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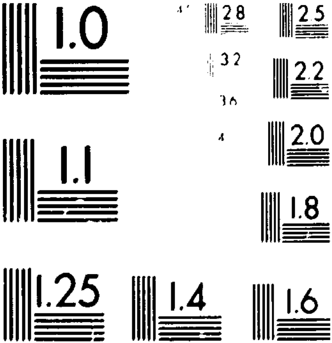
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LOW-COST BUILDING MATERIALS TECHNOLOGIES
AND CONSTRUCTION SYSTEMS

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Technical Report: Feasibility Study on the Production of Rice Husk Ash Cement and Stabilized Soil Hollow Blocks for Low-cost Building Materials and Construction Systems *

Prepared for the Government of the People's Republic of Bangladesh
by the United Nations Industrial Development Organization,
acting as Executing Agency for the United Nations Development Programme

Based on the work of
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Consultants

United Nations Industrial Development Organization
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Most of all our grateful acknowledgement to our Director Florentino O. Tesoro, Mrs. Lilia Cassanova and her staff of the Regional Network in Asia for Low-Cost Building Materials Technologies and Construction Systems without which our going to Bangladesh as consultants would not have been possible.

NIEVA B. LAXAMANA

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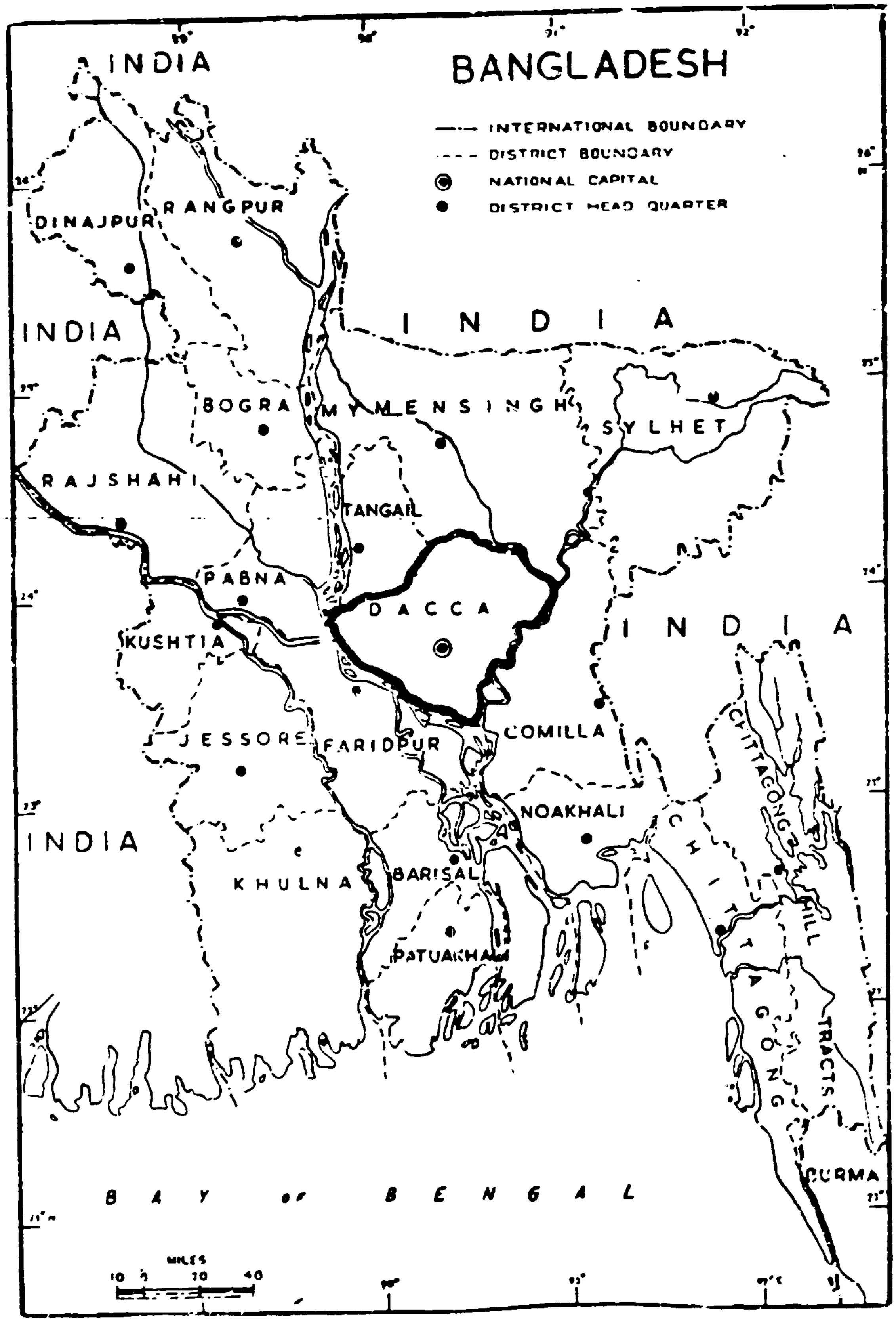
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PART I.. BACKGROUND AND SCOPE

1. Background

This project of Technology transfer and feasibility study on the production of ricehusk ash cement and fabrication of stabilized soil blocks is an integral part of the Regional network in Asia's development project on "Low-cost building materials technologies and construction systems." It is one of the many activities of the network outlined for implementation in 1984 during the months of April and May. Due to certain unavoidable circumstances, however, the implementation was delayed to 1985. Finally it has gotten through and the first phase of its implementation covering the period from 12 January to 12 February, 1985 was undertaken in Dhaka, Bangladesh in collaboration with the Building Materials Division of the Housing and Building Research Institute (HBRI), Ministry of Works. The second phase 13 February to 13 March, 1985 was undertaken in the Philippines.

Introduction

The purpose of the mission was to assist the Housing and Building Research Institute with its research program on the construction of ricehusk incinerator, production of cement as binder from ricehusk ash and fabrication of stabilized soil blocks for low-cost building materials and construction systems.

The assignment was coordinated by the Regional network in Asia for Low-Cost Building Materials Technologies and Construction System of the Ministry of Human Settlements of the Philippines and was approved by UNIDO. The consultants arrived in Dhaka, Bangladesh on 12 January, 1985. After a briefing with Director Kazi Haque of HBRI and discussions with the researchers of Building Materials Division of HBRI and viewing the research facilities and equipments, a detailed research activities was drawn for a one month period, 12 January to 12 February, 1985. In the course of our exchange of views with their researchers, we learned indications of immediate urgency and desirability of the intended technology transfer in our mission to Bangladesh.

The development of a low-cost technology on the production of blocks utilizing ricehusk ash and stabilized soil blocks can possibly bring down the cost of these materials to the level of the middle and low income groups. Tapping the use of local resources and utilizing agricultural by-products and wastes will show great potentials for generating employment.

Millions of tons of ricehusks are produced annually, and only a fraction is reduced to ash and now the amount of ricehusk production is fast increasing due to increased palay production and improved ricemill operations. Developing economically viable industrial product using these wastes and by-products is therefore a formidable challenge for R & D organizations, technologies, entrepreneurs, marketers and most especially to provide and maintain adequate housing for families belonging to the low and middle income levels who cannot afford to build without some form of assistance. This assistance is needed if we are to make available down to the lowest economic stratum of the society, the benefits of a decent habitable dwelling.

The mission of S & T in any country is to improve the quality of life of its people so the task of developing and dessiminating costcutting innovations ultimately belongs to the scientific community who must backstop the housing industry in terms of new materials and designs.

POLICY ON HOUSING

The Government of the People's Republic of Bangladesh has a gigantic task of providing housing units for its poor population both in the urban and rural centers. Like the other developing countries in Asia, the government of Bangladesh views housing as a social concern and public responsibility. This means housing is not simply the provision of shelter alone but includes the improvement of site and services and the development of viable communities with facilities and amenities, education, livelihood, employment and recreation. The people's culture should also be integrated into the lives of the residence of the community. The efforts of the government of Bangladesh to me[illegible] responsibilities on housing, however, is seriou[illegible]ged by rapid increase in population and sky-high p[illegible]es of construction materials.

Bangladesh has a total land area of 55,598 square miles with a population of over 96 million. The population annual growth rate is about 3.6%.

The annual requirement for housing is 701,131 dwelling units. There is no available information on how many units are actually built annually.

The annual requirement for cement is 1,390,000 metric tons and the annual production is only 307,000 metric tons. The balance are imported from various sources. The current price per bag of 50 kg. is TK 110. Because brick is the main construction material in Bangladesh cement is a very essential construction material as binder in the installation of the brick.

These situations obviously underlines the importance of this project under review.

PROPERTIES OF RICE HUSK

Ricehusk is the outer covering of the rice grains obtained during the process of milling. Yield of rice husk after milling amounts to one fifth of the paddy by weight. Chemically, ricehusk is composed of 2 parts: namely: 1) Organic matter-constitutes 70-80% by weight of the dry husks and the main components being cellulose and lignin. These two components can be separated by chemical extraction but the most economical method is by combustion, 2) Inorganic mineral matter-constitutes 15-30% in ricehusk mostly consists of silica up to 90%. By scanning electron micrographs of the husk, it shows that the mineral matter is arranged in the body of the hull concentrating along the views.

Properties of both the organic and the inorganic mineral matters also depends on the: a) variety of rice; b) soil and climatic conditions; c) prevailing temperature and d) agricultural practices like the application of fertilizers and insecticides.

CHEMICAL COMPOSITION OF RICE HUSK

Constituent	Percent by Weight
1. Crude Protein	1 5 - 7.0
2. Crude fiber	31.5 - 50.0
3. Nitrogen free extract	24.5 - 38.8
4. Cellulose	16.0 - 22.0
5. Lignin	20.0 - 47.5
6. Pentosans	31.5 - 50.0
7. Crude fat	0.5 - 3.0
3. Ash	15.0 - 30.0
9. Loss on Ignition	2.0 - 2.8

PHYSICAL PROPERTIES OF RICE HUSK

Color	- Straw or Gold
Length	- 4.4 mm.
Density	- 0.6249 g/ml.

PROXIMATE ANALYSIS OF RICE HUSK

Moisture, %	-	20.7
Volatile matter[1/] %	-	59.9
Ash, %	-	23.3
Fixed carbon, %[2/]	-	16.8
Heating value, cal/gm	-	3,102

CHARACTERISTICS OF RICE HUSK ASH FOR CEMENT MAKING AS BINDER

Ricehusk ash must contains 82-90% silica mostly in amorphous state with high reactivity towards alkalies and pozzolanic activity. For its use as a pozzolana, silica has to be enriched by ashing. Generally ashing should be carried out under controlled temperature (between 500-700 deg. C) for a period of 3-4 hours to obtain an amorphous silica. Samples obtained above 700 deg. C indicated increased in crystobalite and trydimite. Crystal growth gradually increases with rise in temperature and longer burning time. Cooling time should be overnight.

[1/] Based on oven-dry weight of the sample

[2/] Percent volatile matter + percent ash subtracted from 100

Grinding the samples to a specific fineness is very important. Efficiency of the ball mill and the method of grinding are of extreme importance. Grinding time of between 1 to 2 hours is sufficient to produce a sample with satisfactory reactivity. A similar effect can be achieved by intergrinding the ricehusk ash with portland cement which contributes to the improvement in the strength characteristics of the portland cement-ricehusk ash mixture.

COMPOSITION OF RICE HUSK ASH (RHA)

Constituents	Average Composition Percent by Weight
1. SiO_2	32.0 - 87.6
2. CaO	0.84- 2.0
3. MgO	0.81- 2.0
4. K_2O	0.91- 2.8
5. Na_2O	2.0 - 2.3
6. Fe_2O_3	Traces
7. P_2O_5	0.2 - 3.0
8. SO_3	0.1 - 1.5
9. Sulfur	Traces

2. OBJECTIVES:

a. To promote scientific and technical cooperation between Bangladesh and the Philippines in the field of rice husk utilization and other agri-waste materials;

b. To extend technical assistance to Housing and Building Research Institute with its research program on the production of rice husk ash cement and fabrication of stabilized soil blocks on the technology of ricehusk utilization and other wastes materials being developed and applied in the Philippines;

c. To discuss with Bangladesh experts, scientists and laymen engaged or interested in ricehusk utilization and other agri-waste materials; and

: To prepare cooperative projects and/or activities of scientific and technical cooperation which maybe of interest as important to host country.

PROCESS TECHNOLOGY AND SCOPE OF ACTIVITIES OF THE CONSULTANTS ARE DETAILED IN TERMS OF REFERENCE (TOR) as follows:

a. Collection of raw materials - this includes survey of the availability of raw materials and their landed cost.

b. Design of an effective low-cost incinerator for optimum production of ricehusk ash - Simplicity in incinerator operation will be required so that it can be done by semi-skilled workers, involve lower capital investment and low gestation period. Installation of this incinerator is designed to be intended for the rural areas so as not to cause any problem of transportation, operation and maintenance and most important, to give employment to the rural people.

c. Ashing run or incineration of ricehusk to obtain highly active ash for solid and hollow blocks manufacture.

d. Analysis of the rice husk ash produced.

e. Demonstration of the actual grinding of ricehusk ash to produce better and stronger blocks.

f. Formulation of various mix of rice husk ash, cement, and sand or clay at different proportions.

g. Fabrication of wooden moulds - Fabrication of blocks will be primarily intended for the rural areas on a self-help basis, so emphasis will be given to fabrication with the use of a hand wooden mould.

h. Preparation of blocks in a wooden mould.

i. Curing of the moulded blocks.

j. Physical and mechanical testing of blocks for domestic/industrial uses.

k. Analysis and interpretation of results.

l. Preparation and submission of terminal report.

PART II. FINDINGS/OBSERVATIONS AND DISCUSSIONS

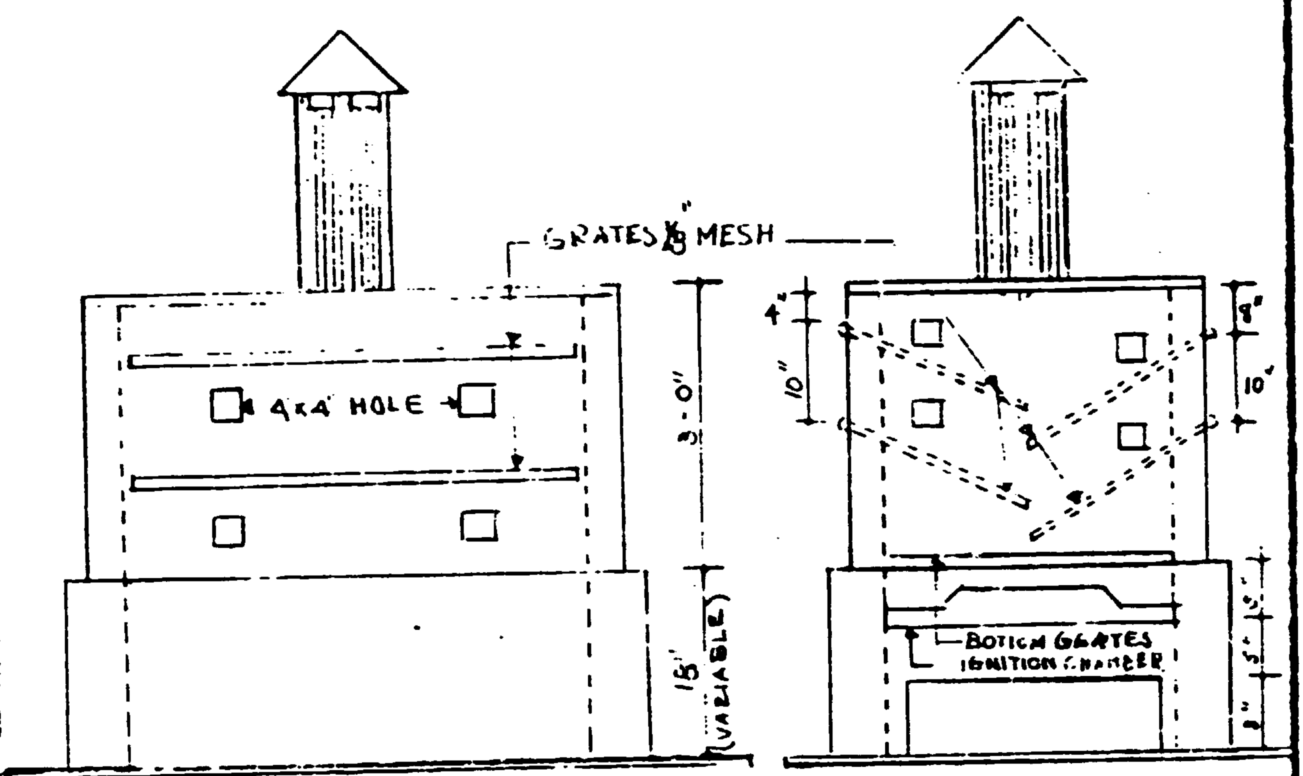
This part of the report covers the discussions with their scientists on the different aspects which have bearing on ricehusk utilization, stabilized soil blocks and other agri-waste materials for low-cost building materials and construction systems. Its scope follows generally the matters described in the Terms of References.

Discussions also dwelt about the policy on science and technology as regards to housing/human settlement of the government of the People's Republic of Bangladesh and related information such as culture, population, income levels and economy which may not be attainable within the project period.

EXPERIMENTAL WORK/FEASIBILITY STUDIES

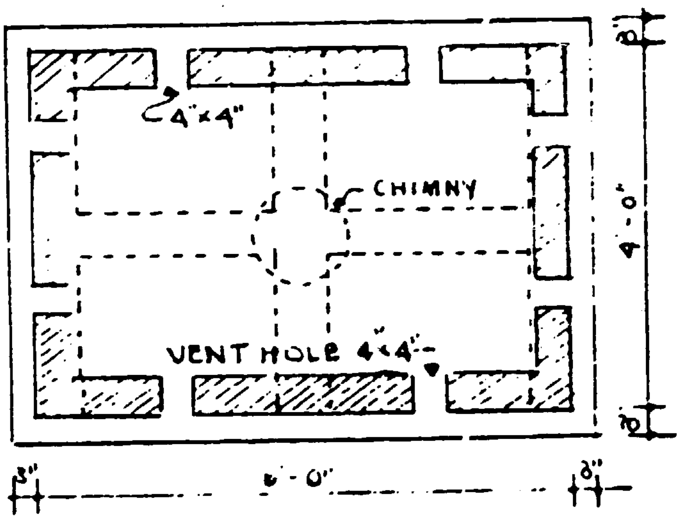
CONSTRUCTION OF THE INCINERATORS

Designed and constructed two ricehusk incinerators patterned after the Forest Products Research & Development Institute of the Philippines. The incinerators were constructed with bricks with a capacity of 52 cubic feet and 26 cubic feet respectively. See Figures 1 and 2. See Appendixes I and II for bill of materials and cost estimates of 2 incinerators.



ELEVATION (SIDE)

END ELEVATION



PLAN

SPECIFICATIONS

OUTSIDE DIMENSIONS:

LENGTH = 6' - 0" (1.83m)

WIDTH = 4" - 0" (1.22m)

HEIGHT = 3" - 0" (0.91m)

INSIDE DIMENSIONS.

LENGTH = 5' - 1" (1.55m)

WIDTH = 3' - 3" (0.99m)

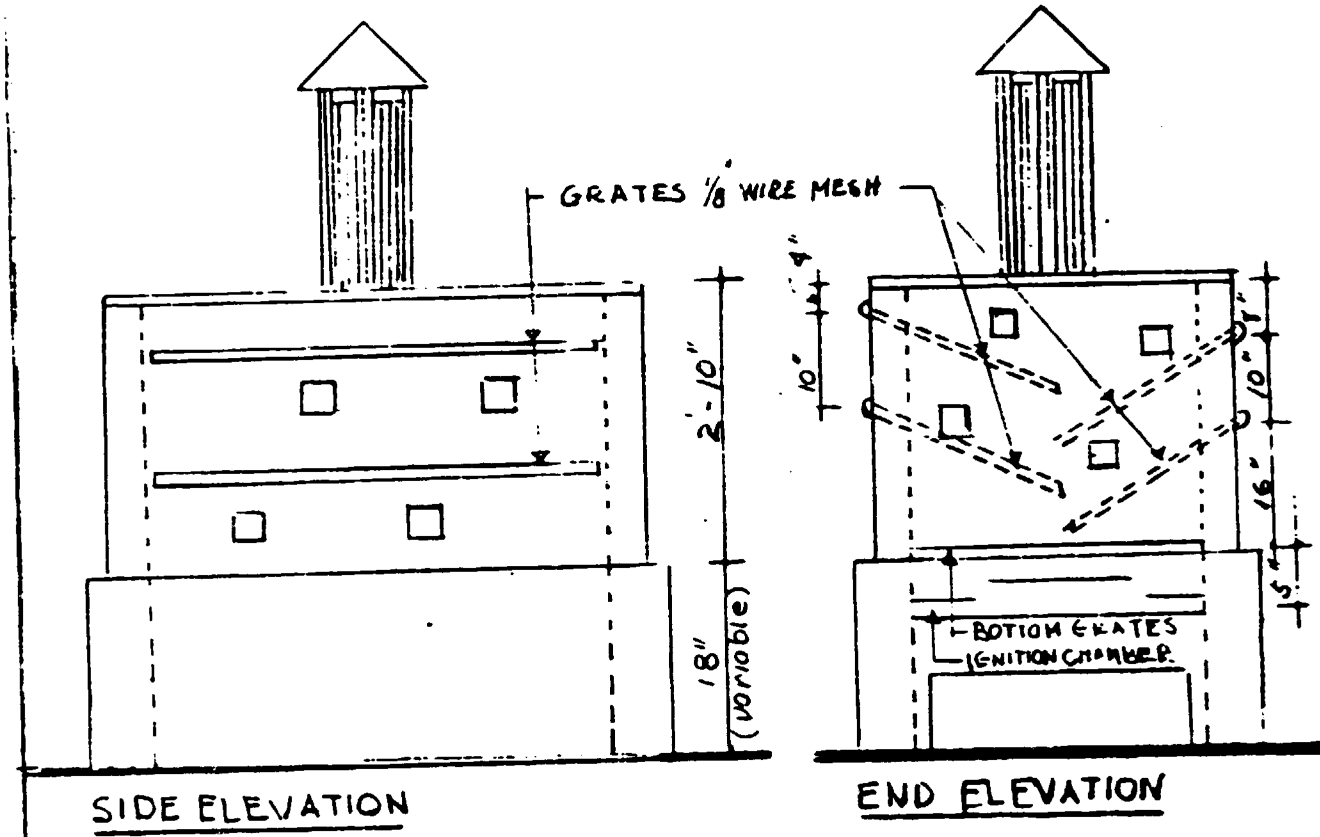
HEIGHT = 3' - 1.5"(0.95m)

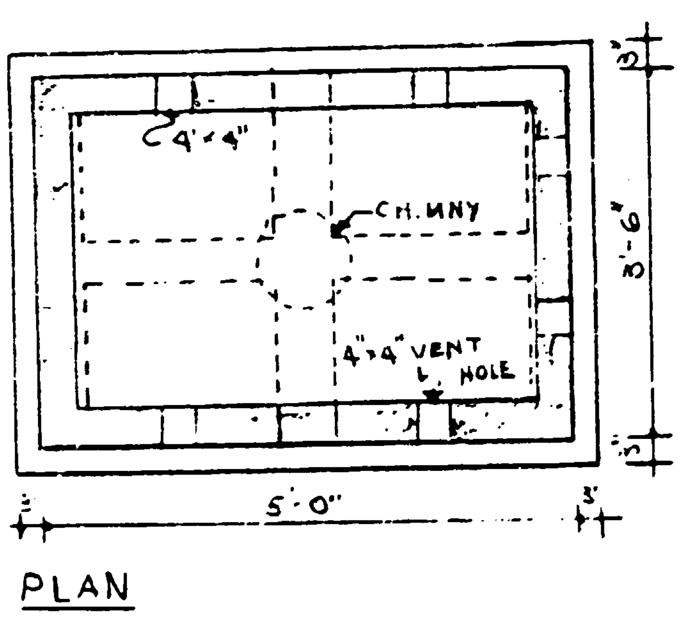
CAPACITY:

CUBIC FEET = 52 (1.46m^3)

MATERIAL BRICK - 3" x 5" x 9"

Figure 1. A 52-cu. ft. incinerator for burning rice husk for the production of rice husk ash cement constructed at the Housing and Building Research Institute (HBRI) Dares-Salam, Mirpur, Dhaka, Bangladesh patterned after the design of PRDI incincerator at College,Laguna Philippines.





SPECIFICATIONS

OUTSIDE DIMENSIONS:

LENGTH: 5' - 0" (1.52m)

WIDTH: 3' - 6" (1.07m)

HEIGHT: 2' - 10" (0.86m)

INSIDE DIMENSIONS:

LENGTH = 4' - 1" (1.24m)

WIDTH = 2' - 7" (0.74m)

HEIGHT = 2' - 5" (0.74m)

CAPACITY:

CUBIC FEET = 26 ($0.72m^3$)

MATERIAL:

BURNT BRICK - 3" x 5" x 4"

Figure 2. A 26-cu. ft. incinerator for burning rice husk for the production of rice husk ash cement constructed at the Housing and Building Research Institut (HBRI) Dares-Salam, Mirpur, Dhaka, Bangladesh patterned after the design of PRDI incinerator at College, Liguna, Philippines.

1. RICE HUSK ASH CEMENT

.. Materials

Rice husks from mixed varieties, obtained from different rice mills in the suburb of Dhaka were ashed in the newly constructed incinerator. The incinerators were constructed with bricks measuring 52 cubic feet and 26 cubic feet. Five incineration runs were conducted.

A.1. Method of Loading or Charging the Incinerator

Openings are provided on the left and right top of the incinerator for loading. Rice husks are poured through these openings, Two layer grates are provided at the left and right sides of the incinerator in an inclined position. These gratess are made up of wire screen and are detachable. The four sides of the incinerator are provided with air-vents for efficient combustion and control of temperature. From the top bottom of the incinerator the samples drop from the first grate to the second grate and finally fall to the bottom grate. The bottom grate is also detachable.

The samples were poured continuously until the upper grate was full. Small openings on four sides of the incinerator are provided for recording the temperature. Temperature was taken every 30 minutes during the process of burning.

A.2. Kindling Materials and Method of Ignition

Pieces of jute sacks sprinkled with kerosene and dried stalks of water hyacinth were inserted to the bottom grate of the charge and ignited. An actively burning surface of kindling materials is observed shortly after ignition. A period of about 30 minutes was usually required to give the fire a good start.

When the fire had enveloped the bottom of the charge, the air-vents were left fully open until the chimney started to emit smoke. The first smoke emitted was dense white and steamy.

A continuous and profuse evolution of smoke through the chimney indicated that ashing had started. Temperature was recorded every 30 minutes. When the smoke becomes bluish in color and decreases in volume it shows that ashing is completed. All the air-vents are kept closed by damping moistened soil for cooling. Ashing was completed within a period of 4 hours. Overnight cooling is required and the sample is ready for unloading the following morning.

A.3. Unloading or Discharging

Grates on the left and right sides of the incinerator were pulled out allowing the ash to drop to the bottom grate. The bottom grate was then pulled out and complete discharge of the ash was done with the use of a shovel.

Percentage yield of ash was 21.5 based on the weight of the charge.

B. Equipments Used for the Preparation of Blocks

a. Laboratory grinder

b. U.S. Standard mesh sieve No. 200

c. Wooden mould (Figure 3)

d. Measuring and compacting devices

e. Spoon and trowel

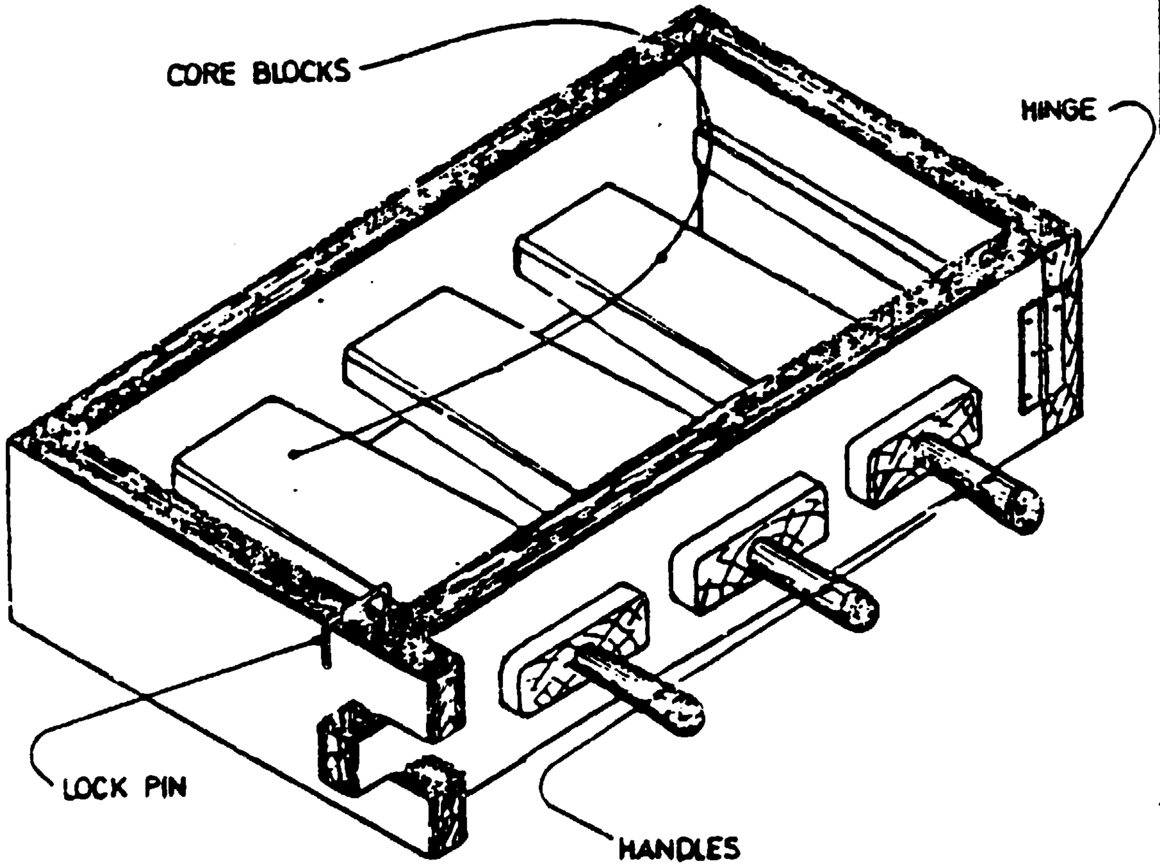


FIG. 3 Isometric Drawing of Wooden Hand Mould

B.1. Preparation of the Blocks

Samples of ricehusk ash produced from the incinerator were ground in a laboratory grinder and finally screened to pass thru 200 mesh sieve.

Ground samples were mixed with cement at different proportions (binder) by weight and the binder produced was mixed with sand (at different proportions) by volume with the addition of enough water to facilitate mashing. Moulding of the blocks are made manually using fabricated wooden blocks measuring 7 cm x 11 cm x 20 cm. Figures 4, 5, & 6.

B.2. Curing of the Blocks (Figures 7 & 8)

The blocks were allowed to dry under atmospheric conditions for a period of 7 to 21 days.

C. Equipment used for Compression Strength Test

1. Hydraulic type compression testing machine
2. Top loading balance

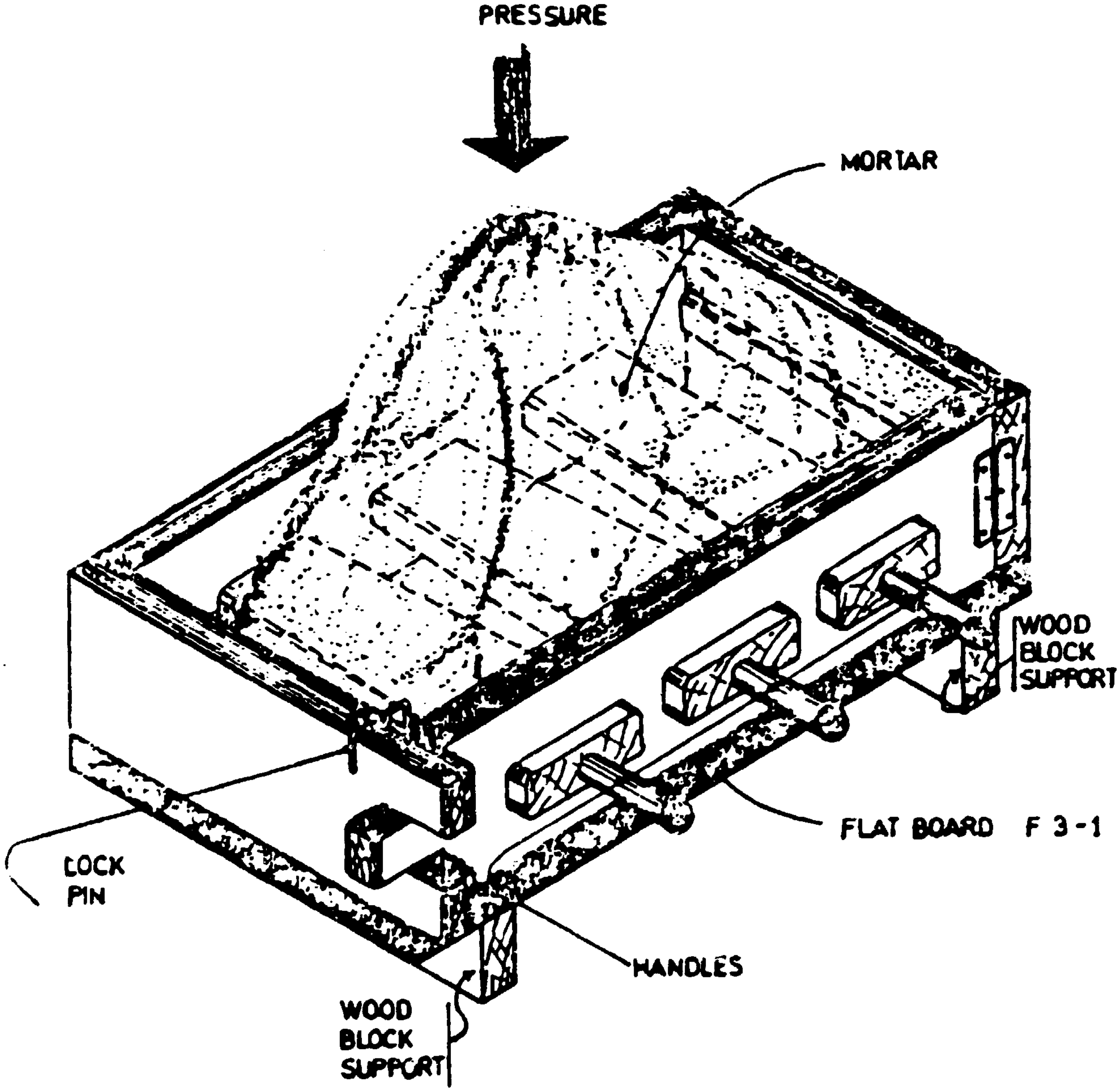


FIG. 4 Moulding Process (Showing the Pouring of Mortar on the Mould.)

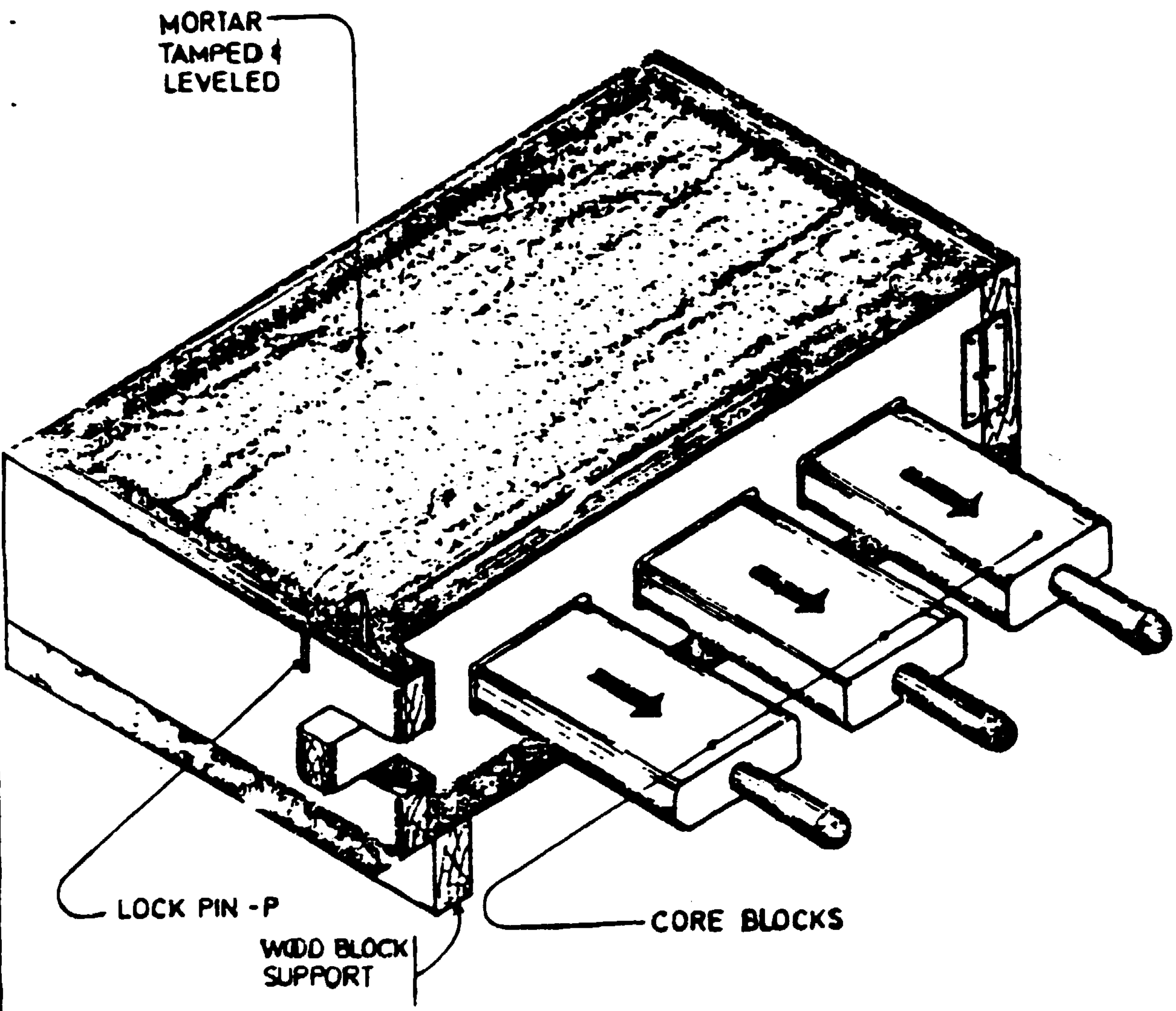


FIG. 5 Showing how the Core Blocks are Removed

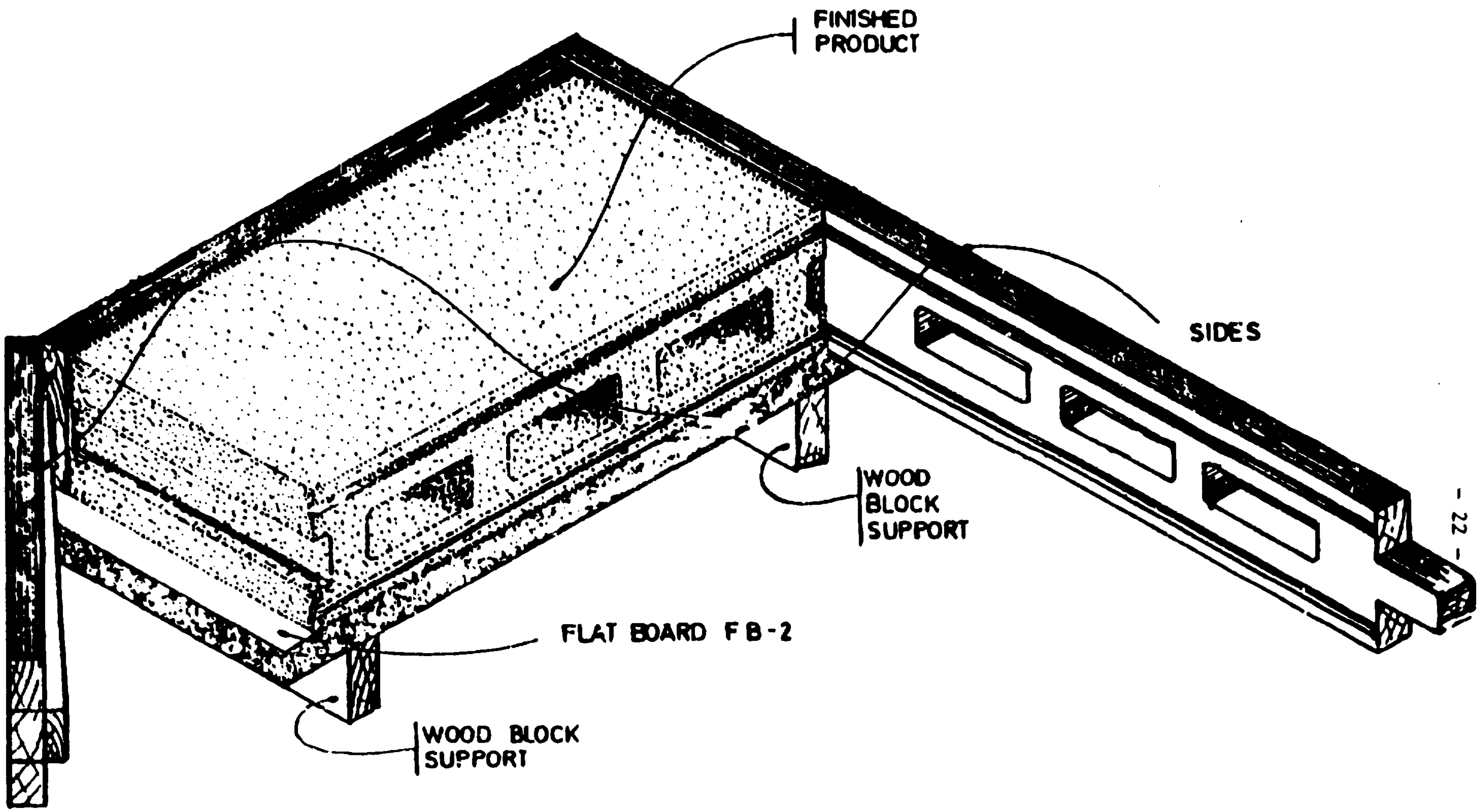


FIG. 6 Showing how the Sides are Opened

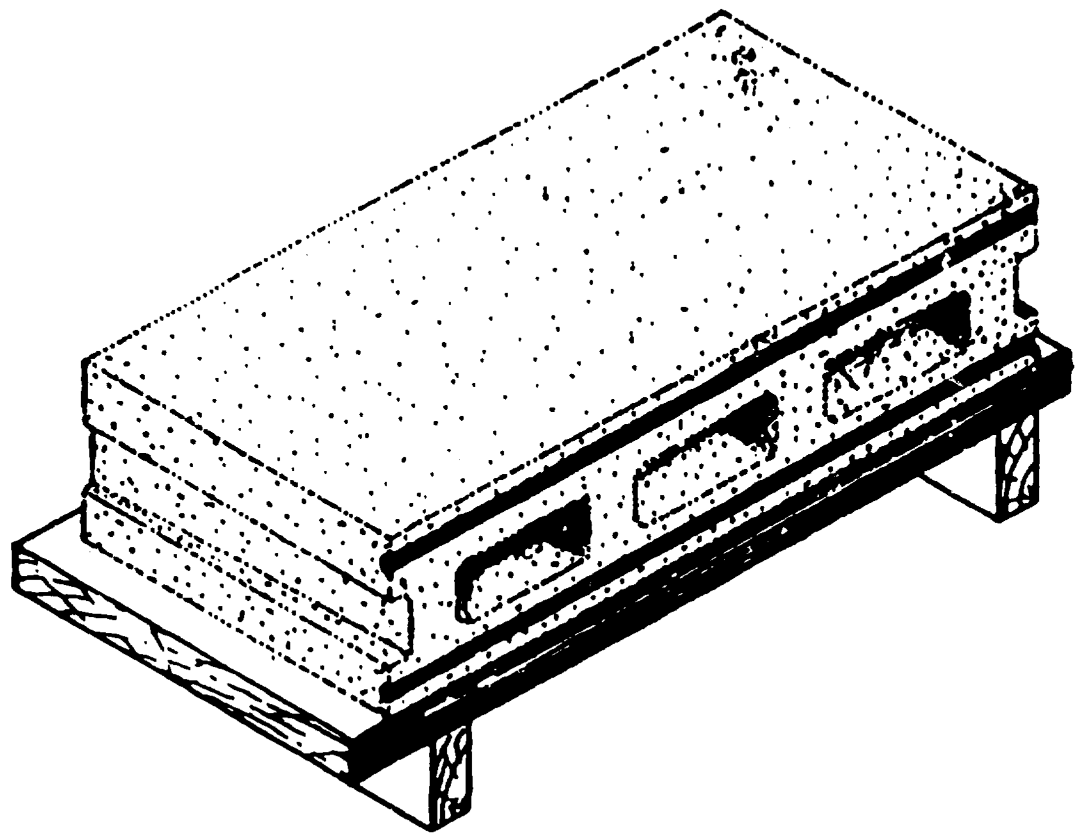


FIG. 7 The Block Just After the Mould is Removed

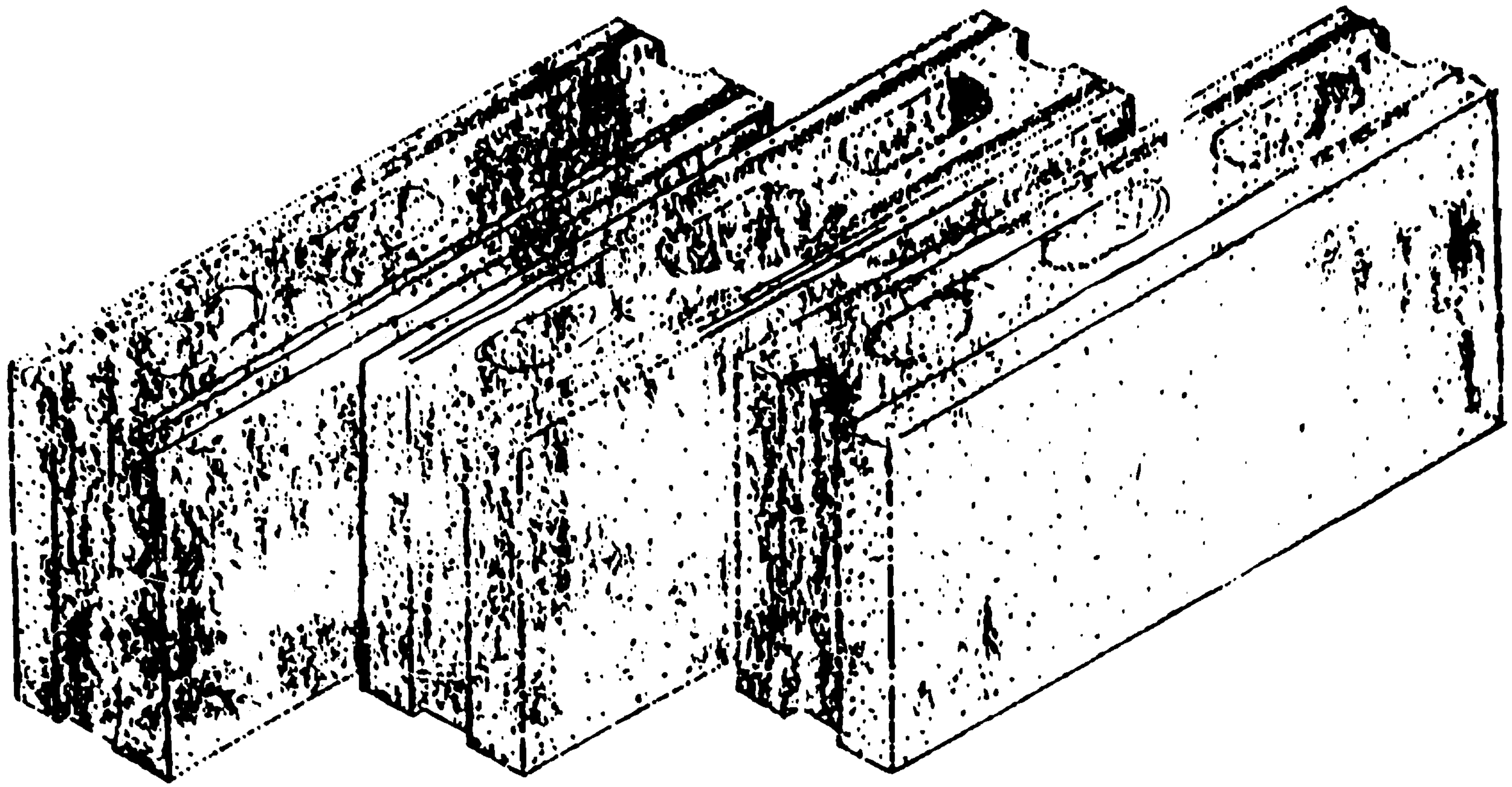


FIG. 8 Hollow Blocks Laid on Narrow Edges During Curing Period

C.1. Compression Strength Test

The ASTM standard method of testing concrete units (ASTM Designation C140-70) was followed. The machine is equipped with the required spherically seated loading block movable crosshead that transmit the load at the upper surface of the specimen and a plane rigid block on which the specimen rest. Since the bearing area of the blocks being tested was not perfectly even it was cushioned with soft boards to eliminate the possible occurrence of load concentration.

The load up to one half of the expected maximum load is applied at any convenient rate of loading, after which the controls of the machine are adjusted as required to give a uniform rate of travel of the moving head such that the remaining load is applied in not less than 1 nor more than 2 minutes.

The compressive strength of the concrete blocks was taken as the maximum load expressed in psi or kPa which was calculated by dividing the maximum load by the gross area of a unit the total area of a section perpendicular to the direction of the load, including areas within cells.

The results of the compression strength tests are shown in Table 1.

D. Equipments Used for the Proximate Analysis of Ricehusk Ash

1. Mortar and pestle
2. Mettler Balance
3. Muffle Furnace
4. Oven
5. Laboratory Hood
6. Bunsen Burner
7. Desiccator
8. Porcelain crucible with fitted cover
9. Tong
10. Wire Basket

D.1. Proximate Analysis of Rice Husk Ash

Method of proximate analysis by Philippine Standard Association Specification for "Methods of Proximate Analysis of Charcoal were used and described as follows:

Table 1. Comparative Compression Strength of Different Proportions of RHA-Cement Binder with Sand at Two Temperature Levels

Binder:Sand Mixture	RHA: Cement (Binder) 50:50				RHA: Cement (Binder) 60:40				RHA: Cement (Binder) 70:30			
	Temperatures, deg. C				Temperatures, deg. C.				Temperatures, deg. C.			
	500		700		500		700		500		700	
	Psi	kPa	Psi	kPa	Psi	kPa	Psi	kPa	Psi	kPa	Psi	kPa
1:2	310.00	2137.[illegible]3	329.70	2273.79	135.76	936.37	155.15	1070.00	77.58	535.03	58.18	401.24
1:1	659.39	4547.51	659.39	4547.51	349.09	2400.62	465.45	3210.00	135.75	936.21	155.15	1070.00
Control	853.33	5885.03	950.30	6553.79	601.21	4146.20	620.61	4280.07	232.72	1604.96	329.69	2273.72

Analysis were carried out in duplicate

1. Muffle furnace with provision to accurately control temperature at 750° $\pm$ 5°C and 950°C $\pm$ 5°C was used. The muffle furnace was heated to 750°C. Previously ignited porcelain crucibles and lids were placed inside the Furnace for 30 minutes.

2. The crucibles were removed and placed in a desiccator for 1 hour.

3. The crucibles were weighed and approximately 1 gram charcoal was added.

4. For moisture content the crucibles and samples were placed in an oven at 105°C and dried for 2 hours.

5. The dried samples were removed from the oven and placed in a desiccator for 1 hour and weighed.

6. For the determination of volatile matter, a muffle funace was heated ato 950°C. The same samples used for the determination of moisture was also used for volatile and ash determinations.

7. The crucibles plus sample and lids were placed in a nichrome wire baskets. With the muffle door open, the samples were preheated for 5 minutes, 2 minutes on the outer edge of the furnace and 3 minutes to the middle part of the furnace.

8. The samples were then moved to the rear of the furnace for 6 minutes with the muffle door closed. The samples were watched through a small peep-hole in the door of the furnace.

9. The samples were removed and placed in a desiccator for 1 hour and weighed.

10. For ash determination, the above samples with the crucibles covers removed, were placed in the muffle furnace and heated at 750°C.

11. After 6 hours, ashing was completed. The crucibles were placed in a dessiccator and weighed.

12. The crucibles were returned to the muffle furnace for an additional hour or until constant weight was obtained.

Computations

A. Oven-dry weight of sample = Weight of moist sample minus loss in weight (Moisture)

B. Percent Moisture = $\frac{\text{loss in weight} \times 100}{\text{weight of sample}}$

C. Percent volatile matter* =

$$\frac{\text{loss of material after heating at } 950^{\circ}\text{C} \times 100}{\text{weight of oven-dry sample}}$$

D. Percent ash* = $\frac{\text{Weight of residue after heating at } 750^{\circ}\text{C}}{\text{Weight of oven-dry sample}}$

x 100

E. Percent fixed carbon* = 100 - (percent volatile matter + percent ash)

All results except moisture are reported on oven-dry basis.

Results of the tests are shown in Table 2.

---

*Volatile matter.- is the loss in weight which occurs when the sample is heated to a temperature of 950 deg. C out of contact with the air under standard condition.

Ash - is the inorganic matter remaining after complete combustion of the sample to constant weight under standard conditions.

Fixed carbon - a calculated value in percent obtained by subtracting from 100 the sum of the percentages of volatile matter and ash on oven-dry basis.

Table 2. Proximate Analysis of Ricehusk Ash

	Samples	Volatile Matter[1/] %	Ash[1/] %	Fixed Carbon[2/] %
I	RHH (direct from rice mill boiler)	24.60	40.01	35.39
II	RHA (produced in a cylindrical HBRI incinerator)	24.62	42.19	33.19
III	RHA (produced in the newly constructed incinerator, 700 deg. C)	32.35	37.83	29.82
IV	RHA (produced in the newly constructed incinerator 520 deg. C)	15.20	56.35	28.45

[1/] Based on oven-dry weight of the sample

[2/] Percent volatile matter + percent ash subtracted from 100.

E. Silica Determination

Equipments Used:

- Muffle Furnace
- Mettler Balance
- Oven
- Bunsen Burner
- Platinum Crucibles
- Desiccator
- Hood
- Tong

a. Sulfuric Acid Determination of Silica

Five samples of ash were analyzed. All analysis were carried out in duplicate determination. Samples were ground manually in a mortar and pestle and oven-dried.

One gram of the powdered materials are weighed in a platinum crucibles with enough concentrated sulfuric acid.

The crucibles and contents are heated gently in a bunsen burner and then placed in the muffle furnace at 600°C for about 15 minutes or until the weight is constant.

After heating, the residue in the crucible is cooled in a desiccator and weighed.

About two millimeters of concentrated sulfuric acid and 5 millimeters of 48% hydroflouric acid are added continuously to the residue under the hood. The acidified residue is heated gently in a bunsen burner to avoid spattering. The flane is gradually increased to drive off the residual sulfuric acid. Heating is continued until the weight is constant. The heated crucible is continued until the weight is constant. The heated crucible and content are next cooled in a desiccator and weighed. From the loss in weight due to the volatilization of the silicon dioxide in the form of silicon tatraflouride ($Si\ F_4$) and water vapor, the percentage of the silica in the oven-dried material was calculated.

Results of the test are given in Table 3.

Table 3. Analysis of Silica, %

Sample	
1. RHA (From rice mill boiler)	76.1705
2. RHA (Combination of rice mill ash + raw rice husk)	76.2386
3. RHA (Produced in HBRI Incinerator 1,000 deg. C)	77.3155
4. RHA (Produced from the newly constructed incinerator 700 deg. C)	80.7295
5. RHA (Produced from the newly constructed incinerator, 500 deg. C)	82.8353

CONCLUSIONS AND RECOMMENDATIONS

Results of the above feasibility studies showed that the performance of the incinerator for the production of ricehusk ash is viable and economically feasible. Considering that the annual production of rice husk in Bangladesh is 5.4 lakh tons or 540,000 metric tons the development or transfer of this technology has to be effected on the following specific advantages:

1. The design of the incinerator is of low-cost which can be constructed using local materials like bricks, clay, etc;

2. Simplicity in incinerator operation which can be done by semi-skilled workers or laymen;

3. Assured quality of highly reactive and easily grindable rice husk ash;

4. Lower capital investment and low gestation period; and

5. Uplifting of rural economy and generation of employment potential in rural areas as well as build houses for the poor people.

Due to the texture of the raw materials it is recommended that:

1. Samples should be air-dried before loading in the incinerator;

2. Loading of the sample should be such that there is enough space in between the grates close to the walls, while at the center there should be continuity of the pile of mass from bottom to the top;

3. Kindling should continue until the fire has engulped the bottom of the charges which usually takes a period of 20-30 minutes.

4. Temperature should be controlled such that it should be confined within the range from 500 to 700 deg. C. This would necessitate the taking of temperature every 30 minutes interval and manipulation of the air-vents; and

5. All air-vents should be completely closed after completion of burning as indicated by the decrease in volume and bluish color of the smoke from the chimney.

Results of the compressive strength of RHA binder and sand confirm that ash can play the useful part as a pozzolana only if ground fine. Intergrinding of RHA and cement together developed higher strength than by simply mixing them in usual manner by hands.

6. In general the strength of blocks increases as the ratio of binder to sand increases as well as the ashing temperature is elevated up to 700 deg. C but above 700 deg. C the compressive strength decreasing due to the formation of crystalline silica;

7. Also, the strength of the block is decreased with proportion of RHA to cement is increased in both of the proportion of 1:2 and 1:1 for binder to sand;

8. The strength of a mixture of RHA to cement at 1:1 and 1:5 and 2.2 decreases in both the 500 deg. C and 700 deg. C.

9. The block produced from 1:4 cement to sand ratio is comparatively low in compression strength in the ratio of 1:1 and 1:5 RHA/cement and mixture of 1:1 and 1:2 parts binder to sand.

10. The binder (RHA/cement) at 60:40 ratio is the minimum mixture required to produce RHA cement bonded block for low cost housing and building materials.

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II STABILIZED SOIL HOLLOW BLOCK

This is a non-load-bearing building block. The nominal size is 10 cm x 20 cm x 40 cm (4" x 8" x 16"). It is primarily for walls. It is installed in a way that the wider face (8" x 16") is in the plane of the wall.

The technology was developed in the Philippine some years ago as a substitute/alternative to the traditionally commercial sand-cement mortar hollow block which price continued to increase due to the growing scarcity of sand supply and increase in transportation cost due to the oil crisis. Although it is not yet produced in commercial scale, it is steadily gaining acceptance as a construction material.

The fabrication of this type of building block has been demonstrated at the HBRI as part/component of the implementation of the current project on technology transfer and feasibility study to the Government of Bangladesh. The process is described as follows:

A. Materials: The materials used were: ricehusk, soil, portland cement and water. Their chemical composition are:

1. Soil: (Reddish hill soil)

PH - 4.85%	CAO - 0.75%
Organic Matters - 5.69%	MgO - 0,41%
SiO_2 - 65.06% by weight	Cl - .0016%
Al_2O_3 -14.19%	SO_4 - .0153%
Fe_2O_3 - 5.00%	

2. Ricehusk (obtained from mill)

Cellulose	- 40%
Lignin	- 31%
Ash	- 20%

3. Portland Cement:

SiO_2 - 21.36%	SO_3 - 1.35%
CAO - 60.82%	MgO - 3.42%
P_2O_3 - 10.30%	Less on ignition - 2.50%

B. Equipment: The equipment used were:

1. Wooden mould
2. Measuring pot
3. Compacting device
4. Cementer's spoon and trowel
5. Water container

C. Procedure: The various steps in the fabrication were:

1. Soil preparation - The soil was dried and grounded to fine particles in a ball mill.

2. Proportioning - With the use of a measuring pot the desired proportion by volume was made as follows: 3 parts ricehusk, 2 parts soil and 1 part portland cement.

3. Mixing - The ricehusk and soil were first mixed in the dry. Then the cement was added and all together were mixed thoroughly still in the dry. The mixing continued as water was added until the right consistency was attained. The right consistency is said to have been attained when the mixture or stuff is neither two dry to stay pack when moulded nor too wet to slump when the mould is removed.

4. Moulding - The mixed stuff was filled into the wooden mould and throughly tamped to avoid the occurrence of honey comb which reduce compressive strength of the black. (Fig. 4)

5. Removing of mould - The mould was removed carefully and the block was left lying on its wider face in the shade (Figs. 5, 6 & 7). The following day it was made to lie on its narrow face in the open shade to continue the curing period of 14 days (Fig. 8). After which a compression test was conducted on the block.

D. Compression Test - The compressive strength test has been and still in the primary parameter in concrete structure. Therefore the best test to evaluate the suitability of a concrete product for construction is compression.

Accordingly, six (6) sample/demonstration hollow blocks were tested in compression at the HBRI, testing laboratory using a hydraulic type compression machine in accordance with practice consistent with the ASTM on concrete materials to evaluate their compressive strength. Normally compressive test are conducted on experimental blocks or sample blocks after 28 days of curing. Due to time constraint the tests were performed in the present case after only 14 days after fabrication.

The results showed an average compressive strength of 1367 kPa or 198.2 psi based on the gross area in bearing of the block. This value is expected to be much higher after the block reaches 28 days.

The results of the compression test are shown in Table 1.

E. Water absorption test - another important indication of the suitability of a construction material is its stability against water or excessive moisture. Therefore water absorption is another important test. Due to time constraint this test was not performed. Experience in the Philippines however, have shown favorable results from water absorption test of similar materials of the same proportion. An experimental wall has been constructed in an open space at the HB:I compound from which performance may be observed.

Table 1. Results of compression tests on 10 cm x 20 cm x 40 cm (4" x 8" x 16") Nominal size ricehusk-soil-cement Hollow Block.

Mix Ratio by Volume			Specimen No.	Weight in kg	Maximum Load in kN	Compressive strength kPa	Strength/ weight ratio
Rice Husk	Soil	Cement					
3	2	1	1	8.7 (19.14)1/	52.84 (11.880)1/	1279.712 (185.6)1/	321.81 (9.7)1/
3	2	1	2	9.0 (19.80)	50.85 (11440)	1232.826 (176.8)	136.98 (9.0)
3	2	1	3	9.0 (19.80)	65.56 (14.740)	1587.918 (230.3)	176.44 (11.6)
3	2	1	4	9.3 (20.46)	59.69 (13.420)	1445.192 (209.6)	155.40 (10.2)
3	2	1	5	9.5 (20.90)	60.67 (13.640)	1469.245 (213.1)	154.66 (10.2)
3	2	1	6	9.2 (20.24)	48.93 (11.000)	1185.251 (171.9)	128.83 (8.5)
			x	54.70 (120.34)	338.54 (76.120)	8200.144 (1189.3)	1074.12 (59.2)
			$\bar{x}$	9.12 (20.05)	56.42 (12.686.67)	1366.70) (198.2)	179.02 (9.87)

1/ Numbers in parentheses are equivalents in Imperial Units.

F. Conclusions and Recommendation:

1. There is a wide range of compressive strength values from 1185-1585 kPa (171.9-230 psi) which indicates high variability. This is attributable to human factor rather than the quality of the materials used because the fabrication was done manually by rather unskilled hands. This variability could be narrowed down by improved skill in the art of fabrication;

2. The minimum compressive value of 1185 kPa (171.9 psi) from the test is quite safe for a non-load bearing wall for house construction. The block at the bottom layer of a wall 10 feet high is subjected to stress of only 30.2 kPa (4.38 psi) as against available strength of 1185 kPa (171.9 psi).

3. The mixture used in this demonstration of 3 parts ricehusk, 2 parts soil and 1 part portland cement by volume is not the hard and fast rule. This mixture was used in the demonstration because it had been found to be satisfactory in the Philippines both in strength and economy. In other words other proportions may be used depending on the level of strength required consistent with economy or cost.

4. Vertical reinforcement of at least ½" ∅ m.s. rod is recommended to be placed at every other block or a horizontal distance of 32" O.C. Horizontal reinforcement is also recommended at every 4" to 5" O.C.

5. Plastering of both faces of the wall with sand-cement mortal is recommended to avoid deterioration due to excessive moisture absorption and of course for aesthetic reason.

6. The use of ricehusk-soil-cement (stabilized soil) hollow-blocks as alternative construction material for low-cost housing in Bangladesh has been shown to be technically feasible and more practical and much more economical and practical as the comparison shown in Appendix IV indicates.

7. It would be desirable for a researcher from HBRI Bangladesh to be sent to the FPRDI, Philippines for a period of one month as an extension of this project on technology transfer.

G. Cost - The cost of production of the hollow block based on current prices of materials and labor cost prevailing in Bangladesh is TK 4.00 per block of 10' cm x 20 cm x 40 cm (4" x 3" x 16") nominal size or a minimum wall area of .08 sq. m. (.39 ft^2).

A theoretical cor, arison of the economy of using stabilized soil bloc ,ricehusk-soil-cement), and the traditional brick shown by the cost of construction of one (1) square met.: of non-load bearing wall of each material as illustrated in Appendix IV indicates that the stabilized soil hollow block is cheaper by 42.84%.

Cost of the traditional brick wall - - -	TK 366.00
Cost of the stabilised soil H.B. wall -	TK 209.20
Difference - -	TK 156.80

APPENDIX I

Bill of materials and cost estimate for the 52 cu. ft. Incinerator

1.	Brick :	800 pcs CTK 1280	= TK 1280
2.	Cement :	8 bags CTK 110/bag	= TK 880
3.	Sand :	30 ft^3 CTK 4/ft^3	= TK 120
4.	Sand (Sylet :	2 ft^3 CTK 10/ft^3	= TK 20
5.	Khao(big chips) :	5 ft^3 CTK 18/ft^3	= TK 90
6.	M.S. rod:*		
	(1) 4/8" Ø x 43'-6"	CTK 8.5/lb	= TK 247
	(2) 3/8" Ø x 57'-8"	CTK 8.5/lb	= TK 184
	(3) 2/8" Ø x127'-3"	CTK 9.0/lb	= TK 192
	(4) 1/8" Ø x 98'-0"	CTK 10/lb	= TK 41
7.	Steel work and wire mesh sieve		= TK 2185
8.	Wire mesh 20 W.G. 4 ft^2	CTK/ft^2	= TK 20
9.	Mason :	13 days CTK 50.00/day	= TK 650
10.	Labore :	13 days CTK 28.00/day	= TK 364
		Total	= TK 6273

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* 4/8" Ø: 1.4 per lb.

3/8" Ø: 2.75' per lb.

2/8" Ø: 6.0 per lb.

1/8" Ø: 12' per lb.

APPENDIX II

Bill of materials and cost estimates for the 26 cu. ft Incinerator

1.	Brick	: 650 pcs - CTK 1.6/pcs	=	TK 1040.00
2.	Cement	: 6 days CTK 110/bag	=	TK 660.00
3.	Sand	: 24 ft^3 CTK 4/ft^3	=	TK 96.00
4.	Sand (Sylet)	: 1.5 ft^3 CTK 10/ft^3	=	TK 15.00
5.	Khao	: 4 ft^3 CTK 18/ft^3	=	TK 72.00
6.	M.S. rods:			
		(1) 4/8" Ø x 32' - 9" CTK 8.5/lb	=	TK 196.00
		(2) 3/8" Ø x 46' - 0" CTK 8.5/lb	=	TK 144.00
		(3) 2/8" Ø x 102'- 0" CTK 9.0/lb	=	TK 153.00
		(4) 1/8" Ø x 78' - 4" CTK 10.0/lb	=	TK 65.00
7.	Steel work and wire mesh sieve		=	TK 1748.00
8.	Wire mesh 20 W.G. 3.5 ft^2 C 5.0/ft^2		=	TK 18.00
9.	Mason : 10 days. CTK 30.00/day		=	550.00
10.	Laborer: 10 days CTK 28.00/day		=	280.00
		Total	=	TK 5038.00

APPENDIX 111

Calculation of cost of production of one (1) hollow block of 10 cm x 20 cm x 40 cm (4" x 8" x 16") Nominal standard size

Materials:	Ricehusk:	4.5 pots @300 g = 1350 g	= 1.35 kg
	Soil :	3.0 pots @1520 g= 4560 g	= 4.56 kg
	Cement :	1.5 pots @1650 g= 2475 g	= 2.48 kg

Price of Materials:	Ricehusk	= TK 1.00/kg
	Soil	= TK 0.10/kg
	Cement	= TK 2.20/kg

Cost of Materials Used:	Ricehusk	= 1.35 x 1.00	= TK 1.35
	Soil	= 4.56 x 0.10	= TK 0.46
	Cement	= 2.48 x 2.20	= TK 5.47
		Sub-Total	= TK 7.28

Cost of Labor: Rate/day = TK 28.00

No. of block/day = 40

$\frac{28}{40}$ = TK 0.70

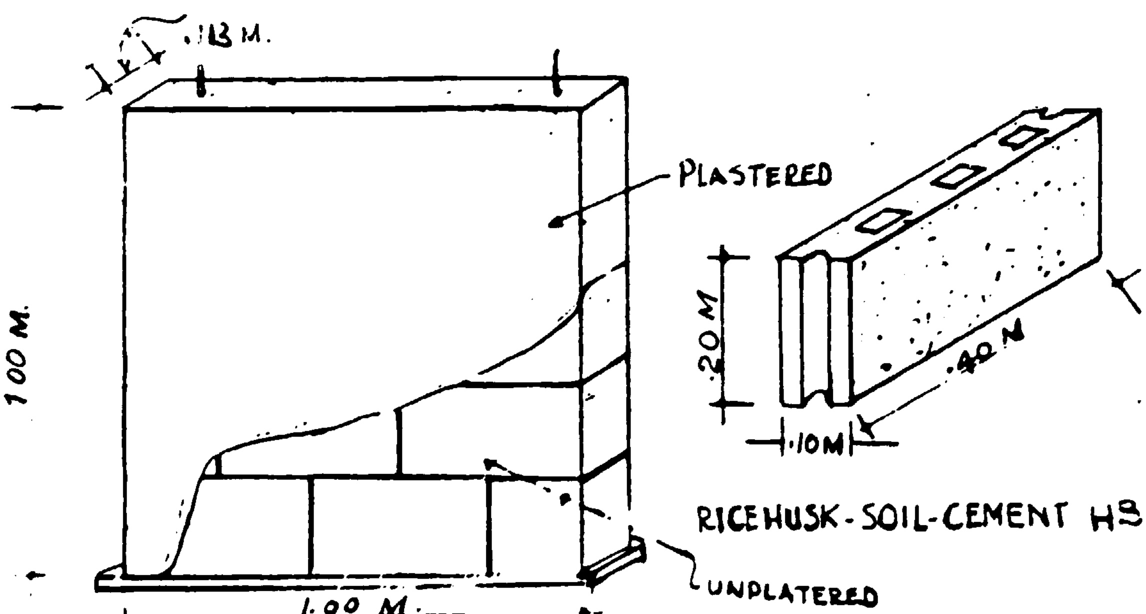
TOTAL = TK 7.98 or

= TK 8.00

APPENDIX IV

To compare the relative economy in the use of stabilized hollow block 10 cm x 20 cm x 40 cm (4" x 8" x 16") and the traditional brick 7.6 cm x 12.7 cm x 23.0 cm (3" x 5" x 9") it is in order to cosider the cost of construction of one (1) square meter of non-load bearing wall. This demonstrates the economic feasibility of the production and use of rice-hull-soil-cement hollow blocks in lieu of the traditional burnt brick.

A. Hollow Block



HOLLOW BLOCK WALL

Materials:

1. Required mortar to fill the hollow

   Volume of block = .10 x .20 x .40 = .008 m^3 =

   8000 cc = 8 liters or pot

   Volume of hollow = .008 x .25 = .002 m^3 =

   2000 cc = 2 liters or pot

   For 13 block - 2 x 13 = 26 liters or pot

2. Required mortar for bonding in construction

   assuming the thickness is 1.3 cm (½")

   Horizontal joints - 5 x 100 cm x 1.3 cm x 10 cm =

   6604 cc = 6.604 pots

   Vertical joints - 2 x 100 cm x 1.3 cm x 10 cm =

   2642 cc = 2.642 pots

   Total = 9.246 pots

   say 10.00 pots

3. Total volume of required mortar:

   a. For filling hollows = 26 pots

   b. For joints = 10

   Total - - = 36 pots

   Allow for 25% waste = 9

   Required 45 pots

4. Calculated cost of mortar needed for installation

Mixture 3 parts ricehusk
by volume : 2 parts soil
1 part portland cement
6 parts

a. Ricehusk: $\frac{3}{6} \times 45 \times \frac{400 \times 1.00}{1000}$ = TK 9.00

b. Soil: $\frac{2}{6} \times 45 \times \frac{1650}{1000} \times 2.20$ = TK 27.22

Total = TK 38.50

5. Calculate cost of mortar for plastering

Volume = 1.3 x 110 x 110 x 2 = 31.460 cc = 31.46 pots

Allow for 25% waste = 7.90

Total = 39.36 or 40

Mixture: 1 part cement
4 parts sand
5 parts

a. Cement = $\frac{1}{5} \times 40 \times \frac{1650}{1000} \times 2.20$ = TK 29.04

b. Sand = $\frac{4}{5} \times 40 \times \frac{1340}{1000} \times 0.16$ = TK 6.86

TK 35.90

6. Calculate cost of M.S. Rod

$\frac{4"}{8}$ ø 8' .0" TK 17/kg = 4/3 x TK 17.00

= 22.67

3. Labor:

A team of 1 mason and 2 helpers makes 12 square meters of wall a day.

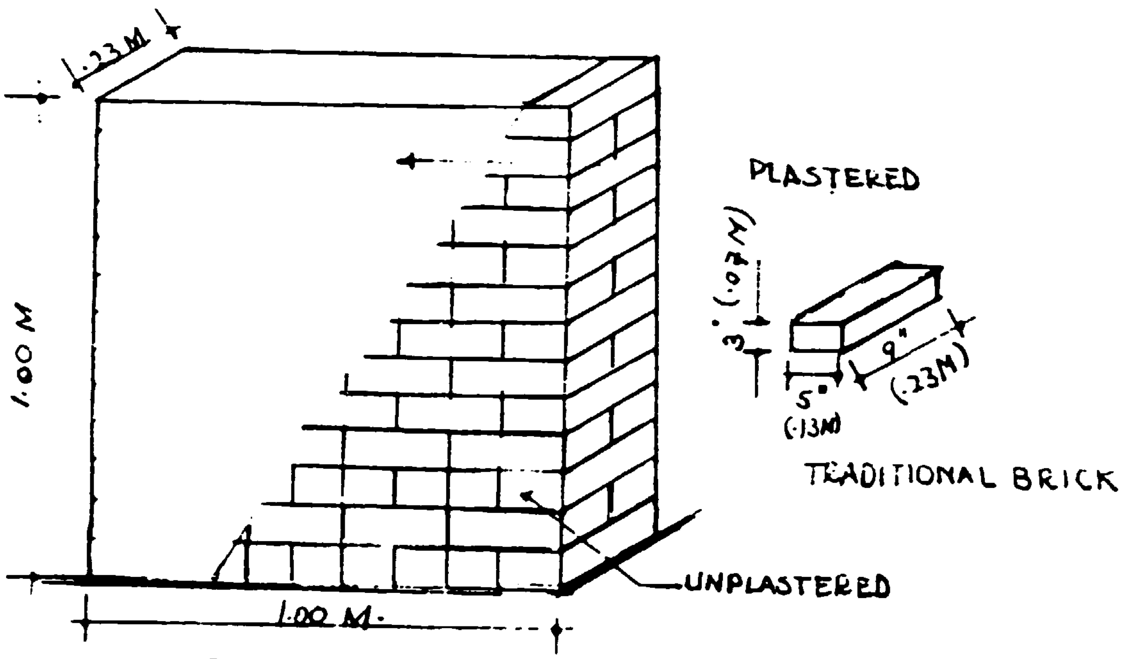
1 mason @ TK 60/day - - - - - =	TK 60.00
2 helpers @ TK 25/day - - - - =	50.00
Total - - =	TK110.00

Labor cost/square meter - - - TK 9.20

Summary:

Materials - - - - - - - - - - - - -	TK 200.00
Hollow block - - - - - - =	TK 104.00
Mortar for installation=	TK 38.50
Mortar for plaster - - =	TK 35.00
M.S. Rod - - - - - - - - =	TK 22.67
Sub-Total - - =	TK 200.17
Labor: - - - - - - - - - - - - - - - - -	TK 9.20
TOTAL COST -	TK 209.20

B. Brick



BRICK WALL

Materials:

1. Calculate cost of brick

$$\text{No. of brick required} = \left[\frac{100}{3 \times 2.54} \times \frac{100}{9 \times 2.54} \right] 2 = 115$$

Current price of brick per piece = TK 2.00

Cost of brick = 115 x 2.00 = TK 230

2. Calculate cost of mortar for joints of 1.3 cm (½") thick

Mortar mix by volume

Cement - - 1 part

Sand - - - 6 parts

7 parts

$$\text{Vol. Hor.} = \frac{14 \times 100 \times 1.3 \times 9 \times 2.54}{1000} = 41.60$$

$$\text{Vol. Vert.} = \frac{4 \times 100 \times 1.3 \times 9 \times 2.54}{1000} = \underline{11.88}$$

53.48 pots

Allow for 25% waste = 13.37

Total = 66.85

$$\text{Cost of cement} = \left[\frac{1}{7} \times \frac{66.85 \times 1650}{1000} \right] 2.20 = \text{TK } 34.67$$

$$\text{Cost of sand} = \frac{6}{7} \times \frac{66.85 \times 1340 \times 0.16}{1000} = \text{TK } 12.29$$

or = TK 46.96

Cost of mortar for joint = TK 81.63

3. Calculate cost of mortar for plastering (1.3 cm or ½" thick)

Volume required: $\left[\frac{1.3 \times 122 \times 122}{1000}\right] 2 = 38.69$ pots

Allow 25% wastes = 9.67

Total = 40.36 pots

Mixture by volume

Cement - - 1 part

Sand - - 4 parts

Total - - 5 parts

Cost of cement $= \frac{1}{5} \times 40.36 \times \frac{1650}{1000} \times 2.20$ = TK 29.30

Cost of sand $= \frac{4}{5} \times 40.36 \times \frac{1340}{1000} \times 0.16$ = TK 6.92

Cost of plaster = TK 36.22

Labor:

Under current labor cost in Bangladesh 10 ft. square or 9 square meters of brick wall costs = TK 165.00

Therefore labor cost/square meter $= \frac{165.00}{9}$ = TK 18.33

Summary of Costs

Materials		TK 347.85
Brick	TK 230.00	
Mortar for joints	TK 81.63	
Mortar for plastering	TK 36.22	
	TK 347.85	
Labor		TK 18.22
	TOTAL COST	TK 366.07

Comparison:

Cost per square meter of Brick wall	= TK 366.00
Cost per square meter of HB (Stabilized soil)	= TK 209.20
	TK 156.80

Conclusion:

Stabilized soil Hollow Block (Ricehull-Soil-Cement HB) wall is cheaper than brick by 42.84%

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