Use of Modern Techniques in Precast Housing with special reference to Ceylon

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Summary
This paper describes the need to evolve new techniques to meet the challenging problem of satisfying the ever growing demand for housing in this country. Some typical techniques applied in other countries are outlined in order to enable a comparison with the precast systems adopted by the State Engineering Corporation in the Housing Scheme at Naraheni.

The Housing Problem
Building construction industry till recently had been the least developed of the production industries partly due to the slow evolution of the building technology and partly due to the social barriers imposed by traditional patterns of living.

In most societies living patterns have been largely dictated to by social and cultural traditions which were so in-grained in the society that effecting any changes was quite difficult. In Ceylon which is predominantly an Agricultural Country houses are often distributed over a very wide area consuming a considerable amount of cultivable land. Fragmentation of land has proceeded without attention to urban requirements for development and generally the standard of housing has been very low, even though the society has clung to these traditional patterns fervently. Under such conditions, provision of social amenities and modern services has been extremely costly which in turn has pushed the overall cost of housing higher and higher. The growth in urban population around industrial and commercial nuclei with little regard for urban planning has tended to create considerable social problems. For example, the spectable of sub-standard dwellings and slums around the major towns has been a major problem over the recent years. Investigations conducted about six years back show that these problems are quite wide spread and growing rapidly. The following table shows the requirements of urban as well as rural housing at the time of these investigations and their anticipated growth over the next ten years.
TABLE I

<table>
<thead>
<tr>
<th>Habitable dwellings</th>
<th>Available Housing Units in 1962</th>
<th>Housing shortage in 1962</th>
<th>Housing shortage in 1972</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Colombo</td>
<td>38,959</td>
<td>35,327</td>
<td>61,290</td>
</tr>
<tr>
<td>Urban areas in Colombo region</td>
<td>27,862</td>
<td>22,838</td>
<td>40,500</td>
</tr>
<tr>
<td>Other urban areas</td>
<td>63,092</td>
<td>62,358</td>
<td>105,700</td>
</tr>
<tr>
<td>Rural areas</td>
<td>1,536,900</td>
<td>169,511</td>
<td>738,400</td>
</tr>
</tbody>
</table>

(Report of the Special Committee on Housing—May, 1963).

Considering the economic, social and technological development of this Country, meeting a demand of this nature in one sector of the economy would call forth for the greatest ingenuity in planning for the co-ordination of all resources available as well as bringing forth revolutionary changes in the social attitudes towards planning. According to this report itself, the requirements of capital to meet this demand over the ten years 1962-1972 is of the nature of 3,000 million rupees, or 30 million rupees a year.

Considering that the demand for better housing is directly related to the economic development and sociological change in the habits, attitudes and desires of the general population, it may be added that under the present circumstances if half the above demand could be met with, the acute demand for housing as it exists today will be overcome. Looking back over the achievements of the last few years, reaching the targets that have been set seems to be almost unthinkable by the methods that have been adopted so far.

Concentrating our attention to the engineering aspects of the problem the main tasks that are being faced with are (1) to find ways and means of procuring the materials required for house building in such a big scale. (2) The evaluation of techniques which will produce adequate numbers of housing units in stipulated time intervals. (3) Training of skilled labour to undertake the house construction.

Development of Local Materials and Equipment

Traditionally Ceylon has been extremely backward in the adoption and development of suitable local raw materials required by the construction industry on scales large enough to meet the demand. Even today, about half of the requirements of cement is being imported at a considerable expense in foreign exchange. Even cement that is being produced in this country has been found to be quite expensive as compared to its cost in most of the developed countries. For example, the cost of cement in this
country is about Rs. 12/- per cwt. as compared to a price of
Rs. 2.50 per cwt. in U.K. Rolling of steel has been undertaken
only recently and even then the progress with its manufacture
has been delayed for various reasons thus making the available
products quite expensive. Similarly the other basic raw materials
required for the building construction industry such as Sheet
Glass, Steel Plates, Steel Sections, Prestressing Wire etc., have
yet to be imported. The nett result of an industrial policy of this
nature has been to push the cost of production higher and higher.

In the development of local raw materials it would be quite
necessary to attract the attention of local industry to the need for
a co-ordinated plan for development of suitable materials to
replace imported materials and in addition wherever possible
to replace imported equipment that are being used in the process
of manufacture and processing of the raw materials itself.

For example, apart from cement, the major items involved in
concrete work are metal and sand. It is unfortunate that these
materials which are usually produced locally, are not available
freely as there is no suitable organisation to meet the demand
adequately. As small scale suppliers using traditional methods
often fail to meet increased targets it is vital that either the public
or private sector must take to the supply of such essential items
to sustain an adequate level of growth in the construction industry.

As far as construction equipment and plant are concerned,
almost all these items are being imported now making the use of
machinery almost prohibitive. Lately this has been found to be
one of the greatest impediments to the development of new
techniques in construction and increasing the speed of construc-
tion. Wherever local machinery has been developed either to
take the place of imported equipment or to fulfil new demands
it has been found that such equipment are quite comparable to
the imported items which proves the potential of the local industry
in the heavy engineering sector. Even here the most significant
bottleneck has been the shortage of primarily raw materials
such as processed steel sections, steel plates and suitable high
grade metals required by modern industry. If the building industry
is to catch up with the growing demand for new and better
buildings, it is quite vital that the interrelated industrial sectors
are suitably co-ordinated so that most of the bottlenecks that
are being faced by the industry could be overcome.

Development of New Techniques

The most significant development in the building industry
over the recent years has been the evolution of systems construction
largely based on precast concrete. Standardisation of building
components, continuous production systems for standard items
and rapid methods of assembly have reduced the cost of erection
per unit of dwelling appreciably.
Precast concrete construction based on a centralised factory system of production for components has been found to be conducive under the following conditions, where

1. A high speed of construction is required.
2. Standardisation of components is possible with scope for repetition on a large scale.
3. Mechanisation of construction is feasible and desirable.
4. Weather and other natural factors affecting construction is to be avoided.
5. High degree of quality control is desirable, thus economising on design and use of materials.
6. Skilled labour is not available in large numbers.
7. Labour costs are high and expected labour productivity is high.
8. Light weight aggregates are used in the building elements.
9. Density of construction is high with reduced cost on transport and shifting of plant and equipment.
10. Regular production at a rate of 500-3000 dwelling units per year can be guaranteed with in the economic periphery of the factory.

Training of Labour

In spite of a high degree of general education, training of skilled labour has been slow in this country due to the poor organisation and slow growth rate of the field of technical education. Vocational training both at school level and at the level of special trade schools is required immediately to train adequate numbers of workmen. The shortage of technical teachers who can conduct such courses has been a problem which has yet to be solved. In other countries where such problems have been singled out crash programmes of training to meet the immediate demand, and suitable long term provisions for future needs have been successfully adopted. Expanded apprentice schemes such as those sponsored by the State Engineering Corporation to supplement the output from the regular sources are to be encouraged.

Modular Standardisation

Mass production of the building process can only be achieved with a high degree of standardisation. To achieve the best results, the manufacturer of Precast Concrete Elements must produce units in sufficiently long runs of continuous mass production. Such production will give the minimum cost to the article produced. The various component parts of the building so produced will arrive at the building site ready for erection. If these elements are to be assembled in some pattern, there should be co-ordination in their dimensions. It is always possible to maintain a simple dimensional relationship by means of a basic unit called "the module" popularly known as modular co-ordination. This
module is internationally established as 10 cm, where the metric system is used, and 4" for others.

Such component parts produced according to modular standardisation should be available for sale to prospective house builders from stock.

If this system of modular co-ordination is to be successful, the consumer's demand for variety must be balanced by the manufacturer's desire for minimising variants. If properly handled by a systematic study of the real needs of variety in combination with a systematic selection of the variants, it will bring about solutions which will satisfy all reasonable needs for variety.

Some Typical Foreign Systems

Most precast systems are evolved around local requirements based on locally available raw materials and social demand. They differ largely in the sizes of units that are being handled in one piece. The larger the unit, that is being precast, the smaller the amount of work to be done at the site of erection and the consequent wet concrete work.

During the thirties and forties considerable headway has been made in precast concrete construction in the Soviet Union. Some of these developments have been outlined in a paper submitted to this institution by Mr. D. G. Atukorale and Mr. M. L. Perera in 1961. During the last two decades most of the Western European Countries have consistently applied precast methods to accelerate the rate of construction and to introduce mechanisation to the construction industry. Today over a large number of patented precast systems are available in these countries and are generally referred to as Systems Construction. By and large these systems are based (1) on development of more and more efficient systems of precasting building components under controlled factory conditions (2) erecting of these units at sites with ease and speed. In most production factories a high degree of quality control and precision in casting is attained as in most of these plants casting and curing of concrete are carried out under controlled environments using a high degree of mechanisation. The size and shape of units are largely dependent on the capacity of the handling equipment available.

Russian Monolithic Box System

In the Soviet Union where development of equipment for precast construction has been evolved over a longer period, large handling plants have been developed so that in some of the Soviet Systems, the size of the units handled can weigh up to 29 tons. In the Russian Monolithic Box System the standard units consists of 33'10" × 10'5" × 8'11" completely fitted with built-in services, all assembly work being carried out in factories using sophisticated equipment, see Fig. (1) and (2).
A plan of a typical flat

FIG. 1. RUSSIAN MONOLITHIC BOX SYSTEM

A typical monolithic box unit

FIG. 2. FACTORY LAYOUT FOR RUSSIAN MONOLITHIC BOX SYSTEM

It has been reported that the time taken for casting and assembly of a unit such as above is about 9 hours, 65 to 67% of the total work is being carried out in the factory. The labour consumed for construction of these units are of the order of about 4 man hours per cubic meter of flat space. In a typical erection of blocks of flats using the Monolythic Box System it has been found that the average rate achieved is about 1 1/2 months to do the preperatory work at site and further 1 1/2 months for a block of 45 flats consisting of 75 Monolythic Box Units using one labour gang and a crane.
In general it has been found that in less developed countries it is preferable to consider units of smaller size limiting the maximum weight of a unit to about 2 tons. In British and Danish Systems the maximum size of the units are kept to about 2½ Tons. It has also been found that in smaller units of this nature a higher degree of precision could be attained while the smaller units are also easily amenable for architectural variations.

**Jesperson System**

In the Danish Jespersen system the basic module for wall and floor units is 30 c.m. This has enabled considerable standardisation in the components thus simplifying casting and erection. For example, in multistorey flat construction using this system it has been found that only 8 different types of walling units are required in all (see Fig. 3). In a typical factory (Fig. 4) producing these items it has been found that a labour force of 15 could turn out 4 flats per shift or 10 flats in 3 shifts over 24 hours, each flat consisting of 4 rooms with a total area of 50 sq. meters. These units are assembled at sites using a 5 ton crane. The floor units are placed directly over the wall units using dry joints.

In one of the large schemes consisting of 3500 flats the reported rate of erection that has been achieved has been about 16 flats a week with a working gang of 29 men and 2 cranes.

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**Fig. 3. Jespersen System Precast Elements**

<table>
<thead>
<tr>
<th>WALL ELEMENTS</th>
<th>FLOOR ELEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 cm</td>
<td>120 cm</td>
</tr>
<tr>
<td>Electrical outlets</td>
<td></td>
</tr>
<tr>
<td>180 cm</td>
<td>180 cm</td>
</tr>
<tr>
<td>210 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 cores</td>
</tr>
<tr>
<td></td>
<td>5 cores</td>
</tr>
<tr>
<td></td>
<td>5 cores</td>
</tr>
<tr>
<td></td>
<td>6 cores</td>
</tr>
</tbody>
</table>
S.E.C. Panel System

The first large scale multistorey precast system in Ceylon is for a set of 800 flats at the Housing site at Narahenpita. They consist of 20 blocks each block consisting of 40 flats of 930 sq. ft. each. The flats are arranged in units of 10 flats in each block per floor. The lay out of the flats is shown in figure (6).

The precast factory shown in figure (5) has been laid out for the construction of 500 flats a year, as it was expected that this site was ideally suited for the development of this area of Colombo. The main sections in the factory consist of a prestressed bed 400' x 60', moving shutter track and Trolley System for Wall Panels, a 5 Ton Tower Crane, ancillary workshop, material storage and office space. Most of the basic equipment that is required in this yard have been developed and assembled in the Corporation workshops. A boiler house has been incorporated into this scheme in order to provide a constant supply of steam for the curing of concrete. Two concrete weigh batching plants have been provided, one to cater to high strength concrete for prestressed concrete floor slabs and the other to cater to lean concrete for wall panels.

The basic floor units for the flats consisted of 8" core slabs which are cast using a continuous extrusion machine moving on steel rails. See Fig. (7). The slabs are of a standard width of 4' the lengths of which could be varied as required by merely separating the concrete at required sections. The rate of casting of slabs has been about 8 sq. ft. per minute. These slabs are cured.
by passing steam under steam jackets for 4 to 6 hours. When
the strength of the concrete is about 3000 p.s.i., the wires are
detensioned and the slabs separated and removed to the stacking
yard. The concrete mix used in these slabs was 1 : 1.75 : 3.5 with
a water cement ratio of 0.35 and a maximum size of aggregate
3/8". Careful control of the concrete mix was essential to prevent
the collapse of the cores formed by the extruder. Table (2) shows
the labour and cost analysis of casting, handling and transport
of these floor slabs.

In all there are 21 different types of wall panels used in these
flats, of which 16 Nos. are 6" thick designed to act as load bearing
walls and the others 4" thick to serve as partition walls. Details
of these walls are provided in Fig. 9. The wall panels are cast
in a horizontal position with steel shutters mounted on moving
trolleys, which are pushed to each of the working bays manually.
The mix used was 1 : 3 : 6 with a water cement ration of 0.5 with
the maximum size of aggregate 3/4". The concrete from the
mixer is transported to the concreting bay by pneumatically
operated skips. The concrete is vibrated using shutter vibrators.
BATTERY MOULD FOR CASTING WALL PANELS PRECAST YARD, NARAHENPITA
attached to the sides of the moving trolleys. Panels are cured using steam jackets for 6 to 8 hours. Immediately after steam curing the upper side of the panels are given a 1/2" Gement Mortar rendering. Panels are removed on a tilting table using an overhead 6 Ton Gantry Crane. The maximum rate of casting achieved was 63 panels a day spread over 3 shifts.

A set of battery moulds have been installed subsequently to increase the rate of production of wall panels. Each of these moulds consists of 2 sections to cast 2 panels side by side, which are cured by passing steam through jackets built into the shutters. The cycle time for the battery mould was about 6 hours as compared to the cycle time of 9 hours for the moving shutter.

Wall panels are transported to the erection site which is about 400 yds. away in specially designed trailers capable of transporting 2 panels at a time. The panels are erected in position and jointed together by welding steel inserts. These joints which are 6" wide are filled in with in situ concrete. The rate of erection achieved was 25 panels or one flat every 8 hour shift using a gang of 33 men and one crane. However, provided favourable working conditions can be maintained with no machine break downs or shortages of materials the above rate could be easily doubled.

The floor slabs are placed directly on the wall panels and gaps between slabs and wall panels are filled with dry motor packing. Gaps between floor slabs are filled up during subsequent screeding and finishing. In addition to the above standard items which are cast at the precast factory other units such as concrete staircases, concrete roof beams, prestressed concrete purlins are cast either at the site or at the precast yard as and when required.

A complete labour and cost analysis of the casting and erection of these flats is given in tables (2) and (3).
CONSTRUCTION DETAILS, NATIONAL HOUSING SCHEME, NARAHENPITA
TABLE II

Labour and Plant involved in Precast Work

<table>
<thead>
<tr>
<th>Item</th>
<th>Labour in man hours per square</th>
<th>Plant hire charge per square in Rs. cts.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casting 6&quot; Wall Panels</td>
<td>55.5</td>
<td>9.70</td>
</tr>
<tr>
<td>Handling and Transporting 6&quot; Wall Panels</td>
<td>8.2</td>
<td>35.00</td>
</tr>
<tr>
<td>Erection of 6&quot; Wall Panels</td>
<td>35.5</td>
<td>47.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99.2</strong></td>
<td><strong>91.70</strong></td>
</tr>
<tr>
<td>Casting 4&quot; Wall Panels</td>
<td>44.5</td>
<td>4.60</td>
</tr>
<tr>
<td>Handling and Transporting of 4&quot; Panels</td>
<td>6.6</td>
<td>28.00</td>
</tr>
<tr>
<td>Erection of 4&quot; Wall Panels</td>
<td>24.0</td>
<td>31.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>75.1</strong></td>
<td><strong>64.10</strong></td>
</tr>
<tr>
<td>Casting Core Floor Slabs</td>
<td>40.0</td>
<td>31.00</td>
</tr>
<tr>
<td>Handling Slabs</td>
<td>4.6</td>
<td>23.50</td>
</tr>
<tr>
<td>Erection of Slabs</td>
<td>12.0</td>
<td>12.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>56.6</strong></td>
<td><strong>67.00</strong></td>
</tr>
</tbody>
</table>

TABLE III

Total Labour Component involved in each Flat

<table>
<thead>
<tr>
<th>Item</th>
<th>Labour in mandays*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skilled</td>
</tr>
<tr>
<td>Casting Panels and Core Floor Units</td>
<td>84</td>
</tr>
<tr>
<td>Transport and Handling</td>
<td>12</td>
</tr>
<tr>
<td>Erection and Handling</td>
<td>6</td>
</tr>
<tr>
<td>Finishes and Joints</td>
<td>19</td>
</tr>
</tbody>
</table>

Total Labour per cubic meter = 2 Mandays.

*A man day refers to a shift of 8 hours.
Acknowledgement
The authors wish to acknowledge with deep gratitude the encouragement and advice given by Mr. A. N. S. Kulasinghe, Chairman, State Engineering Corporation of Ceylon in bringing out this paper. The assistance of Mr. P. C. Fernando and Mr. Galixtus Perera in the preparation of the typed draft is greatly appreciated.

Reference
4. Precast Concrete in the Soviet Union. N. Kvisnky.
FIG. 6 WALL ELEMENTS IN SEC PANEL SYSTEM