Chapter 1

INTRODUCTION

1.1 GENERAL

The housing requirement in Sri Lanka is rising due to the growth of population and urbanisation. Due to changes in socio-economic conditions and the living patterns of the society, there is a tendency for every individual family to own a house. Persons of middle income and low income groups have only limited funds at their disposal for house construction.

Majority of the population raise the funds required for house construction through bank loans, generally at around 15% to 20% interest rates with a payback period varying between 10 to 20 years such as those given by National Savings Bank of Sri Lanka. Since the amount of money made available through loans by state and private banks is generally limited to ensure that monthly instalments are within 40 % of the income, the maximum amount of money that can be raised for house construction is also limited. This calls for construction techniques that achieve an better economy in house construction to suit the income of average and low income wage earners.

The cost of housing in Sri Lanka has risen rapidly in the recent past due to many factors, one of which is the shortage of building materials to meet the demand of the building industry (Fernando, 1979). One example is shortage of sand due to excessive sand mining. Another is the non-availability of suitable land for clay mining to produce bricks. A direct consequence of this shortage of materials is the rapid increase in cost of building materials. This therefore calls for an urgent investigation into the possibility of using locally available alternative building materials which can be used to replace the conventional building materials.

The conventional building materials used for house construction in Sri Lanka consist of random rubble for foundations, bricks for walls, reinforced concrete for slabs, sawn timber for roofs and asbestos sheets or clay tiles as roof covering material (Perera, 1992). The finishes applied to the basic structure generally depend on the wealth of the client. Out of these materials, only random rubble masonry appears to have an abundant supply. The following problems can be identified with respect to conventional building materials:

1. Bricks are manufactured in areas where suitable clayey soils are found. Since a large number of rivers originate from the central part of Sri Lanka, brick manufacturing sites are generally located along these rivers. However, in the recent past, excessive clay mining has caused a number of environmental problems such as large clay pits that degraded the buildable lands and caused erosion of soil in the surrounding areas, sometimes associated with lowering of water table (Ranasinghe, 1997).

2. Sand used for cement sand mortar, concrete and plaster work has been in short supply in recent times which led to a detailed study into the determination of alternatives for sand. At present, excessive sand mining in major rivers is causing the saline water intrusion during dry spells which sometimes cause problems with drinking water supplies (Dias et al., 1997).

3. Concrete was used liberally by builders some time ago, but now the tendency is to optimise its usage due to rising costs. It is possible to obtain about 10% reduction in construction cost by using loadbearing brick wall construction instead of reinforced concrete framework in two storey houses (Jayasinghe, 1997). Another area that may warrant further optimisation is in concrete slabs where concrete below the neutral axis only provides durability to steel. Insitu cast reinforced concrete floors also need formwork supported on false work. These are generally out of bamboos and rubber wood; another depleting source of construction materials.

4. The roof framework is out of sawn timber which has become a very scarce material in Sri Lanka due to depleting forest cover. The total forest cover now available in Sri Lanka is only 31.5% (Central Bank Report, 1996). This has led to the importation of a wide variety of timber from other countries which may have a questionable durability record unless properly treated. In the recent past, coconut rafters and purlins have been extremely popular due to low cost and sufficient strength, but this is also becoming scarce due to over exploitation.

5. The widely used roof covering materials are clay tiles and asbestos. Asbestos sheets have been manufactured in Sri Lanka and widely used irrespective of health hazards. Clay tiles suffer from the draw back of excessive requirements of timber for the framework (Somadasa & De Silva, 1996).

6. In Sri Lanka, the usual practise is to plaster the external and internal walls with cement, lime and sand plaster. This plastering requires large quantities of sand which is in short supply (Dias et al., 1997).

This clearly shows that there is a significant problem in Sri Lanka with respect to conventional construction materials and practises. In this research work, attention is focused in finding alternative materials for walls, either loadbearing or non-loadbearing and optimising the usage of concrete and reinforcement in floor slabs. There is a considerable scope for further investigations into the development of alternative materials for roof coverings and wall finishes.

When alternative materials are introduced, it is extremely important to pay sufficient attention to safety. However, it should be noted that it is not possible to achieve absolute safety, since there is always a small possibility for failures to occur. In construction engineering, these are many uncertainties, and five such main sources have been identified as those in calculation models, design parameters, material properties, construction use and maintenance of structure (Thorburn, 1997).

In this research, emphasis was to address the performance of alternative materials with respect to above five areas. In order to ensure adequate safety, the structures using these alternative materials should be designed to be robust, which is its capability to withstand some misuse and to tolerate accidental damage without catastrophic consequences. Attention was also focused on achieving this objective in economical and practical ways.

1.2 OBJECTIVES

The main objectives of the research work presented in this thesis is

> *to find suitable cost effective, environmentally friendly alternative building materials and systems that can be used for residential buildings, which are as strong and durable as the conventional building materials.*

For the loadbearing and non-loadbearing walls of residential buildings, cement stabilised soil blocks are introduced. For the floor slabs of multi-storey buildings, a more efficient and economical composite reinforced concrete precast slab system is introduced.

Thus the objectives can be described briefly as follows:

<u>Cement stabilised soil blocks for loadbearing and non loadbearing walls:</u> Laterite soil is found few centimetres below the organic top soil in most parts of Sri Lanka. Laterite soil is an ideal material for stabilisation with cement. The stabilised soil can be used to make blocks using a suitable block making machine. However, the use of these blocks as a building material is yet to find wide acceptance due to inadequate data on the strength and durability characteristics. In order to popularise this as a loadbearing material for residential buildings in Sri Lanka, a detailed study was carried out with the following as sub-objectives:

1. to select an appropriate machine that can be used to manufacture cement stabilised soil blocks suitable for loadbearing construction

2. to find design parameters that can be used for structural design purposes of cement stabilised soil block loadbearing walls,

3. to find the construction practices that need to be followed to achieve the required strengths and durability,

4. to develop design guidelines that can be used at the initial layout planning stage with cement stabilised soil blocks, and

5. to find cost implications of using cement stabilised soil blocks as a loadbearing material.

Composite reinforced concrete beam slab systems: In Sri Lanka, reinforced concrete solid slabs are used for the upper floors of residential buildings. The majority of floor slabs constructed in Sri Lanka are of insitu cast reinforced concrete. These solid slab systems are not very efficient structurally since a considerable depth is required to control the deflections. In recent times, precast prestressed concrete composite slab systems also have been introduced, which need less formwork but need sophisticated factory conditions for manufacturing of precast components. Since the timber used for false work is in short supply, it would be quite useful to develop a slab system that can be cast with minimum formwork and falsework. The ability to precast the components at site may also be useful in reducing the costs. Thus, the sub-objectives of the research work carried out to develop an alternative slab system can be presented as follows:

1. to develop a simple slab system which can be cast with minimum usage of formwork, falsework and skilled labour, and also optimises the usage of concrete and steel,

2. to determine the actual behaviour of such a slab system under service and ultimate conditions by constructing full scale models and load testing them,

3. to determine whether such slab systems can be designed using the standard methods such as those given in BS 8110 : Part 1: 1985, and

4. to determine the cost implications of using such a slab system by carrying out a detailed cost study.

1.3 METHODOLOGY

When alternative building materials are introduced, it is necessary to give comprehensive details on manufacturing processes, design data, design methodologies and construction practices. In order to fulfil the above requirements, comprehensive experimental and design studies have been carried out for the alternative building materials and systems introduced in Section 1.2. The details are as follows:

Methodology for cement stabilised soil blocks: When cement soil blocks are used as a loadbearing material, those structures should be designed. For structural design purposes, the design guidelines, material strengths and methods of achieving such strengths in practice, should be established. It is also necessary to show that it is a cost effective material when used for loadbearing construction. Thus, the methodology adopted can be presented as follows:

1. A detailed literature review was carried out to determine the block making practices, design data and construction practices that could be adopted for Sri Lanka.

2. In order to determine the design strengths for cement stabilised laterite soil blocks, a comprehensive experimental programme involving testing of individual blocks and panels made with these blocks was carried out. In order to identify suitable soil types, laterite soils with different fines contents were used. Cement contents were also varied to find the optimum cement percentages.

3. A detailed design study was also carried out to show that cement stabilised soil blocks can be used as a loadbearing material. This design study was also used to develop guidelines that can be used at the preliminary design stage of residential buildings.

4. The experimental data was also used to determine the quality controlling practices that can be adopted during construction.

5. Detailed cost studies were also carried out to determine the cost effectiveness of cement stabilised soil blocks.

Methodology for composite precast reinforced concrete beam slab systems: Reinforced concrete is a traditional building material used for floor slabs of residential buildings. In order to optimise its usage, a beam slab construction was considered since the slab thickness can be reduced considerably from those required for solid slabs. Precasting of components was introduced to minimise the use of formwork and falsework. The methodology adopted for developing the precast beam slab system can be presented as follows:

1. A detailed literature review was carried out to determine the alternative slab systems that could be adopted for Sri Lanka. A composite precast reinforced concrete beam slab system was selected for further development.

2. This composite beam slab system was designed in accordance with BS 8110 : Part 1 : 1985. In order to show that the precast components designed in accordance with the guidelines given in BS 8110 : Part 1 : 1985 would behave satisfactorily, a full scale load test was carried out. Since all the precast components were connected with insitu concrete, it was necessary to show that those components would not disintegrate until reaching the design ultimate loads.

3. Since the load sharing characteristics of precast panels connected with insitu concrete were required for structural design of individual precast panels, load tests were carried out on slabs formed by connecting precast panels. The results of these load tests were analysed to provide design guidelines for the structural design purposes.

4. A detailed cost study was also carried out to determine the cost effectiveness of this alternative slab system.

1.4 MAIN FINDINGS

Since two areas were covered in the research work presented in this thesis, the main findings are presented separately.

1.4.1 Main findings for cement stabilised soil blocks

The following can be presented as the main findings for cement stabilised soil blocks.

1. It was shown that cement stabilised soil blocks manufactured using a manually operated machine with a minimum compaction ratio of 1.65 can develop sufficient strength for loadbearing construction.

2. On the basis of the experimental study, it is shown that 240 mm thick blocks manufactured with 6% cement and soil containing fines less than 30% can be used for loadbearing wall construction. Such block walls constructed with 1:6 cement sand mortar can develop a characteristic wall strength in excess of 0.9 N/mm^2. Such block walls constructed with blocks containing 4% cement can develop a characteristic wall strength in excess of 0.85 N/mm^2.

3. On the basis of the design study, it can be stated that blocks of size 240 mm x 240 mm x 90 mm manufactured using a soil containing fines less than 30% and with a cement content of 6% can be used for the ground floor of properly planned residential buildings. In this context, the most important dimension is the thickness of the wall, where 240 mm can be recommended as the minimum thickness for the ground floor walls. For the upper part of the ground floor load bearing walls, it is possible to use blocks containing 4% cement as well.

4. It was also shown that 290 mm x 140 mm x 90 mm blocks giving a wall thickness of 140 mm can be successfully used in the upper floors of residential buildings with 2% or 4% cement contents.

5. It is reasonable to expect minor variations of fines content and cement content when manufacturing the cement stabilised soil blocks using laterite soils. It was shown that such variation would have a minimum effect on the structural performance of the block walls.

6. It is necessary to have sufficient quality controlling when cement stabilised soil blocks are used as a loadbearing material. Bend testing of blocks was introduced

as a quality controlling measure by developing relationships between the bend test of blocks and compressive strength of walls. This bend test can be used for quality controlling instead of determining compressive strength of blocks and wall panels since bend test can be determined with simple equipment that can be provided with the machine whereas compressive strengths have to be determined using compression testing machines at a testing laboratory.

7. Careful curing of blocks would be extremely useful during the manufacturing of blocks since it could improve the compressive strength. Hence, proper curing of blocks was recommended as a good construction practice for cement stabilised soil blocks.

8. It was shown that cement stabilised soil blocks could be a cost effective alternative to loadbearing brickwork. These can also be used in non-loadbearing walls.

1.4.2 Main findings for precast beam slab system

The following can be presented as the main findings for the composite reinforced concrete beam slab system.

1. On the basis of experimental programme, it was shown that the design guidelines given in BS 8110 : Part 1 : 1985 could be used for the structural design of the composite slab system consisting of precast beams and slabs connected by insitu cast concrete. This is of significant advantage since a similar slab system can now be designed for other superimposed dead and imposed load intensities as well.

2. The construction techniques and concrete mixes that could successfully be used for the construction of the proposed beam slab system were also found.

3. On the basis of the cost study, it was shown that the proposed composite reinforced concrete precast beam slab system can give a cost saving in the order of 50% when compared with conventional solid slabs.

1.5 ARRANGEMENT OF THE THESIS

Chapter 2 of the thesis gives a detailed literature review on the cement stabilised soil blocks and the alternative floor slab systems.

Chapter 3 presents the details of the experimental research study carried out to determine the suitability of cement stabilised soil blocks for loadbearing construction. The characteristic strengths that can be used for design purposes are also presented. The methods required to maintain the quality of construction for the successful application of limit state design philosophy are also highlighted.

Chapter 4 covers the detailed design and experimental research programme carried out for an alternative precast beam slab system that can be used with loadbearing cement stabilised soil block walls. The details required for structural design purposes such as composite behaviour of precast components connected with insitu concrete, load sharing characteristics of precast slab panels connected with insitu cast concrete and the dynamic characteristics of the composite slab system are provided.

Chapter 5 presents a detailed design study carried out to determine the suitability of cement stabilised soil blockwork for loadbearing construction. The design data presented in Chapters 3 and 4 are used for the design calculations.

Chapter 6 gives a detailed cost study carried out for cement stabilised soil blocks and the composite beam slab systems to show the cost effectiveness of the alternative building materials and methods.

Chapter 7 includes the general conclusions with respect to adopting cement stabilised soil block construction and precast reinforced concrete composite beam slab systems for Sri Lanka. A brief account is given for future work on the basis of experience gained in this project.