as well as equipment. Self-help input was not included, so savings could ensue. U.S. 1973 costs based on minimum wage was calculated at $3,800.

## The Shelter

The Shelter Unit #1, (Fig. 8) made with the same block for walls and floor, included a butterfly white enameled minimum cost aluminum roof, fastened down to an aluminum angle frame with self tapping screws as in the other House #3. Since this unit was to satisfy the capabilities of a minimum income family in the most impoverished countries to pay, it was to cost no more than $100-$200. Thus the use of split bamboo grilles under the roof instead of windows. Two galvanized steel tanks were built into the back wall to collect water from the roof for use in a precast low cost sink and toilet. A septic tank was to be built out of the soil-cement block. (see Fig. 8A below)

The roof was of the lightest gage low cost aluminum, corrugated and textured, white enamelized to last for many years, and not need replacement every 5 years as is the galvanized iron roofing used in many parts of the world.

Other types of roofs are locally available in many countries and now may be considered as effective and low cost as the roofs described above. Asbestos cement roofings of the deep draw type are now available. These were considered for a more recent proposal for the government of Indonesia, for the larger housing units. They might be most economic, since they, as did the deep draw aluminum, span across the whole house without additional framing support.

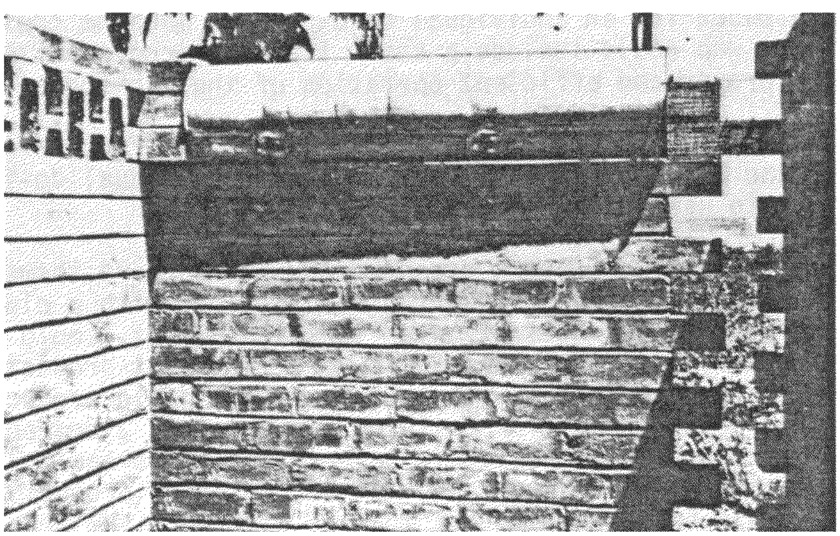
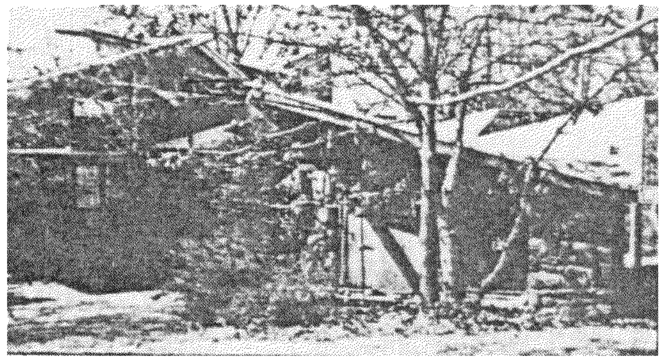


FIG. 8A
Shelter Water Tanks

Another type roof which has been proposed, and is further suggested herein, requiring further design, research and testing, is a small modular Hypar thin shell roof structure of 2 types of units (Fig.9A) as shown. These might be made of ferro-cement by unskilled self-help labor, similar in type to the units that the author designed for his own residence. They were Shotcreted using a dry gun process.

FIG. 9
Bush House Hypar Roofs



## 'Systems From Tools' - A Concept for Appropriate Technology Development

Many years use of the Cinva-Ram Machine suggested that a system of manufacture and creation of jobs was feasible through its local application to housing and community development. Each step in the process of adapting inserts and extending its use revealed the implication of another mini-industry which could feed into the end product of construction (see Fig.10).

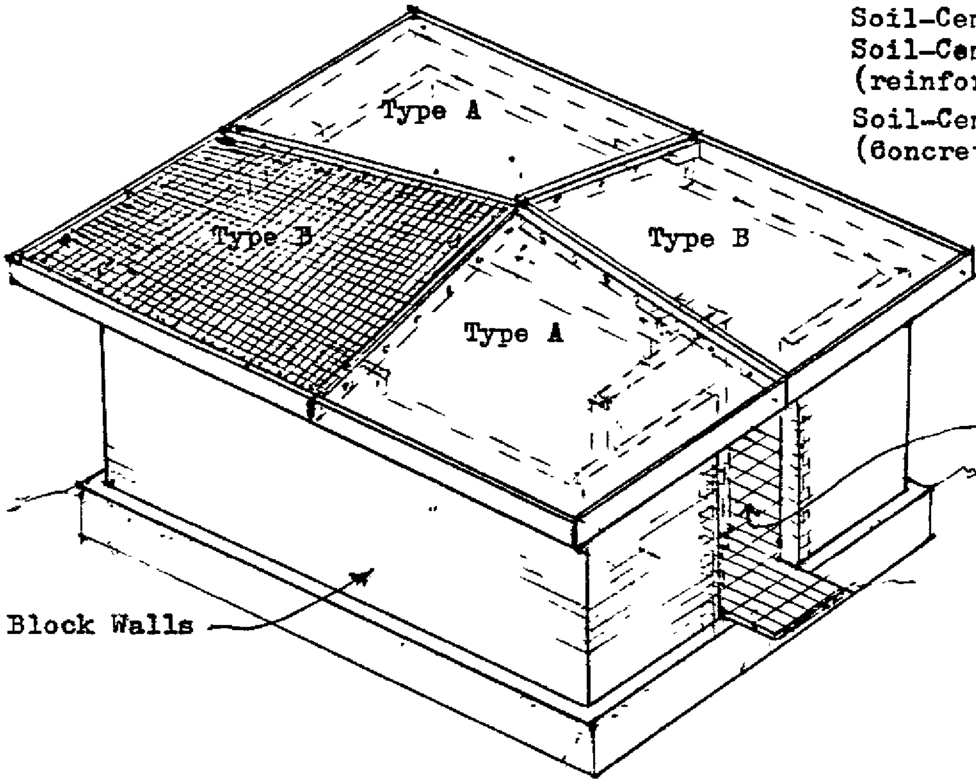
Starting with the inserts, a small woodworking craft shop could manufacture the parts to go with each machine. The machines themselves could be sold to communities or small cooperative groups who could be trained to move out to a site and produce block for an individual need, or the machine could be leased by an entrepreneur who could include a short training program with the leasing charges to teach proper and efficient operation of the machines.

Another group might organize to use special block to manufacture sub-assemblies such as lintels and beams which they could sell to individual do-it-yourselfers or to contractors to use in construction.

A mini-manufacturing mobile center, organized by its workers themselves, including a demountable shelter for curing block, along with a cluster of 4 machines, a mixer, plank and covers, water tank and cement, could move to a building site for a cluster of houses for a more efficient production of block and parts. Twelve to sixteen men with this equipment could produce up to 5,000 block in one week; enough for building one complete 2 bedroom house. The soil would be taken from immediately beneath the top organic layer from each surrounding building site and moved to the center of production. Then the cured block would be moved back out to each site once the proper number of each type had been completed. Upon finishing the block for all the houses in the cluster, the equipment and demountable shed would be moved to the next cluster site and so on.

Sketch of Shelter - Proposed Study

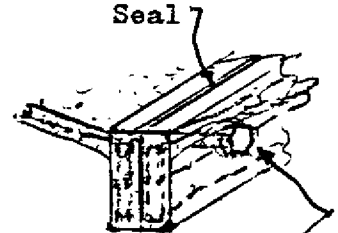
Warp Shell Module Roof Panels (Hypar)
Ferro-Cement Units
Soil-Cement Block Walls
Soil-Cement Grade Beams
(reinforced as required)
Soil-Cement Tie Beams
(Concreted & reinforced)




Floor Tile

Block Walls

Seal



Typical Roof
Joint(bolted)

Roof Procedure

Precast Frame Edge w/Cage & Mesh
Place on Roof Supports,Bolt &/or
Grout Together Connect to Wall Anchors &
Stucco w/Mortar on Top &/or Under
Cover & Moist Cure(7 day minimum)

Tie Beam

Soil-Cement Walls
(reinforced)

In Situ
Soil-Cement
Grade Beams
(reinforced)

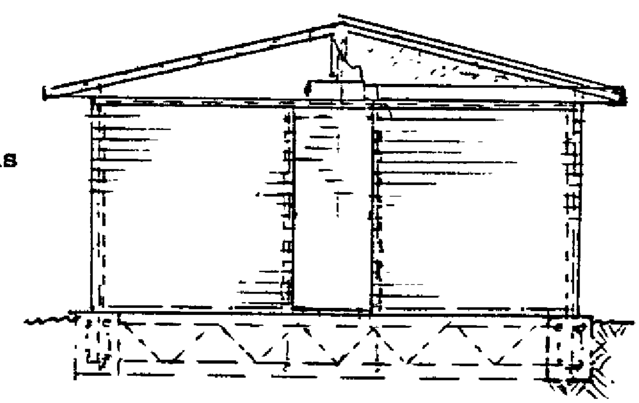


FIG. 9A
Proposed Test Structure

2/25/80
HV

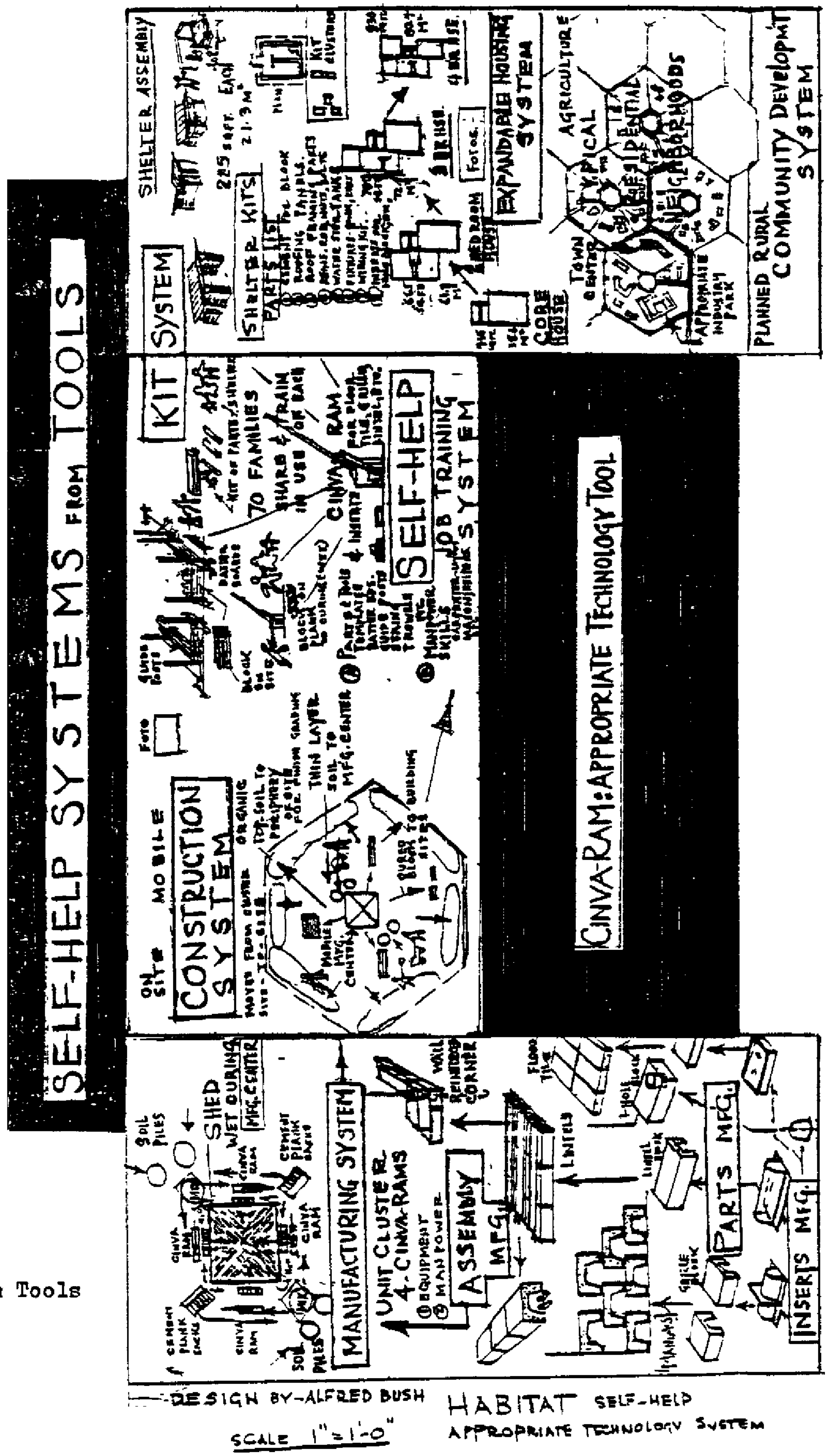



FIG. 10
Systems From Tools

Having studied the economics of low cost planning for low income cooperative communities around the U.S., the author has conceived the hex unit cluster site plan indicated at the lower right hand corner of the Fig.10). This provides minimum road and utility runs as well as an equitable distribution of land for each family, with the central site, temporarily used for manufacture of the block, to become a recreation play area for the children and youth living in the immediate cluster. This suggests another industry- the planning organization which can develop sites in the local or nearby communities. They would to acquire some of their more advanced skills and training through the secondary or college level institutions of the country. By training students with these potential developments in mind, there will be continuity in their development, so they can go right out to participate in their own community growth in a more orderly manner than being thrown into the market place looking for jobs for which they might not be trained.

Two other concepts are included in this system; one the Kit of Parts concept, the other the Expandable House Design concept. The Kit of Parts would be sold to a do-it-yourselfer or self-helper who would acquire all the pieces, equipment and training necessary to build himself the minimum unit shelter. He would have the use of a Cinva-Ram and necessary inserts for a period of time; so many bags of cement, depending on the soil analysis; reinforcing rod, anchors, framing for the roof and roof panels as required for the particular area, tanks for water storage, fittings, pipe and fixtures for sink and toilet connections and a minimum set of parts for surface wiring and electric outlets where electricity is available.

Absolute minimum kits could provide for roofing, framing parts, reinforcing rod and cement along with the Cinva-Ram machine for making a partial shelter; sufficient for making block walls to hold up the roof. The remaining walls might be installed using temporary materials such as slit bamboo mats. A sub-floor of soil-cement might serve until additional income was available to purchase more cement and a further use of the machine. Then floor tile and additional wall block might be made and tied in with the existing permanent structure.

An option for someone with a little more income might be the purchase of two or more kits. These could be combined and tied together with extended roof panels to make larger units (see Fig.11).

The other concept is concerned with the expansion of a house from a minimum core of some 415 sq. ft. forming a complete living core - a basic house. By the addition of 2 or up to 4 bedrooms, this house becomes up to 930 sq. ft. in size. (see Fig. 10)

Thus a great range in size and type of housing becomes available for meeting varied income needs, all buildable with local soil, and providing the potential for satisfying the additional need for jobs and development in areas even where seismic problems exist.

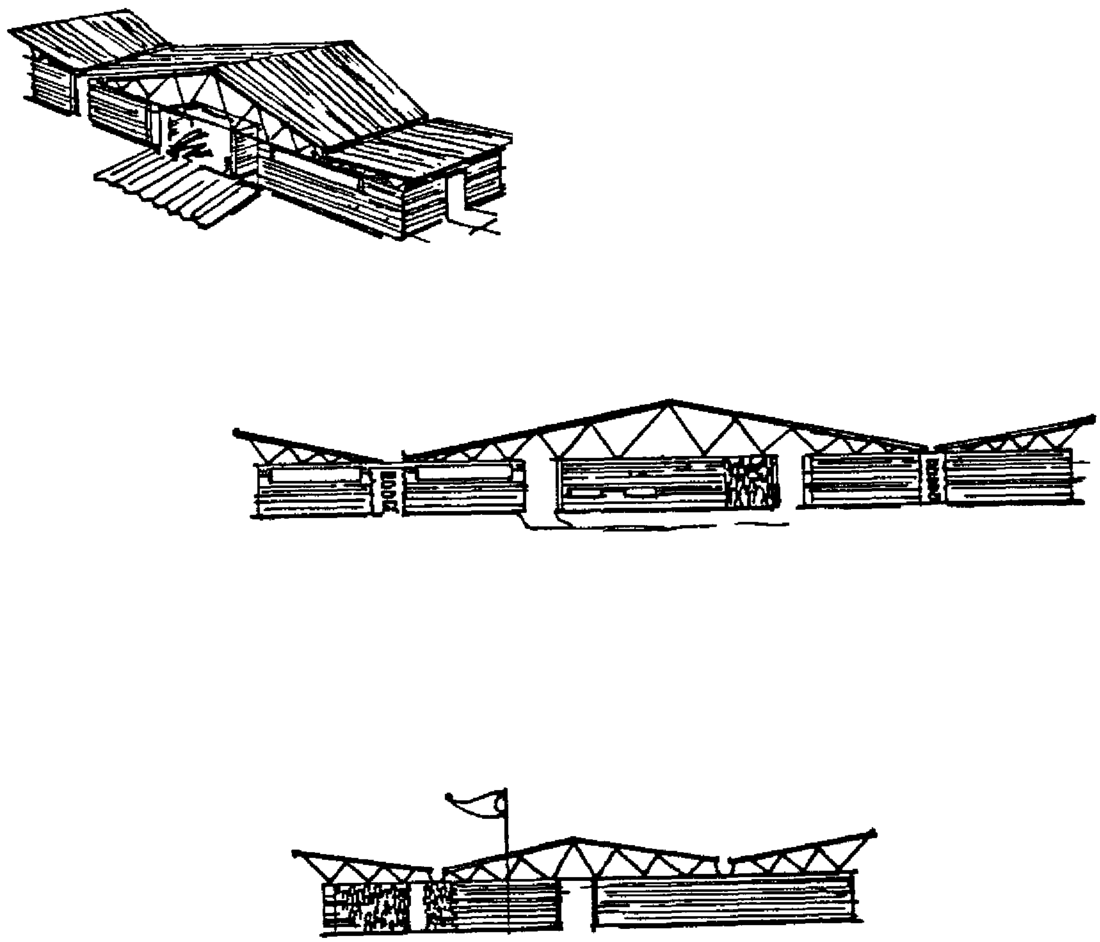


FIG. 11
Kit Expansions

## Reasearch Needs

Soil-cement research has been conducted by the Portland Cement Association for many years. They published manuals for laboratory use (3) and field construction (4) on highways, irrigation canals and ditches, runway shoulders and sub-bases. Tables for mixes and test standards have been worked out for optimum mixes. More recently, they have published work on fatigue of soil-cement (5) and thickness design for pavements (6), but no study seems to have been carried out with reinforced soil-cement.

Testing has been performed by the National Bureau of Standards on 6" thick soil-cement block walls made from the Cinva-Ram or similar machine, comparing them favorably with brick and concrete block walls, but no analysis or comparisons seem to have been made with the block laid on its 4" side.

Cost comparisons determined by the author on 4" vs 6" soil-cement block walls indicated a savings of some 35%, since it only takes 2/3rds as many block to cover the same wall area as the 6" wall. So since 4" thick walls are adequate for load carrying capacity for low cost houses, great additional savings could be entailed in the thinner walls. This would be especially valuable at the poverty end of the scale, where permanent materials are looked on only as a dream, and housing is usually thrown together and maintained with any second hand materials available. Therefore, I would like to see comparative strength tests run on the block in the two directions. Ideas for mold inserts for use of reinforcing in the 4" wall have been studied.

Tests on the lintels have never been performed, so variations on the use of soil-cement vs concrete mortar for reinforcing embeddment could well be tested, as could even be embeddments with sand-sulphur. Therefore, a program for testing these would be of value.

In addition, it would be necessary to determine bond strengths and pullout resistance of reinforcing bars in these various materials and soil-cement mixes. To determine the best anchoring techniques, perhaps different types of anchor ends might be tested and experimented with, considering the skills required to make and assemble them, and the need to keep costs down.

For a permanent roof, a program for design, fabrication and testing of Hypar units should be organized, to determine the most economic amount of steel to use for the most effective roof slope. Joining techniques have to be worked out and evaluated, and tests run to determine the best joint method to use for the small test structure to follow.

Lastly there is a need to determine the ability to make and develop a simple reinforced grade beam of soil-cement to resist the serious effects of earthquake loading, when combined with the monolithically tied together walls, tiebeams and roof panels. This is recommended as an alternative to stone or rubble structures or concrete block building.

Finally, there is a need to assemble a composite of all these above parts into a small structure to test for earthquake loadings. It was this program that I had hoped to carry to fruition through NSF funding. It was estimated that the research and test program would run for some 12-16 months; that dynamic loads though desirable to test with, might be simulated with certain static loading. All in all a very exciting program to serve a very great need on an all too shrinking planet.

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