9.17	511.69	100%	——[a]	511.69	34.11
Corr. Aluminim	16.26	0.04	16.30	909.54	100%	——[a]	909.54	60.64
Corr. Asbestos Cement	24.25	0.07	24.32	1357.06	100%	——[a]	1357.06	90.47
Sulphur Impregnated Corrugated Cardboard	7.06	0.07	7.13	397.85	100%	——[a]	397.85	26.52
Reinforced Concrete Slab	11.09	0.80	11.89	513.65	100%	——[a]	513.65	34.24

THREE LOWEST FIRST COST:

Traditional Makuti $3.33

Local Fired Clay Tiles . . . 3.72

30 cm Purlin Alternate Type 3 . . . . . 4.15

THREE LOWEST COST PER YEAR:

Local Fired Clay Tiles $13.83

I.T. Workshop-Corrugated Fiber Cement Tiles . . . 18.60

Traditional Makuti 25.71

[a]Indicates no major replacement of any system or sub-system of the roof resulting in a negligible maintainence cost.

V. Footnotes

1) Purushotham, A. and Rana, K. S., Treatment Against Decay and Fire of Grasses and Palmyra Leaves Used For Thatched Roofs, Ideas and Methods Exchange, No. 14, Item II, 1954, pp. 1-8.

CONCLUSIONS AND RECOMMENDATIONS

I. Summary

The following list summarizes and ranks in order of preference the alternative roof systems as they compare to one another. It is based on the relative importance of general evaluation criteria described on the following pages and a judgement of each system and its relationship to the criteria as seen by the authors.

RECOMMENDED:

- I.T. Workshop, Corrugated Fiber Cement Tiles
- Traditional Makuti
- Corrugated Galvanized Iron Sheets
- Reinforced Concrete Slab
- Preservative Treated Makuti

RECOMMENDED WITH RESERVATIONS:

- Local Fired Clay Tiles
- Sulphur Impregnated Corrugated Cardboard Shingles

NOT RECOMMENDED:

- As Built Makuti Systems Types 1, 2 and 3 (With tar paper underlayment)
- Corrugated Aluminum Sheets
- Corrugated Asbestos Cement Tiles

II. Evaluation Criteria

The conclusions and recommendations given here are based on the authors judgement of the relative importance of the criteria listed below. There is no clear-cut "best system" which satisfies all criteria and distinguishes itself as an ideal solution.

The final decision on an alternative roofing system would most sensibly be made after a field testing and evaluation of those which have shown the most promise in this study. Further, the decision-makers should carefully evaluate the weighting (or relative importance) of the criteria to best reflect their goals.

The criteria used in the evaluation are:

Low Cost - Based on the value of this project as a prototype of housing solutions possible in Somalia and considering the scale of the demand, a relatively high importance has been placed on cost in this evaluation. It is, however, important to achieve a balanced perspective. The least expensive makuti roof evaluated represents a first cost of only 7% of the total original cost estimate of $2,450.00 which is quite likely understated. It follows, therefore, based on

the masonry house type chosen (which is relatively expensive) that cost should not be the exclusive criterion for selection.

Life Cycle Cost - It is very likely that the responsibility for maintenance of the houses will fall on the inhabitants or district authorities, neither of whom have the excess resources for extensive long-term expenditures to keep a sound roof overhead. This concern argues against thatch, which, although inexpensive even in the long-term, will require frequent replacement beginning shortly after construction is finished. Regardless of the system chosen, planning and provision of funds for maintenance should be considered.

Use of Indigenous Materials and Labor - In addition to foreign exhange considerations which argue against imports, it is also important to consider the multiplier effect of housing investment on the local economy. Investment in corrugated steel manufactured in the United States benefits workers in Pittsburg, Pennsylvania and the merchants to whom he spends his wages. Investment in locally manufactured roof systems has a similar effect in Genali or Mogadishu. A Genali worker paid for making roofing material distributes his income locally for goods and services he requires. This is then passed on in a local economic ripple-effect that benefits the entire community.

Environmental Impact - The establishment of a village the size of Kurtunwaare has by its very existence put a burden on the water and vegetation in the area. Given the fragility of the local ecosystem, the construction of all components of the housing must result in a minimum impact on the environment.

Ease of Construction - In many cases, the life of a construction system depends as much on the quality of craftsmanship as on the durability of the materials. Systems which require excessive skills beyond the reasonable training potential of the resettled nomads should be avoided, as should systems requiring the use of complex or difficult-to-repair machinery.

Responsiveness To Climate - Conventional wisdom in a climate zone, such as Kurtunwaare would indicate light structures which are well ventilated and do not have a great thermal mass. Overhangs to provide shade and that keep water away from walls and windows are also sensible.

Appropriateness Of Image - The importance of the desirability of the housing to the nomads, although a non-physical criterion, should not be minimized. The ultimate success of the village may depend upon winning the confidence of the former nomads that the village life is right for them. I. M. Lewis reports that nomads are destainful of agricultural life. He suggests that a more urban and modern-looking house may serve to ease this prejudice.

Flammability - Materials which promote the potential for quick catastrophic spread of fire are unfavorable.

Infestation Potential - Materials which provide habitat or food for insects or animals are considered inferior.

III. Recommendations

Based on these criteria the roofing systems have been evaluated and grouped into three categories:

1) Recommended
2) Recommended with reservations
3) Not recommended

RECOMMENDED

I. T. Workshop, Corrugated Fiber Cement Tiles - This system stands out as the best compromise of all factors. Although it requires imported cement, it is made locally with indigenous fibers and labor. Its manufacturing process is very inexpensive and simple. The first cost is moderate with a very low life cycle cost. All the physical properties are favorably comparable to more expensive imported products and it has a similar appearance.

The Experimental Low Cost Construction Unit has constructed the manufacturing apparatus and done some preliminary research with fibers available in Kurtunwaare; namely coconut, banana and bagasse. Bagasse appears to be the best choice. Banana and coconut, although more readily available, are more difficult to use. It is felt that with more research, any of the fibers would produce satisfactory roofing tiles.

Traditional Makuti - The single layer makuti with a 15 cm vertical lap is a very attractive option. It has the lowest first cost and a reasonable life cycle cost. Excepting the structure, it is made entirely with local indigenous materials and due to its light weight, an acceptable alternative structural system should be easily found that uses local

materials. Although it suffers from problems of flammability and infestation and does not have the "modern" image, it is an appropriate climatic response. Additionally, the construction system is well known and easily mastered by the settlers.

The currently used makuti system with the tar paper sublayer does not appear to be cost effective. It is likely that over time the felt, which is only narrowly lapped and supported in an unconventional way without a continuous flat deck, will deteriorate or incur damage. It is also possible as makuti shingles wear and need replacement, that worker climbing on the roof are likely to cause tears. If this or any makuti solution is chosen, care should be taken to manage the harvesting of the makuti so as not to damage the ecology. If it is agriculturally feasible, coconut palms might be grown on Kurtunwaare land near the river. The fire hazard for the traditional makuti roof can be somewhat reduced by careful siting of the houses.

Corrugated Galvanized Iron - Although the corrugated galvanized iron roof is nearly three times as expensive in first cost as the traditional makuti and almost twice the life cycle cost of locally made fiber cement tiles, it is a recommended system. It is durable, resalable, fireproof, infestation-proof, of popular appeal and very easy to install. As opposed to concrete products, there is little breakage in transportation or installation and compared to makuti it can be stored for long periods without deterioration. Coating the galvanized metal with white paint can reduce most of the negative climatic effect of reradiated heat to the living space. With a low thermal mass the iron roof cools quickly when the sun goes down.

Reinforced Concrete Slab - The concrete slab roof, with an even higher first cost, but similar life cycle cost as compared to corrugated iron, is quite different from the other systems considered. The flat roof changes the spatial characteristics of the rooms and makes ventilation more difficult as there is nowhere for hot air to rise. Although the slab is relatively reflective it has a high thermal mass and would gain heat in the day which would be reradiated to the living space for several hours in the evening. A minor advantage to the system would be the potential for outdoor sleeping or possible addition of enclosed space on the roof. The concrete slab roof uses imported cement and reinforcing steel and requires a high degree of quality control. Structural failure of the roof can be catastrophic. This is particularly dangerous given the use of salty sand which reduces concrete strength and corrodes reinforcing steel in Kurtunwaare. The advantages of the concrete slab are its durability, lack of maintenance, fire resistance, complete infestation resistance and urban, modern image.

Preservative Treated Makuti - This system is similar to traditional makuti except that it is much more expensive and more resistant to fire and infestation. It is estimated to have a fifteen year life span which reduces the burden on the environment and as all costs are first cost, there is no estimated maintenance expense. The preservative treatment can be considered as an upgrading procedure in the future. If the village or individuals in the village can afford to, they might choose preserved makuti at a re-roofing stage.

RECOMMENDED WITH RESERVATIONS

Local Fired Clay Tiles - The great concern preventing strong recommendation of this system is the shortage of wood fuel for the kiln. It is a long lasting, fire resistant, infestation resistant, environmentally sound, climatically appropriate, and very inexpensive solution except for the intolerable damage that would be done if wood from the village surroundings were used for fuel. If a substitute fuel could be obtained the clay tiles would be as attractive as the corrugated fiber cement tiles. A mock-up using the tiles was constructed adjacent to the staff compound which proved the system to be easy to construct and weather tight.

Although the tiles are simple to form they are rather bulky and heavy. Additional experimentation might be helpful in improving the design.

Sulphur Impregnated Corrugated Cardboard - The principal reason that the sulphur cardboard shingles cannot be highly recommended is that they are not sufficiently developed to risk application in Kurtunwaare. Were Somalia to have an indigenous supply of sulphur this and other applications of sulphur in construction would be attractive. Sulphur cardboard shingles are durable, relatively fire resistant (it will not sustain combustion but will burn with applied flame), infestation resistant, climatically appropriate and moderately inexpensive. Fuel is required to heat the sulphur and this could pose an environmental threat if wood were used. Temperature control while melting the sulphur is important, requiring sensitive equipment and operation, thereby detracting from the attractiveness of the system.

NOT RECOMMENDED

As Built Makuti Systems Types 1, 2 and 3 - Although more exact data will be available as the currently constructed units wear, it appears that the asphalt felt underlayment is not cost effective. Of the three types evaluated, only type 3 was comparable to a traditional makuti roof. Since this system is more costly, requires imported materials, and is no more effective then the traditional makuti, it has not been recommended.

Corrugated Aluminum and Corrugated Asbestos Cement - Both of these systems are more expensive then corrugated galvanized iron but have no additional benefits. Aluminum is lighter and more reflective but nearly twice the cost of iron. Corrugated asbestos is easier to damage than iron yet is more reflective, at least initially. Its cost, however, is nearly three times that of iron.

BIBLIOGRAPHY

Bibliography

Bomhard, M.L., Palms, U.S. Department of Agriculture, Forest Service, Washington, D.C.

Building Research Station, Overseas Division, Termites and Tropical Buildings, Overseas Building Notes, No. 170, Building Research Station, Overseas Division, Garston, Watford, UK, 1976.

Callaway, T.R., Thatching, Unpublished Manuscript, 1964.

Department of Housing and Urban Development, Office of International Affairs, Mud Brick Roofs, Ideas and Methods Exchange, No. 42, Department of Housing and Urban Development, Office of International Affairs, Washington, D.C., 1978.

Division of Social and Economic Programs, UNEP, UNEP Expert Group Meeting on Human Settlements Technology, corrected draft of proceeds, UNEP, Nairobi, Kenya, 1976.

Erkelens, P.A., Low Cost Timber Roof Truss and Provisional Rules for Nailed Joints, Housing Research and Development Unit, University of Nairobi, Kenya, 1980.

Eygelaar, J., Cost of Metal Roof Sheeting for Low-Cost Structure, Housing Research and Development Unit, University of Nairobi, Kenya, 1974.

Eygelaar, J. , Roofs For Low-Cost Structures, Housing Research and Development Unit, University of Nairobi, Kenya, 1978.

Eygelaar, J., and Kaszner, O., Makuti Roofing for Farmer's Housing, Housing Research and Development Unit, University of Nairobi, Kenya, 1978.

Givoni, B. and Hoffman, M.E., Effect of Roof Design on Indoor Climate in Hot Arid Zones, Build International, No. 6, UK, 1973.

Hasan, A. and Ahmad, A. Q., The Zed-Tile Roof, Building Research Station, Lahore, Pakistan, no date.

Hussain, C.G. and Hanif, M.M., Room Sizes for Zed Tile Roofing, Building Research Station, Lahore, Pakistan, no date.

Intermediate Technology Development Group, Low Cost Handmade Roof Sheets Of Strong Fiber Reinforced Cement, I.T. Workshop Publication, Warley, UK, no date.

Iyer, S.K., The Concept 'Integral Type' in Building Technique and Successive Improvements to Reduce the Cost of Construction, Structural Engineering Research Centre, Madras, India, 1976.

Louis Berger International, Inc. and Florida A&M University, School of Architecture, Experimental Low-Cost Construction Unit, Technical Assistance for the Kurtunwaare Settlement Project, Low Cost Minimum Shelter Construction Program, Technical Proposal, Louis Berger International Inc., 100 Halsted Street, East Orange, New Jersey, U.S.A., 1979.

Mukhtar, Y.A., Roofs in Hot Dry Climates, with Special Reference to Northern Sudan, Overseas Building Notes, No. 182, Building Research Establishment, Overseas Division, UK, 1978.

Nellis, W.R., Roofing for Developing Countries, Masalah Bangunan, Vol. 19, No. 2, 1974.

Purushotham, A. and Rana, K.S., Treatment Against Decay and Fire of Grasses and Palmyra Leaves Used for Thatched Roofs, Ideas and Methods Exchange, No. 14, Item II, Department of Housing and Urban Development, Office of International Affairs, Washington, D.C., 1954.

Sinnamon, I.T. and Van't Loo, G.A., Cyclone-Resistant Rural Primary School Construction-A Design Guide, UNESCO Regional Office for Education in Asia, Bangkok, Thailand, Educational Building Report, No. 7, 1977.

Sun, B.C. and Hyun, S.K., Low-Cost Housing for Agro-fishery Villages in Korea, Masalah Bangunan, Vol. 19, No. 2, 1974.

Swift, D.G. and Smith R.B.L., Fiber-Cement Building Materials, Paper presented at CIDOK Symposium-Exibition on Low Cost Housing in Developing Countries, Appropriate Technology Centre, Kenyatta University College, Department of Civil Engineering, University of Nairobi, 1980.

U.S. Department of Commerce, National Technical Information Service, Roofing in Developing Countries: Research for New Technologies, U.S. Government Printing Office, Washington, D.C., 1974.

USAID, Somalia Project Paper, Kurtunwaare Settlement Project Number 649-0103, USAID, Washington, D.C., Request for Proposals, 1978.

U.S. Department of Housing and Urban Development, Office of International Affairs, Palms - Their Use In Building, U.S. Government Printing Office, Washington, D.C., 1964.