SCIENCE EDUCATION SERIES

NO. 32

BUILDING MATERIALS IN SRI LANKA

by

V.T.L. Bogahawatte

NATURAL RESOURCES ENERGY & SCIENCE AUTHORITY
47/5 MAITLAND PLACE
COLOMBO 7

January 1993

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

BUILDING MATERIALS IN SRI LANKA

By

V.T.L. Bogahawatte

B.Sc. (Ceylon), B.Sc. Hons(Sheffield)
M.Sc. (London), Ph.D. (London)
F.I.M. (U.K.)

Director & Head
Building Materials Division
National Building Research Organisation
99/1, Jawatte Road
Colombo 5

January 1993

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

CONTENTS

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

LIST OF TABLES

LIST OF FIGURES

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

BUILDING MATERIALS IN SRI LANKA

INTRODUCTION

Background

The objectives of this work are to examine the building materials available in Sri Lanka, look at their geographic distribution, present some of their known characteristics and discuss the research taking place on local building materials. No attempt at detailed completeness is made, rather, it is hoped that with some insight into the properties of the materials, a greater awareness will be created for the effective use of local building materials.

The building materials used to varying degrees in Sri Lanka are as follows: burnt clay bricks, cement and cement products including asbestos-cement sheets, corrugated iron, aluminium, alloy, fibre glass and bituminous sheets, structural steel, earth, common clay and soil blocks, natural stones, lime, timber (including bamboo) and tiles. Agricultural fibre wastes are used to a limited extent in specific applications. Building components such as glass and ceramics (sanitary ware, tiles, pipes) are also used. The choice of materials is determined by the particular environment of their use (rural and urban), cost, aesthetic appearance, functional considerations and their availability.

The use of building materials is quite different in rural and in urban areas. Locally available indigenous materials are widely used in many rural areas.

Traditional materials

An islandwide survey on rural housing conducted by the National Building Research Organisation (NBRO) in 1984 (1) revealed that earth (61.8%), burnt clay bricks (16.2%), rubble (8.1%), cement products (4.8%), cabook (4.1%), timber and other materials (0.9%) are the materials used in superstructure walls of rural houses. Earth construction was mainly in the form of wattle and daub

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

(50.4%) with rammed earth (8.4%) and adobe (4.6%) confined to certain areas of the country.

As regards the roofing material, cadjan is the most popular with 42.6% of the housing units using it as the prime material. Straw and palmyrah thatching have been used in 4.1% and 1.6% houses respectively. Clay tiles constitute 33.8% of the houses while 10.8% houses are roofed with corrugated sheets.

The majority of urban houses have brick walls (62%) tiled roof cover (47.7%) and cement floors (78%) (2)

Recent trends

Burnt clay brick is the obvious choice as a walling material in place of wattle and daub, adobe (puddled earth) and pise (rammed earth). Cement and cement products, the basic materials used in urban areas have become widespread in many rural areas. They too have displaced earth, natural stones and even burnt clay bricks and other traditional indigenous materials. The use of cement has also led to the widespread use of structural steel. In a similar manner, cement-asbestos and iron sheets have partially replaced thatch and country tiles.

Evaluation of building materials

Many building materials, for example country bricks fail to conform to Sri Lanka standards, thereby affecting the quality and durability of construction. Another problem is the increase in cost of construction due to indiscriminate use of cement with no attention paid to its rationalization.

The approach taken here is to attempt to explain, simply and briefly, the basic and intrinsic properties of the building materials used in Sri Lanka. From these properties the criteria for their evaluation are prsented wherever necessary and some of the typical uses and limitations are described.

CHAPTER 1

WALLING MATERIALS

1.1 Burnt Clay Bricks

1.1.1 Tradition of building with clay bricks

Burnt clay brickmaking technology was known to the Sri Lankans as early as the time of the formal introduction of Buddhism to Sri Lanka in the 3rd century B.C (3). The tallest brick edifice of mankind, the Jetawana stupa (400 ft) constructed by king Mahasen in the 3rd century A.D. still stands in Anuradhapura. Quality framed brick structures that were arched, vaulted and domed were also constructed by the ancient Sri lankans.

Majority of the superstructure walls of the residential buildings in Sri Lanka are constructed with burnt clay bricks (1). Clay bricks available in Sri Lanka are either handmade and fired in clamp kilns in cottage units or extruded and fired in permanent kilns in mechanized factories. It is estimated that about 4% of the bricks are made in modern factories. The total number of brickmaking establishments in the country in 1980 was 3950 (4), each producing an average of 150,000 bricks per year. The total annual production in this semi-formal sector was 600 million bricks.

Clays used in brickmaking in Sri Lanka may be divided broadly into two classes, *viz.*

(i) residual deposits formed by in--situ weathering of rocks (eg. in central highlands, particularly in Kandy area) and

(ii) sedimentary deposits which are formed in tanks (eg. in Polonnnaruwa and Anuradhapura districts) or transported and formed by sedimentation along the courses of rivers (eg. in Dankotuwa and Hanwella areas).

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

All these clayey materials have one thing in common. They are always composed of secondary or water-containing minerals of extremely fine particle size, that have been produced by the action of weathering agents (water and air) on the feldspars and micas of igneous rocks.

The predominant constituents identified in our alluvial and residual brick clays are kaolinite, quartz and K, Na, Ca-feldspars. The accessory minerals included vermiculite, amphiboles, gibbsite and iron-bearing minerals (5). The clays from intermediate and dry zones contain illite as the mojor constituent. Iron compounds, usually present as goethite and hematite are nearly always present as impurities in brick clays. These and calcium carbonate account for the wide range of colours found in the finished bricks.

1.1.2 Soil selection for brickmaking

The most suitable soils for brickmaking are identified with respect to granulometric composition (grain size distribution). The basis of selection is that plastic properties correlate with specific granulomentric compositions. The favourable limiting ranges are represented in Fig. 1 which also shows the classification of some of the common brickmaking clays in Sri Lanka with respect to their end uses (5).

However, when specific characteristics are desired, a laboratory evaluation is necessary. A clay having the following characteristics is normally considered suitable for brickmaking (6).

Clay and silt	-	25-50%
Sand and coarser material	-	75-50%
Liquid limit	-	25-40%
Plasticity index	-	7-15%
Volumetric shrinkage	-	15-25%

1.1.3 Brick manufacture

In small scale brickmaking, winning of clay is carried our manually. The use of mechanical shovels to extract clay could only be seen in some industrial clay fields in Dankotuwa area. Preparation of won clay by treading (cattle/foot) and if necessary by blending followed by tempering is a must if the bricks shall be of good quality. This operation is very much neglected today. Only the mechanized factories blend lean and plastic clays to obtain the rquired consistency. The processed soil is traditionally shaped in a wooden mould. Moulding tables (State Engineering Corporation factory) or extruders (Lanka Ceramics Limited factories) are also used for shaping. Before the bricks are fired the free-water must be removed. Uncontrolled traditional air-drying adds many defects such as cracking and distortion at this stage. A typical process flow chart for the production of bricks is given in Figure 2.

Firing of bricks is one of the most important quality determining stages in brickmaking. Throughout the process of firing of a clay brick, a series of physical and chemical changes take place. The critical temperatures and changes for local clays are summarised below.

30 - 150^{0}C	-	Drying of brick.
150 - 320 ^{0}C	-	Dehydration of clay mineral by removal of combined water.
350 - 450^{0}C	-	Burn-out of carbonaceous matter.
500 - 600^{0}C	-	Breakdown of clay mineral structure with simultaneous transformation of quartz accompanying volume expansion.
900^{0}C	-	Finishing temperature (~ 1000^0 C) - Sintering and vitrification leading to development of fired stength.

Differential thermal analyses of common Sri Lankan brick clays carried out recently (5) reveal that the range of peak temperature at which the final exothermic reactions leading to the strength development of these clays spans

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

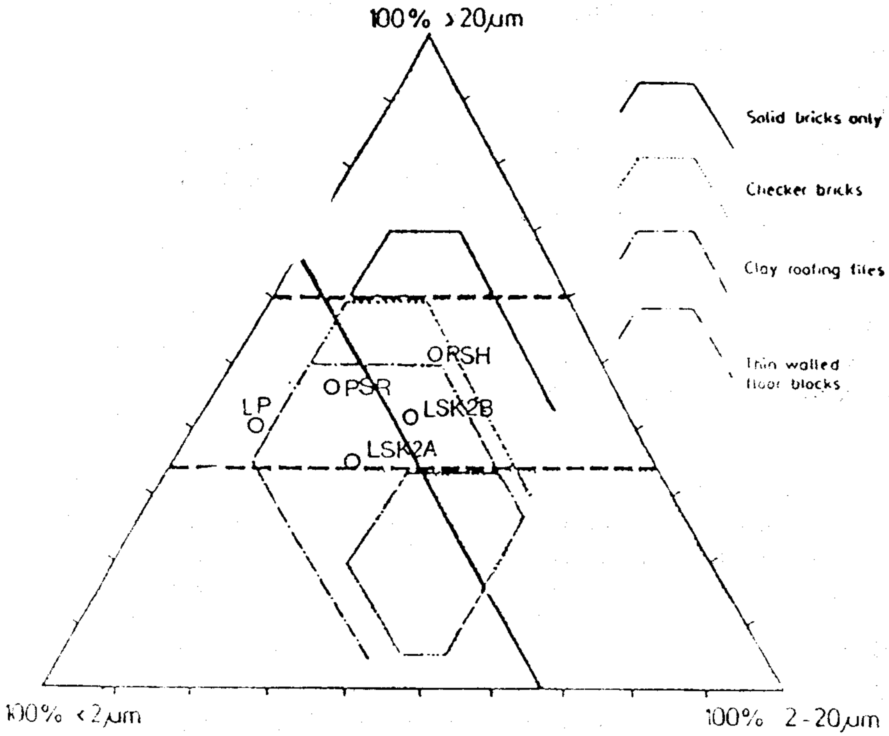

Figure 1: Grading triangle (after Winkler) which shows the classification of some local clays

(1) LSK2A & LSK2B - Lateritic soils from Kandy
(2) PSH - Podzolic soil from Hanwella
(3) PSR - Podzolic soil from Ratnapura
(4) LP - Latosol from Puttalam

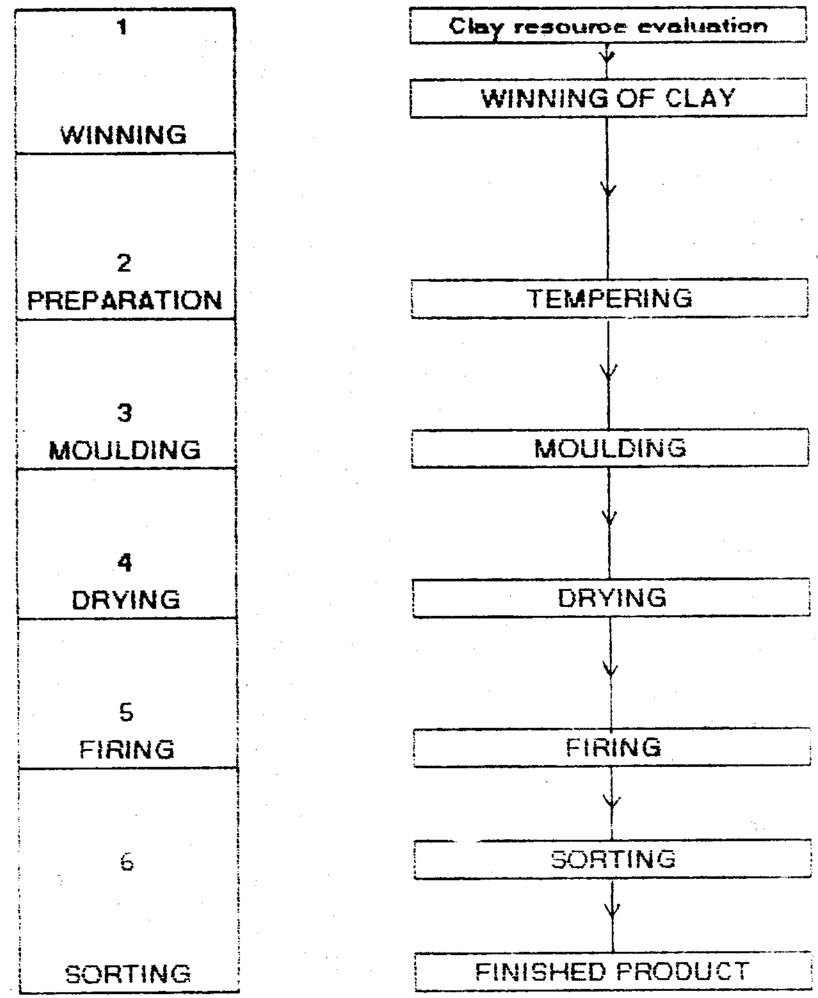

Figure 2: Process flowchart for the production of bricks

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

from 870^0 to 950^{0}C. The peak temperature depends on the type of clay. However, the firing schedule [rate of heating, peak temperature and soaking time], rather than the peak temperature alone, plays a more significant role in the completion of reactions and therefore in the development of fired strength. It appears that a minimum firing temperature of 950^{0}C is required, among other considerations to impart acceptable durability to a brick clay. The critical stage of firing is between 500^{0}C and 700^{0}C since α/β quartz change which causes expansion at 573^{0}C invariably leads to cracking, if firing is not carried out under carefully controlled conditions.

The presence of very coarse fragments of quartz of the order of 5mm in ancient bricks amply supports the view that the ancient Sri Lankan brickmaker had an intimate knowledge of the material behaviour and firing schedule. Firing of a brick clay with quartz of this size fraction without the loss of quality does require considerable modifications of the firing schedule of even a modern brick kiln.

A study carried out (7) revealed that the localized minimum and maximum firing temperatures of a common clamp kiln subjected to investigation at Malwana was 600^{0}C and 860^{0}C respectively. A range of firing temperature as low as this is hardly sufficient to impart adequate strength and durability to brick. Inappropriate firing gives rise to defects such as black-core and bluish grey colour development, dimensional and porosity variation, low stength and durability, warpage and cracking.

1.1.4 Properties of clay bricks

Sri Lanka's Standard Specification for Burnt Clay Bricks began life in 1968. It was superseded by SLS 39 in 1978. SLS 39 specifies numerical limits for dimensions and tolerances, compressive strength and water absorption. It does not cover such aspects as durability, efflorescence etc. In the opinion of the author, laying down of specifications for durability is of utmost importance particularly in the light of the present practise of low-burning of handmade

bricks and their use in the restoration of ancient monuments and in structural brickwork.

The following evaluation criteria are specified in standard specifications.

(a) Dimensions

Dimensions of handmade bricks produced in different brickyards vary widely (8). Consequently, the dimensional tolerances of present day country bricks show considerable departure from the specified limits (Table 1).

(b) Compressive strength

It is disappointing to note that most of the country bricks fail to satisty the strength criterion (Table 1). Study of failure patterns of handmade brick under compressive load shows that the brick material being more closer to an underburnt clay does not exhibit a brittle failure characteristic of a well burnt ceramic material. As a result, the determination of the true failure point of an underburnt handmade brick is somewhat ambiguous.

(c). Water absorption

High water absorption associated with handmade bricks is due to inadequate sintering and vitrification of brick body (Table 1). The characteristics of different types of bricks available in Sri Lanka including those of bricks from ancient monuments are presented in Table 2.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

Table 1: Characteristics of handmade bricks produced in different brick-making areas.

Brickmaking Area	Property		
	Average Compressive Strength in N/mm^2 (p.s.i. in parenthesis)	Average Dimensions in mm	Average % water Absorption
1. Hanwella	1.38(200)	197 x 97 x 52	29
2. Malwana	0.64(93)	201 x 96 x 55	23
3. Dankotuwa-Kochchikade	1.54(223)	198 x 96 x 49	25
4. Kandy	0.98(142)	224 x 106 x 51	20
5. Kurunegala	1.24(180)	227x 102 x 58	17
6. Deduru Oya	1.44(200)	205 x 96 x 53	20
7. Polonnaruwa	1.63(237)	223 x 98 x 57	13
8. Galle	1.07(156)	200 x 99 x 52	33
9. Hikkaduwa	0.54(78)	219 x 101 x 49	16
10. Kalutara	0.83(121)	211 x 108 x 56	25
11. Ratnapura	0.77(112)	223 x 109 x 54	26

Table 2: Observed and specified characteristics of bricks

Property	Average value for the type of brick shown			Specified
	Handmade*	Extruded+	Ancient+	Value (SLS 39 : 1978
Comp. strength - N/mm2 (p.s.i. in parenthesis)	1.1 (160 p.s.i.)	4.7 (680 p.s.i.)	14.1 (2045 p.s.i.)	2.8 (410 p.s.i.)
Nominal dims. (mm)	212x101x53	221x106x63	436x221x63	220x105x65
% Water abs.	22	10	12	28 (max)

\+ - Unpublished data from NBRO records

* - NBRO monograph

1.1.5 Research and development

Following the identification of problems of inadequately fired handmade bricks, a moulding table and a Bull's trench kiln for moulding and firing of bricks were introduced in 1988 by the NBRO in collaboration with the Building Materials Manufacturing Corporation. The Bull's trench kiln of continuous type has an estimated daily output of 15,000 bricks. Moulding table enables shaping of bricks more accurately.

1.2 Cement, Concrete And Cement-sand Blocks

1.2.1 Status of cement production

The first cement factory in Sri Lanka was established in 1950s at Kankesanturai. This factory is presently out of production. After about a decade, a factory was

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

established at Puttalam by the Ceylon Cement Corporation. Both these factories employ suspension pre-heater systems for the manufacture of Ordinary Portland Cement (OPC). The method of manufacture is basically a "dry process". The installed capacity of Puttalam works, limited by the output of its two rotary kilns is 1300 M. tons of clinker per day. The Cement Corporation has also established a clinker-grinding plant at Galle. This paved the way for better distribution of cement in the Southern region. The grinding plant has a daily output of 625 M.tons of cement. Taken together, the three manufacturing plants at Kankesanturai, Puttalam and Galle at full capacity have an output in excess of 700,000 tons of cement per year.

In the 1980s there was rapid expansion in cement industry. Two more plants were established at Kankesanturai and Trincomalee by Lanka Cement Company (a subsidiary of Ceylon Cement Corporation) and Tokyo Cement Company respectively. The projected demand of cement for 1991 is 1.9 million M. tons. About 48% of this is met by domestic production. The gap between demand and supply necessitates importation of OPC, which is mainly handled by NGOs.

1.2.2 Manufacture of cement

Only one type of cement is presently produced in Sri Lanka which is specified in the Sri Lankan standards (SLS 107:1982) as Ordinary Portland Cement. Portland Cement is prepared by intimately mixing calcareous, clayey and iron oxide bearing materials (Limonite from Ratnapura area), burning them at a clinkering temperature, and grinding the clinker. The basic raw materials, except gypsum added to prevent rapid setting of cement are available locally. Calcareous limestone resources are available in the Jaffna Peninsula and in a belt stretching to Puttalam, South-west Aruwakalu, and Dutch Bay region. Inland coral limestone, suitable for cement manufacture exists in the southern coastal areas. The process of manufacture of cement is illustrated diagrammatically in Figure 3.

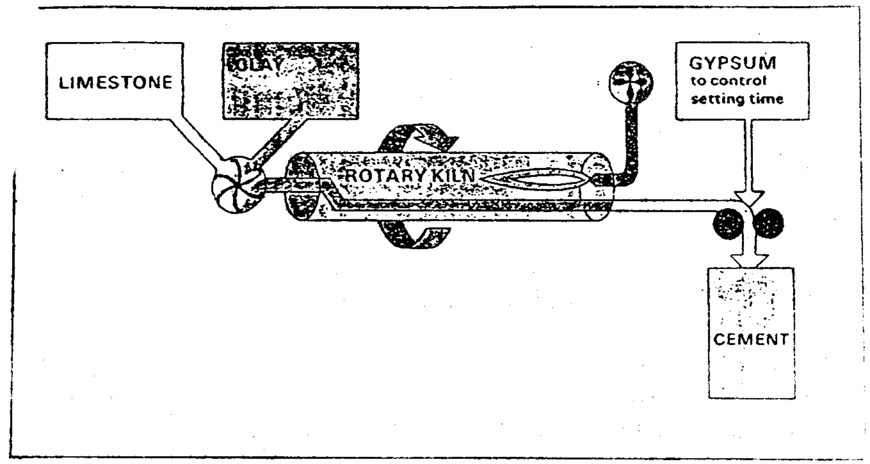

Figure 3: Schematic diagram - Process of manufacture of cement

The main compounds present in OPC are tricalcium silicate (Ca_3SiO_5), dicalcium silicate (Ca_2SiO_4), tricalcium aluminate ($Ca_3Al_2O_6$) and calcium aluminoferrite ($2Ca_2AlFeO_5$). It is the reaction of these with water to form hydrated compounds that causes cement to set and harden.

Sri Lankan Standards for cement lay down limits for properties such as chemical composition, fineness of grinding, setting time (initial and final), soundness (delayed expansion) and strength for two types of Ordinary Portlant cement. However, only Type 1 cement is presently being manufactured locally. The minimum physical requirements are shown in Table 3.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

Table 3: Physical requirements for Ordinary Portland Cement

Type	Strength of mortars	Setting times	Fineness(min)	Soundness
1	23MN/m^2 at 3 days 41 MN/ m^2 at 28 days	Initial 45 min Final 10h	225M^2/Kg	< 10mm
2	15 MN/m^2 at 3 days 38 MN/m^2 at 28 days	Final 10h	225M^2/Kg	< 10 mm

1.2.3. concrete

Concrete is a conglomerate of aggregate (crushed stone or gravel) with sand and cement or lime. Lime concrete was used by ancient Sri Lankans particularly in foundation applications as is evident in excavated basal layers of stupas.

1.2.3.1 Aggregate

Only crushed stones are used in Sri Lanka as the coarse aggregate. These are of granitic, gneissic or of mixed dolomitic-charnockitic origin. Fine aggregate is mainly river-sand. The required qualities of a concrete will develop, only if the aggregates are correctly chosen, graded and mixed in appropriate proportions with cement and water and compacted and cured properly.

The bulk density of Sri Lankan coarse and fine aggregates is of the order of 2.8 and 2.5g/cm^2 respectively, whereas the crushing value of coarse aggregate is in the region of about 25. The crushing value is important in the evaluation of the suitability of an aggregate for concreting.

1.2.3.2 Properties of hardened concrete

It is usually necessary to test the concrete to determine whether the desired quality is being maintained. The following tests on fresh and hardened concrete are usually carried out in Sri Lanka.

(a) Workability test (fresh concrete)

Determines the ease of compaction of concrete. The slump test is the most common.

(b) Cube compression test (hardened concrete)

Give an indication of the accuracy with which the mix proportions are maintained to obtain the required target strength.

Hardened concrete is also tested by a number of non-destructive methods such as the ultrasonic pulse velocity and rebound hardness. These methods are, however, not included in a Sri Lanka standard.

1.2.4 Cement - sand blocks

During the past decade there has been a tremendous growth in the use of cement - sand blocks mainly as a substitute walling material for handmade bricks. The present day uses include non-loadbearing applications such as partitioning, infilling and parapet walls. Several manufacturing concerns have established enterprises for the production of hollow blocks. It has also become a cottage industry.

Aggregates commonly used for the manufacture of blocks in Sri Lanka are river sand and mineral waste (quarry dust). Blocks arre manufactured by placing pre-mixed proportions of aggregate and cement at an optimum water cement ratio in a mould and subjecting it to compaction by ramming or vibration. Subsequent curing is usually carried out in open yards. Both wet mixing and semi dry mixing processes are employed.

Blocks are generally available in three standard sizes:
200mm x 200mm x 400mm, 150mm x 200mm x 400mm and 100mm x 200mm x 400mm. Sri Lanka Standard Specifications SLS 855 : Cement Blocks cover the general requirements and test methods. The minimum compressive strength

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

recommended in SLS 855:Part 1 is 1.2 N/mm^2, whereas that recommended for burnt clay bricks in SLS 39 is 2.8 N/mm^2.

1.2.5 Research and development work on cement and cement-sand blocks

The production of a masonry cement incorporating imported blast furnace slag having pozzolanic properties was discontinued in early 1980's.

Exploitation of pozzolanic properties of agricultural wastes such as rice husk ash and of clay minerals is in progress at some research organisations of the country.

It is now realized that certain types of aggregates react with constituents of cement leading to deterioration of concrete. Such deterioration is ascribed to alkali aggregate and alkali silica reactions. Research efforts are directed in most countries to identify reactive aggregates. India too has provided examples of alkali reactive aggregates. Sri Lanka with its rich and varied collection of minerals cannot be considered devoid of harmful aggregates.

Published work on cement-sand bricks is mainly concerned with the production aspects of hand cast blocks. Recent research efforts are directed towards the rain penetration resistance of blockwork (9).

1.3 Building Lime

The use of lime as a building material dates back to the Anuradhapura and Polonnaruwa periods. The Gedige at Nalanda was built entirely of limestone. At Maligawila, a Buddha statue in limestone measuring nearly 40ft. in height had been erected. The crystalline dolomitic limestone used in sculpture, however, underwent rapid weathering unlike gneiss. The material was more susceptible to fragmentation on impact and under changes in climatic conditons. This is probably the reason why even the modern day sculptor avoids the use of crystalline limestone.

The gallery of Sigiri had been coated with lime plaster and polished so well that even today, it shines like glass. However, the use of limestone for architectural purposes was given up, after Sigiri. The seven storey high palace which king Parakramabahu built at Polonnaruwa had its upper storeys built of lime concrete. Numerous examples of the use of building lime in foundation applications could also be seen (11).

1.3.1 Raw materials for lime production

In Sri Lanka, building lime is made from the following calcium carbonate-bearing materials/rock minerals:

(a) Coral stone
(b) Crystalline limestone/dolomite
(c) Sea shells
(d) Sedimentary limestone

Coral stones occur in the southern coastal belt extending from Hikkaduwa to Matara. The deposit of sea shells, only one of its kind in Sri Lanka is located at Hungama. Sedimentary limestone deposits are confined to the north western area. Crystalline limestone mainly occurs in highlands (eg. in Matale area); composition varies from limestone through magnesium limestone to dolomite. No estimates of the extent of limestone deposits are available (10).

1.3.2 Manufacture of lime

Lime is produced by a two-stage process. First, limestone bearing material is calcined in a kiln at a temperature of about 750-1000^{0}C depending on the type of limestone, driving off carbon dioxide, and producing quicklime (calcium oxide)

The second stage is called slaking or hydration. Quicklime is made to react with water. The evolution of heat and expansion accompanying this reaction breaks

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

down lumps of quicklime to a fine powder. This powder is slaked, or hydrated, lime (calcium hydroxide).

1.3.3 Chemical reactions in lime burning

(a). Reaction for the following types of limestone-900-1000^{0}C

$CaCO_3$ + Heat ⟶ CaO + CO_2
Calcium carbonate → Calcium oxide Carbon dioxide

Coral stone
Sea shells
Sedimentary limestone

(b). Reaction for dolomitic limestone -at around 750^{0}C.

$CaMg(CO_3)_2$ + Heat ⟶ $CaCO_3$ + MgO + CO_2
then reaction (a) at around 900^{0}C.

1.3.4 Lime kilns

The kilns used in Sri Lanka for calcining lime are of two basic designs. A rotary kiln installed by the Ceylon Ceramics Corporation at Hungama produces high quality hydrated lime from sea shells. Batch kilns are by far the most common type of small kilns in use in the coastal belt and central region. The design and size of batch kilns vary greatly depending on the locality and lime mineral. Batch kilns are considered to be inferior to continuous rotary kilns in view of their low fuel efficiency and product quality. The Industrial Development Board and Lanka Ceramic Limited in the recent past have introduced two prototype batch kilns of improved design for the manufacture of lime based on dolomite.

1.3.5 Properties of building lime

SLS 552:1982 - Specification for building lime covers the requirements for hydrated lime and quicklime for masonry applications. It specifies the following physical and chemical requirements for evaluation of the suitability of lime.

(a) Fineness
(b) Available CaO
(c) Loss on ignition
(d) Insoluble matter content
(e) MgO content.

However, lime is one of the building materials which enters the market freely without undergoing any quality tests.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

CHAPTER 2

EARTH-WALL CONSTRUCTION

2.1 Ancient, traditional and conventional construction

The ancient mansions of kings and nobles in Sri Lanka were mainly constructed of wood. These have left no traces whatever (11). On the other hand, the ancient residential buildings were built with jungle pole frames and mud, on the principle known as "wattle and daub". They had thatched roofs. Ancient builders highly skilled in the art of construction did not for some reason use their ingenuity towards improving the traditional house. According to Tissera and Weerakkody (12), the reasons could be conjectured from the writings of Robert Knox which say that "...they are not permitted to build their houses above one storey high, neither may they cover with tiles nor whiten their walls with lime, but there is a clay which is white and that they use sometimes...". The use of more permanent materials seems to have been expressly forbidden under feudal laws. Probably the ancients tried to strike a balance between the exploitation of natural resources and their reversible recovery and environmental degradation. These houses of low durability were exposed to vagaries of weather adding to the cycle of recovery. This is perhaps the reason why the remains of dwellings of early settlers are non-existent even in areas where ancient monuments exist.

During the colonial period and thereafter, other methods were introduced. In Nuwara eliya district many buildings were built with adobe (sun-dried blocks). Some such two-storey buildings existing in Horana area are a century old. These building are still giving excellent service, and look as though they will continue to do so many years to come. In Gampaha area and in Kiribathgoda housing scheme, there are examples of pise (rammed earth) constructed with a movable formwork. This technique was introduced to Sri Lanka in 1950s by Professor G.F. Middleton of Australia at the request of the Government of Sri Lanka. The model structures constructed at the first 'Experimental Building Station' at Jawatte, Colombo 5, to demonstrate earth-wall construction techniques were demolished in 1984 to make way for the new buildings of the National Building Research Organisation. These structures were in excellent condition even at the time of demolition.

2.2 Earth-walling techniques

In areas where natural stones are available, the obvious choice for wall construction is rubble in earth material mortar.

A notable addition to the list of earth-wall construction materials is the Cinva-ram block which was developed in Colombia in 1950s. Cinva-ram or compacted stabilized soil blocks have been used only recently in Sri Lanka. Applications are mainly limited to sponsored housing schemes.

Earth-walling techniques used to varying degrees in Sri Lanka can be summarised as follows:

(a) wattle and daub (warichchi bamma)
(b) rammed earth using a movable formwork (thappa bamma)
(c) sun-dried blocks laid in mud mortar (moda gadol bamma)
(d) rubble laid in mud mortar (sakka/keta gal bamma)
(e) limestone/coral stone laid in lime/sand/mud mortar (hunugal bamma)
(f) laterite laid in mud or lime/sand/mud mortar (cabook bamma)
(g) stabilized soil blocks

2.2.1 Wattle and daub

It consists of a framework of poles sunk in the ground with reeds woven horizontally between the poles to make matlike screens called "Wattles". The spaces between the exterior and interior wattles are filled with mud. Both sides of this framework is then "daubed" (plastered) with mud.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

In 1984, The distribution of wattle and daub houses in different districts was from 35.9% (Kandy) to 84.7% (Moneragala and Vavuniya). The average for 'all districts' was 61.8% (1).

Rain, floods and wind affect the stability of such dwellings particularly since they are rarely provided with any footing. The use of mud inevitably gives rise to shrinkage cracks. Water is the principal weathering agent affecting the durability. The wattle structure is also susceptible to termite attack.

To Minimise wetting and erosion of the wall by rain, large roof overhangs and suitable footings should be provided. Chopped straw mixed with the mud as reinforcement to arrest cracking is a good practise used in some areas.

2.2.2 *Rammed earth (pise)*

In this system damp earth is tamped in-situ between temporary, movable formwork.

Not all soils are suitable for earth-wall construction. The soil required is of a sandy loam nature. According to Middleton (13), who was instrumental in popularising this technique in Sri Lanka, earth is suitable for pise if it contains not more than 50% of clay, including loam and silt, and not less than 50%of sand, including gravelly material. It has been found recently (14), however, that the most appropriate soil for rammed earth construction contains

Clay - 10 - 20%
Silt - 15 - 30%
Gravel and sand - 50 - 75%

Most soils could be made suitable by admixture. The simplest test for consistency is to press a handfull of earth into a ball. The minimum moisture content is the one that forms a compact ball. The equipment required for walling is usually two sets of formers, one for straight runs and one for right angles or

corners. A rammer is used to compact the soil in the former (Figure 4). Rammed earth walling requires a foundation and damp proof course.

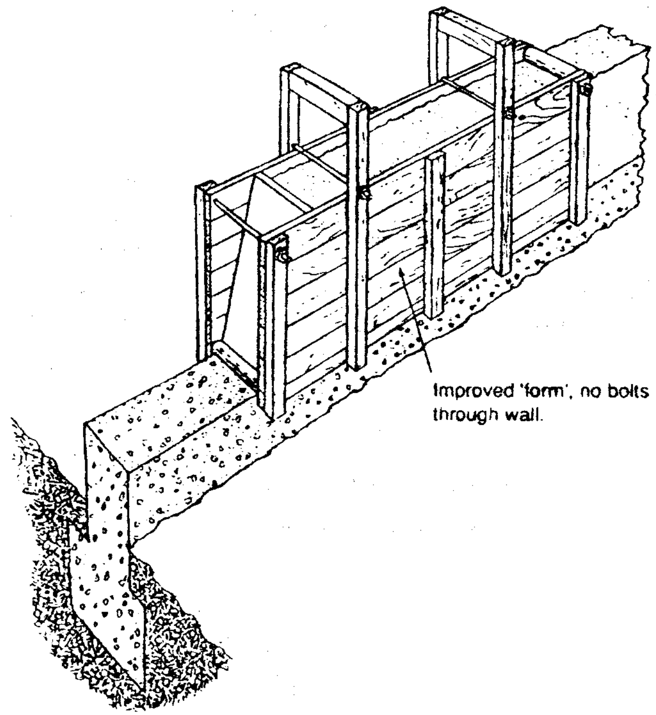

Figure 4: Wooden form for rammed earth walling

High compressive strengths and very low moisture cracking could be achieved by rammed earth technique. Wall is fire resistant. Disintegration due to slashing rain and floods is less severe than in wattle and daub. Moreover, rammed earth offers greater resistance to insects and rodents. This natural material requires no energy input to produce structures of similar strength and

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

durability as those using conventioanal materials. It also causes no wastage or pollution. However, the main advantages are achieved only with a well trained workforce and regular quality controls. Although there is evidence that artisans from the plantation sector have been trained in this technique in 1950's, rammed earth houses remain predominantly in Gampaha district.

2.2.3 *Adobe (sun-dried mud) blocks*

Wall construction with sun - dried, unburnt blocks is popular in the central region although examples of it could be seen in other regions as well. Dimensions vary according to locality. In some agricultural areas, chopped straw is mixed with soil for making blocks. The blocks are hand moulded and after drying laid in mud mortar in the walls. the highest compressive strength of adobe blocks achieved with different types of Sri Lankan soils is of the order of 250 p.s.i. (1.7 N/mm^2).

2.2.4 *Natural stones laid in mud or lime mortar*

Natural stones used in housing and construction in Sri Lanka are gneisses, granitic gneisses, granitoid rocks, migmatites and limestones. Partly intruded rocks of dolomitic-granitic range are used in a number of locations where such rocks exist.

Mud and lime mortars have been extensively used by the ancient Sri lankans in conjunction with burnt clay bricks. There is evidence that mud mortar in the form of very thin layers was used to bond courses of bricks in the construction of colossal stupas. It is believed that the composite material provided the much needed flexibility in moisture movement of bricks. Lime mortars were used in speciic applications. The practice of laying bricks in mud mortar is still continued in some areas; beautiful examples of rural dwellings could be seen in Matale-Katugastota and Anuradhapura areas. Free availability of lime followed by cement paved the way for a gradual transition to processed mortars and an eclipse of a time honoured practice.

2.2.5 *Stabilized soil blocks*

Natural earth stabilized with portland cement has been tried during recent years in wall construction. An attempt has been made by the Building Research Institute in 1978 to popularise stabilized blockmaking with the Cinva-ram press. The use of stabilized blocks, however, is limited mainly to government housing projects (e.g. Dambulla and Nikaweratiya). Lack of information on the selection of soil and the resulting poor quality of bricks prevented them from gaining acceptability.

A soil that has at least one-third sand and between 5 and 30% clay/silt is believed to be suitable. If the soil at hand is not suitable, it can be made suitable by adding sand or clay. Lateritic soil blocks stabilized with 4% cement had 28 day compressive strength of 2.8 N/mm^2.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

CHAPTER 3

ROOFING MATERIALS

3.1 Materials For Roof Structure

3.1.1 Timber

In Sri Lanka, the use of timber in construction dates back to a few centuries B.C. It was used widely in ancient monasteries. The Lowamahapaya built by king Dutugemunu is said to be a nine storey high timber structure.

A large number of magnificient timber structures of the medieval period are still in existence. The Embekke Dewala of the 14th Century, the Audience hall in Kandy, the Malwatte and Asgiriya temples of the 18th Century and the Dalada Maligawa are typical examples of the use of timber in construction. Timber used in ancient buildings are of highly durable species. There is no evidence that the timber had been treated. The timber used for beams and rafters are of a variety suitable for carving, known as Gammalu (Pterocarpus marsupium). With the introduction of Portugese and Dutch styles in buildings, however, the use of timber was gradually diminished (15).

Jungle pole timber is traditionally used as a building matrial in rural dwellings. Main uses are in skeleton walls, roof structures and trusses.

The timber species most commonly used at present in roof structure is Jak. It is used in 39.1% of the villages. Other commonly used species include Satin (10.5%), Palu (8.8%) and Coconut (7.6%). Timber species commonly used for doors and windows are Satin, Milla, Wewarana, Mahogany, Palu and Halmilla in the Northern and Eastern districts and Teak and Jak in Western and Southern parts (1).

3.1.1.1 Classification of timber

In timber used for construction the orientation of the grain affects strength. Full strength can be achieved with timber in which the grains are oriented parallel to the edges of the timber. The presence of defects causes loss in strength.
In advanced countries, engineering timbers are graded on this basis, plus an allowance for dimensions, duration of load and a suitable factor of safety. In Sri Lanka, however, an arbitrary classification based on properties of timber, its availability and demand is in commercial use. The following is the classification used by the State Timber Corporation:

1. Supper luxury 2. Luxury 3. Special 4. Class I 5. Class II 6. Class III.

Sri Lanka Standards on stress grading of timber are yet to be formulated. British Standard code of practice CP 112 is presently being used in structural design considerations. Dry stresses for some local timber species have been recommended by some investigators (16). Approximate ranges (in N/mm^2) for some common species are given in Table 4.

Table 4: Approximate ranges for mechanical properties of local timber

Bending	Comp. parallel to grain	Comp. perp. to grain	Shear parallel to grain	Modulus of Elas.
8-62	6-70	1.7-43	1.5-10	4.-71

However, these values were found to vary depending on the type of species and its location of growth, extent of maturity etc.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

3.1.1.2 Deterioration and preservation

Measures are needed to protect wood from the attack of living organisms. Materials used as wood preservatives in Sri Lanka can be classified as

Oily preservatives: petroleum creosote and tar products (odour and black colour make them identifible).

Non-fixed water soluble salts:boric acid (eg. rubberwood furniture). Good for applications not involving running water.

Fixed water soluble salts : copper chrome arsenate

Solvent soluble organic preservatives: Water insoluble chlorinated phenols. Usually applied or impregnated into wood with a solvent (kerosene oil) which is then evaporated leaving the preservative behind.

Dry wood does not rot. Furthermore, it does not undergo moisture movement. Therefore, seasoning of timber is necessary to keep its imbibed moisture well below the fibre-saturation point. Air drying though adequate is not effected by many timber producers. Timber seasoning kilns are installed at the factories of Plywood Corporation, Kosgama and Timber Corporation, Ratmalana. A recent addition to this field is a solar timber seasoning kiln introduced by the NBRO at the BMMC woodworking complex, Dankotuwa.

3.1.2 Bamboo

Frequently the supporting frame of both wall and roof of a rural village house of the wattle and daub type is built of bamboo. The strength of bamboo makes it attractive for scaffolding. Strength properties of bamboo vary with species, growing conditions, position within the culm, moisture content and other

variables. Some properties (17) of Sri Lankan yellow bamboo (Bamboosa Vulgaris) are given below.

Modulus of rupture (static bending)	-	1010 Kg/cm^2
Modulus of elasticity	-	1.25×10^5 Kg/cm^2
Specific gravity	-	0.6

One of the limitatons in the use of bamboo for housing is its susceptibility to decay, caused by fungi and to attack by insects.

Research was directed by the B.R.I. of the S.E.C. in 1980 to use split bamboo in the construction of plywood doors and panels. The availability of bamboo needs to be considered before any attempt is made to widen its use.

3.2 Materials for Roof Cover

3.2.1 Clay tiles

The traditional hand-made half-round tile has almost fully been replaced by the calicut or mangalore tile. The flat interlocking calicut tile was first introduced to Sri Lanka by the British in the 19th century (18). The mechanised tile industry has a widespread base than the mechanised brick industry. However, it is more concentrated around the sedimentary clay deposits of Kelani Ganga and Maha-oya. The flat burnt tile characteristic of Dutch architecture failed to gain popularity probably because of the heavier roof structure it requires as is the case with the half-round tile.

SLS 2:1975 specifies the following requirements for the calicut or Mangalore pattern clay tiles.

(a). General requirements - nibs
- cross-section

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

(b). Dimensions - length
- width
- weight

(c). Mechanical and physical characteristics -limiting criteria:
- transverse strength (breaking load) Average of six tiles shall not be less than 1KN.

- Water absorption Average of six tiles shall not be more than 18%.

- permeability
- shall show no traces of droplets.

3.2.2 Asbestos - cement sheets

Asbestos - cement sheets for roofing are manufactured by two companies using imported asbestos fibre. There are no restrictions on the manufacture and use of products based on white asbestos in Sri Lanka although some concern was raised by the Central Environmental Authority on the use fo blue asbestos fibre. The popularity of asbestos roofing is founded on the fact that the supporting timber structure is comparatively less expensive. Gradually increasing costs of timber and cement coupled with an awareness of the health hazards of asbestos are expected to reverse this trend. The use of glass and plastics fibres to substitute asbestos is becoming increasingly common in advanced countries.

In the manufacture of asbestos sheets, a mixture of portland cement and asbestos fibre is wetted and pressed into a flat or corrugated sheet. The commonly used sheet has dimensions -3000 mm x 1090 mm x 6 mm.

The limiting requirements covered by SLS 9:1988 Specifications for asbestos - cement products include:

(a). Breaking load - 5KN/m^3
(b). Density - 1200 Kg/m^3
(c). Water absorption - 28% of dry mass
(d). Water tightness - no formation of drops
(e). Resistance to acidified water - 1.15 Kg/m^3

3.2.3 Thatch

Cadjan constitutes (42.6%) the principal roofing material used in vast majority of rural houses. Straw and palmyrah thatching have been used in 4.1% and 1.6% houses respectively (1). The availability of cadjan, its affordability, and the available skill make it an imperative roofing material which is not likely to be substituted in the near future.

The main problem with thatched roofing is its poor durability and susceptibilty to fire. Application of a bituminous/cow-dung/soil coating to improve these properties was carried out on an experimental scale both at the IDB and NBRO. The formulations were based on trials conducted at the CBRI, India. The economics of application, however, was not attractive.

3.2.4 Other types of roofing sheets

A variety of roofing sheets of the following material categories are available as imported products.

(a). Plastics
(b). Bitumin
(c). Zinc-aluminium
(d). Fibre glass

These materials find ready entry to the local market since no evaluation procedures are recommended to assess their performance.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

Evaluation criteria generally used for the roofing sheets include the following.

(a). Strength	- Flexure test for all materials. Puncture test for thin sheets.
(b). Durability	- Resistance to acidified water for metal or coated metal sheets. Resistance to appropriate chemical in the case of other sheets. Resistance to ultra violet rays, resistance to heat and alternate wetting and drying tests applicable to plastics, bituminous materials and fibre glass.
(c). Fire	- Flame spread and ignition time.
(d). Water permeability	- can be a test for most materials.
(e). Composition and coating thickness	- important for coated metal sheets.

CHAPTER 4

BUILDING COMPONENTS

4.1 Structural Steel

The most common types of structural steel used in Sri Lanka are plain round mild-steel bars and cold worked deformed steel bars. Only the latter is covered by the current Sri Lanka Standards SLS 375:1988 - Sri Lanka standard specification for cold worked steel bars for the reinforcement of concrete. Plain round mild-steel bars are locally manufactured to comply with the requirements of BS 4449:1988 - Steel bars for the reinforcement of concrete. Nevertheless mild steel for general structural purposes where guarnateed yield stress is not critical is covered by SLS 14:1977.

The country's requirements of structural steel are presently fulfilled by the products of the Ceylon Steel Corporation and a few local enterprises and also by imported bars. Local manufacturers use imported billets as the starting material. The factories are located at Aturugiriya (CSC), Ratmalana and Polgasowita.

Mild - steel bars have a minimum yield - point stress of 250 N/mm^2 and the tensile strength must not be less than the measured yield - point stress plus 10%. In addition they have a minimum elongation of 22%.

Cold worked bars are usually mild-steel bars, the yield stress and tensile strength of which have been increased by cold-working, generally by twisting. Cold worked deformed bars with a higher yield stress than similar mild-steel bars are widely used in Sri Lanka. The yield stress as expressed by the characteristic strength has a minimum specified value of 460 N/mm^2. Minimum elongation is 12%.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

The critical parameters used in the evaluation are strength as indicated above and dimensions. Ductility though important is not considered critical.

4.2 Aluminium Door and Window Frames

These components of extruded aluminium are widely used in high rise and commercial buildings. Evaluation criteria applicable to these are:

(a). Composition	-	standard tests (conventional chemical analysis or atomic absorption spectrometry).
(b). Strength	-	Impact / indentation test
(c). Durability	-	acid resistance test

4.3 Ceramic Components

A range of ceramic building components and accessories such as sanitary appliances, floor and wall tiles are manufactured locally using mainly indigenous raw materials. Ceramic appliances are covered by a series of standard specifications whereas the general requirements for the ceramic material are covered by SLS 229:1986. However, standard specifications for tiles are yet to be formulated.

Ceramic sanitary appliances are manufactured by Lanka Ceramic Limited at its Piliyandala factory. A variety of imported products are also available in the local market. 'Marble' sanitary appliances manufactured locally are in fact a resin-bonded castable mineral product which does not belong to the category of ceremicware. Floor and wall tiles are manufactured mainly for the export market by the subsidiaries of Lanka Ceramic Limited.

One of the basic requirements of ceramic sanitaryware is that the product should be sufficiently vitreous. A low porosity of ceramic body generally below 0.5% ensures negligible moisture ingress in appliances which are generally in constant contact with water. The crazing and cracking present in some used

sanitary appliances is associated with the moisture expansion and release of thermal stresses of imperfectly processed products.

4.4 Glass

Sheet glass for the building industry is imported to Sri Lanka although pure silica sand, the main ingredient in glass making is available at Nattandiya. Acceptability criteria though not considered presently include:

(a). Dimensions and visual observations
(b). Strength - Impact hardness, Modulus of rupture (flexure), Young's modulus, shear modulus and Poisson's ratio.
(c). Light transmission - Diffuse light transmission factor.
(d). Reflectivity of UV/natural light - for coloured glass.

4.5 fibre Glass Water Tanks

General criteria applicable to plastic materials such as

(a). Strength
(b). Durability, and health (hygienic) aspects evaluated by
(c). Testing of water contained in tank for toxicity and
(d). Determining reisitance of synthetic polythene materials to fungi need to be considered in future appraisal of the components.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

CHAPTER 5

RESEARCH AND INFORMATION INFRASTRUCTURE

A number of research institutes in Sri Lanka (NBRO, NERDC, NHDA, IDB, CISIR, National Universities) are active in the field of building material research and related construction technologies. However, effective mechanisms for making research findings available to potential entrepreneurs and other users are inadequate, with the result that a sizable gap exists between research and application.

Some of the important areas of building material research undertaken by these research institutes are summarized below:

(a) Rammed earth

One of the earliest and most appropriate materials on which the research efforts of Sri Lanka were directed in 1950's with the assistance of the Government of Australia is earth. It was made into oblivion due to the overdependence of other construction materials.

(b) Ferrocement

Ferrocement research, particularly in relation to naval applications was in an advanced state in Sri Lanka in early 1970's.

(c) Cement products

Sri Lanka has in the past pioneered the production of some building components such as structural pre-stressed concrete units. Many applications are found in the local construction scene.

(d) Soil stabilization

Although a great deal of work has been undertaken in this area, the inability to provide essential information about the properties and performance characteristics of the material probably undermined the confidence in its use. Nevertheless this material found use in a number of construction projects.

(e) Burnt clay products

The traditional brick industry faces an alarming situation with regard to scarcity of firewood and clay with attendant problems on product quality. A Bull's Trench kiln of new design with a brick moulding machine has been introduced.

(f) Wood and wood-based products

Research on the promotion of increased use of lesser-known timber species and bamboo has been initiated. A prototype solar timber seasoning kiln has been introduced.

(g) Lime

Kiln designs incorporating energy conservation measures have been proposed. Prototype kilns which use dolomite as the raw material are in operation.

(h) Roofing sheets

Two alternative roofing materials developed viz. coir fibre reinforced roofing sheet and doubly curved roofing sheet have not gained popularity.

The new materials and improved techniques for using traditional materials have not caught on sufficiently to justify expectations of achieving self-reliance.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

References

1. Rural housing survey, National Building Research Organisation Monograph, 1984.

2. Marga Publication on Housing, 1976.

3. Bricks - Their origin and the arch, vault and dome in ancient Sri Lankan construction, Roland Silva, Proceedings of the Eleventh International Conference, Association of South Asian Archaeologists, Berlin, 1991.

4. Survey of Building Materials Industry, Ministry of Local Government Housing and Construction, 1980.

5. Ph.D. Thesis. V T L Bogahawatte, University of London, 1989.

6. Small-scale brickmaking, Technology Series, Technical memorandum no. 6, International Labour Office, Geneva, 1984.

7. Study of temperature variations in a conventional brick kiln, N B M Ranatunga and V T L Bogahawatte, Sri Lanka Association for the Advancement of Science Sessional Paper, 1986.

8. Non mechanized brickmaking, V T L Bogahawatte, NBRO Publication 1986.

9. A review of research on structural blockwork in Sri Lanka, S R De S Chandrakeerthy, Proceedings of the Seminar on Structural Blockwork in Buildings, 1991

10. Mineral based industries of Sri lanka, M M J W Herath, 1977.

11. Sinhalayo, Senerat Paranavitana, Second Edition, 1970.

12. Technology in the construction industry in Sri Lanka Historical overview of some aspects, C H De Tissera and F Weerakkody, ICTAD Journal, pp 1-10, Vol. 2, No 1, June 1990.

13. Earth-wall construction, G F Middleton, Bulletin No. 5, Commonwealth Experimental Building Station, Australia, 1952.

14. Rammed earth construction, Building Technology Series, ESCAP Publication, 1984.

15. Timber Technology, Proceedings of the International Conference on Timber Technology, University of Moratuwa, Sri Lanka, 1984.

16. Structural use of local timber with the available limited design information, S R De S Chandrakeerthy, Proceedings of the International Conference on Timber Technology. University of Moratuwa, Sri Lanka, 1984.

17. Physical and mechanical properties of bamboo, V T L Bogahawatte, Industrial Products Research Institute Publication, Tsukuba, Japan, 1981.

18. Aided self-help housing in Sri Lanka, ODA Report, 1980.

Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org

Offset by NARESA Printing Unit
Digitized by Noolaham Foundation.
noolaham.org | aavanaham.org