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By

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INTRODUCTION

The need for low cost construction in India need not be over-emphasised, as it is well known, that every family should have at least a minimum dwelling place within its means. Moreover, it is necessary that public places like hospitals, offices and school buildings are constructed in an economical way in the larger interests of the country. The industrial development of India has led to the use of mechanised methods (5, 19)[2] for reducing the overall cost of construction. The various methods adopted for achieving sizeable cost reduction of structures in India can be grouped under the following major heads:

a. Advanced Planning and Programming

b. Execution and Management of Works

c. Research and Experimental Construction

Advanced Planning and Programming

This adopted for executing urban housing projects efficiently and to ensure that works are completed (3) as per schedule. Moreover, the projects are phased (10) to limit the investment of man power, material, plant and equipment. The continuity of works is as far as possible maintained to avoid wastage of labour and locked-up capital.

Residential accommodation is planned to create environments (16) for healthy growth of mind and body. Unwanted passages which result in higher cost are carefully avoided. Planning the residential accommodation to effect waving in land has resulted in considerable economy. Modular planning with central corridor has been introduced for accommodations in urban multistoried flats. Grouping of buildings has been resulted in better lay-outs and compact houses.

Due consideration was also given to the orientation (16) of the buildings. Proper orientation of the buildings taking into account prevailing wind directions and solar paths have eliminated sun-breakers, artificial ventilation, etc.

In India, considerabel attention is being given to space planning. This has led to gradual reduction in plinth areas for various categories of buildings, and in the reduction of room sizes. Due to this built-in furniture in place of loose furniture had to be adopted. Provision, to house essential articles in wall spaces, has resulted in considerable saving in space (23) and has afforded better living conditions.

Modular planning and standarization of building components are being increasingly adopted, as these have resulted in considerable economy in time, material and money. Moreover, for repetitive types of buildings, all aspects of planning, design and construction are studied in detail (in some cases by putting up pronto type construction). To achieve overall economy in the use of materials and to get efficient architectural design, spans, heights and spacings of trusses or portals are standardized.

A saving of nearly 15% of the original estimâte has been achieved (26) by standardizing the sizes of portals and adopting modular architectural planning for a Three-Unit Elementary School Building near Madras. This scheme was evolved by the Structures Department of the College of Engineering, Guindy. A proto type of one unit of this precast building was first erected by the side of the Structural Engineering Laboratory to study the various aspects of its erection and performance during adverse weather conditions. The details of this construction are given elsewhere in this paper.

Rational architectural planning, based on functional, cultural and aesthetic considerations, leads to sizable economy in building construction. A slum clearance scheme (4) at Pondichery (S. India), designed by the Senior Town Planner, Government of Pondichery based on climatic conditions and cultural considerations of the user (mainly fishermen), resulted in a saving of 17.7% of the original estimate.

Urban development and building construction form a major part of the outlay of the Fourth Five Year Plan of India, and economy achieved in construction cost, however small, will result in savings of crores of Rupees.

Execution and Management of Works

The Network Techniques (2) (also called as PERT, CPM and RAMPS) have been recently introduced for building construction projects. These techniques have not yet caught up with the projects executed by petty building contractors and are still in the embryo stage. A few projects have been taken up on experimental basis and it has been found that for conditions prevailing in this country the Network Technique is very rewarding and is an invaluable management tool.

Two major instances of the successful use of these Network Techniques can be cited here. The Critical Path Method was adopted (11) for the construction of Vigyan Bhavan Annexe Building, (a project costing Rs.56 lakhs) for completion within 9 months. The Programme Evaluation Review Technique was adopted (25) for the construction of the 100 MW Thermal Station at Neyveli. The advantages of these Network Techniques, as witnessed by the above case studies, are listed below.

The important benefit derived from these Network Techniques was the logical planning on the part of both the department and the contractors executing the project. Those in charge of the job are posted with a clear idea of what they have to do and when they have to finish the work. In a particular project, the work of laying cables, sewer lines

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(2) Numerals in parentheses refer to corresponding items in Appendix - References.

and water mains were coordinated with the construction of roads to ensure that one agency does not dig up the newly laid road and the road contractors do not hinder the work of others.

It was possible to procure the materials in a systematic way using these Network Techniques. But for PERT, the material procurement could not have been so well controlled as to avoid wastage of labour and dead capital on materials, plant and equipment.

Above all, the Network Technique makes both the departmental officers and the field contractors to keep up to the time schedule. It clearly points out the areas where the job could be effectively expedited. Leading organizations like Neyveli Lignite Corporation, Durgapur Fertilizer Project and Cochin Fertilizer Project are now using these techniques.

Research and Experimental Construction

The research institutes in the field of structural engineering in the country (Central Building Research Institute, Structural Engineering Research Centers, Engineering Colleges and Indian Institute of Technologies) have done useful works which are being felt in achieving economy in construction costs.

It is appropriate at this juncture to say that National Building Organization has done very good work in dissemination of building knowledge and bridges the gap between practice and research. So far 16 experimental projects costing more than Rs.80 lakhs have been sanctioned by the National Building Organization. Apart from the work done by the N.B.O. individual organizations and contractors have on their own executed many projects affecting considerable economy.

The following are the details of a few important projects which have been completed under the experimental housing scheme (22) for urban areas sponsored by the National Building Organization (NBO).

1. Construction of 8 numbers of Type III, Four Storied Quarters at Madras

During the construction of type III quarters at South Madras Neighbourhood by the Central Public Works Department it was observed that the site had low bearing capacity. It was decided to adopt hyperbolic paraboloidal footing for one of the blocks as an experimental measure. The work has been completed successfully leading to about 10% saving in the cost of foundation.

2. Construction of 16 bed hostel by Central Building Research Institute, Roorkee

The following new techniques have been adopted in this building.

a. Use of 400 gauge alkathene sheet over 1/2" thick smooth plaster for damp proof course.

b. Use of brick on edge cavity walls instead of 9" brick walls.

c. Use of precast lintals instead of R.C.C. lintals designed as per triangular load theory.

d. Cellular roof units (7,8) partially precast R.C.C. joists and deck concrete instead of conventional R.C.C. roof.

e. 4" soil cement in the sub-base instead of cement concrete base.

f. Pre-cast concrete frames for doors and windows with fixing arrangements.

3. Construction of a Large Span Building by Structural Engineering Research Center (27), Madras.

The Structural Engineering Research Center has developed a prestressed-precast hyperboloidal roofing unit suitable for roofing large areas in the spans ranging from 30' to 70'. The unit is a segment of a form made by the revolution of one sheet and as a result, the surface can be made up entirely of st. lines. This property has been made use of in pretensioning it along its straight lines. The unit is cast on simple masonry mould. The thickness is 2" to 3" even for spans fo 65'.

An experimental building with such precast prestressed hyperboloidal shell roof has been constructed at Madras (7, 27, 28). Such roofs have been found to be very economical especially in the use of materials.

The following are the details of a few important projects which have been completed by some individual agencies.

4. Pre-Fab, Thin Roof Structure (26) by the College of Engineering, Guindy.

The structure consisted of 54 elements of which 12 elements required for the foundation were cast in-situ and the remaining 42 elements were pre-cast in the Structures Laboratory. The six portals (21), (the main load bearing members) were connected with each other by braces at two levels. Window bars themselves were made to serve as connectors for the precast elements. The roof consisted of weld-mesh of two different sizes. Chicken wire-mesh of size 1/2" x 26G was spread over the weld mesh. This was for the purpose of supporting the wet concrete. The concrete mix used for the roof work was 1:1 1/2:3/0.4 using 3/8" coarse aggregate.

Economy was effected in the form work and shuttering for the various components by precasting technique (18). The cost of moulds was practically negligible as each mould was used 30 times before it wore out.

The formwork and shuttering were completely avoided for the roof. Thickness of the roof was only 2 1/2". The roof was designed as a pure tension member with weld-mesh reinforcement, concrete serving the purpose of cover.

The foundations were provided only for the portals. The side walls were supported by beams connecting the portals.

5. Low Cost, Flat Slab Construction by A. R. Santhakumar (26) et. al.

The columns of the structure were taken 4' below ground level. The ground floor slab was cast at a height of 4' above ground level. The roof slab was cast at a height of 14' above ground level.

The entire structure being framed construction was not only cheap but also structurally efficient.

The space below the floor slab can be effectively utilized for storage, gardening and for children to play.

The structure is damp proof and is free from insect trouble. Further it is easily amenable for future expansion.

6. Low Cost, Integral House by S. Krishna Iyer (Engineering Contractor) (20)

Krishna Iyer has adopted few new techniques to reduce the cost of construction of small houses for low and middle income groups. The new techniques were (a) the change in foundation replacing the conventional massive concrete foundation and brick footing by an R.C.C. raft (b) The reduction of wall thickness to 7" by using a new type of bond (c) Roofing with R.C.C. cavity slabs. With these and a few other techniques, it was found possible to effect reduction in cost of construction by about 30 to 40% as compared with conventional buildings.

Subsequently cost was further reduced by replacing 7" thick brick wall by soil cement blocks of 5 1/2" thick. The roofing was also changed to funicular shells, while other things remained the same.

Recently a new method of constructing an integral type of R.C. house which not only results in reduction of cost but also contributes to the strength to the building, has been evolved. The details of this structure and the advantages of using these techniques are available in the phamphlet published by Krishna Iyer.

7. Low Cost Shell House by Regional Engineering College, Surathkal (29).

A funicular barrel shell roof entirely in compression has been developed and adopted for low cost housing experimental project taken up by the Regional Engineering College, Surathkal. The thickness of the shell roof is only 2". They had adopted certain ICI compounds for improving the weathering properties of the roof. In the experimental project taken up they have shown a saving of nearly 50% over the conventional buildings. The details of this structure are available in the thesis "Wire Mesh Reinforced Barrel Shells" presented by M.T. Venuraju of Regional Engineering College, Surathkal for the Masters Degree in Feb. 1970.

Apart from the above, the following experimental projects (22) are being executed by the various construction agencies under the experimental housing scheme of the National Building Organization.

Sl.No.	Experimental Project	Techniques being adopted
9	Construction of 2 Chowkidars' quarters under the Capital Project Scheme of Bhopal, sponsored by the Chief Engineer, P.W.D.(B&R) Bhopal Madhya Pradesh	a. Precast RCC Chowkhats in place of wooden chowkhats. b. Doubly curved shell roofing with partially pre-fabricated RCC slabs. c. Thin precast RCC lintel
10	Construction of 8 Nos Experimental type II double storied quarters at N.H.VIII, R.K. Puram, New Delhi, sponsored by the Superintending Engineer Circle III, CPWD, New Delhi.	Use of fly-ash to replace cement (9) to the extent of 20% in cement mortar and concrete.
11.	Construction of 10 Nos. of Assistant Professors' Quarters at Patiala sponsored by the Principal, Thapar Institute of Engineering and Technology, Patiala (Punjab)	a. Doubly curved shell roof with partially pre-fabricated R.C.C. slabs. b. Cavity walls having 2 leaves of 3" thick burnt brick masonry in cement mortar with a gap in between. c. Provision of 400 gauge polyethylene sheet over a layer of 1/2" thick cement mortar for damp proof course.
12.	Construction of 32 staff quarters for Hindustan Housing Factory, New Delhi sponsored by the Managing Director, Hindustan Housing Factory, New Delhi.	a. Pocket connections of precast columns with foundation (Russian methc b. Replacement of 15% cement with flyash (9) for R.C.C components c. Prestressed concrete beam d. Roof with prestressed hollow core slab (30) e. R.C.C. frames for doors and windows.
13.	Construction of 992 prefabricated houses under Slum Clearance Scheme of Municipal Corporation of Delhi; sponsored by Delhi Municipal Corporation cum The Hindustan Housing Factory, New Delhi.	a. Partial prefabricated framed structure with precast RCC columns and beams. b. Precast battens and hollow blocks with 2" thick cast-in-situ 1:2:4 cement concrete and nominal reinforcement on top for roofs and floors. c. Prestressed concrete frames for doors and windows.
14.	Construction of 96 type III quarters in six four-storied blocks with 9" load bearing	Four storied construction with 9" load bearing walls using high compressive

	walls in New Delhi; sponsored by the Chief Engineer, C.P.W.D., New Delhi.	strength bricks of 4200 psi in ground floor and ordinary second class bricks in top three floors.
15.	Construction of a building for educational and research facilities for students in Bengal Engineering College, Howrah; sponsored by The Principal, Bengal Engineering College, Howrah (West Bengal).	a. Precast RCC columns with brackets erected and fixed in recesses of RCC footing laid in situ. b. Precast and prestressed beams resting on brackets of the columns. c. First floor slab consisting of composite precast RCC battens and hollow cinder blocks. d. Precast and prestressed folded plate roof. e. Walls of special hollow cinder blocks. f. Hollow beams supporting roof to function as rain water drain also
16.	Construction of 2RA and 2RB type quarters at Keenjhar in Orissa, sponsored by the Chief Engineer (R&B), Govt. of Orissa, Bhuhaneshwar.	Under-reamed pile foundations (single under-reamed and multi under-reamed piles) in black cotton soil, (6,17).
17.	Construction of 10 blocks of CH type double storied quarters in Gandhinagar Township, Gujarat, sponsored by the Chief Engineer, Gujarat Capital Project, Ahmedabad-1.	a. Cavity walls on external side having two vanes of 9 cms each with a cavity of 5 cms in between. b. Hollow precast RCC slab for roofs and floors.
18.	Construction of 5 storied block of 50 residential units with single brick construction of Maniktala work-cum-living center by Calcutta Metropolitan Planning Organization, sponsored by the Commissioner, Development and Planning (T&CP), Department, Govt. of West Bengal, Calcutta-1.	a. Precast ribbed units for floors and roofs. b. 5-storied construction with 10" thick load bearing walls.
19.	Construction of 4-storied block of 16 type III quarters at Dhanlaknan, New Delhi, sponsored by the Engineer in Chief, Army Head Quarters, New Delhi.	a. 9" load bearing wall b. D.P.C. with 400 gauge alkathene c. Precast RCC channel units d. RCC door and window frames e. Replacement of cement by flyash (20%) f. Blending of Badarpur sand with Jamna sand.
20.	Construction of 8 experimental type II quarters in 4-storied block at Santagachi, Calcutta, sponsored by the Chief Engineer C.P.W.D., Calcutta.	a. Use of under-reamed piles (17). b. Use of single brick load bearing wall

The Indian Standards Institution took up the work of preparing the National Building Code (24) as suggested by the Planning Commission to effect economy in construction costs. The work has now been completed. It has been reported (1) by the Director, National Building Code, that during the process of formulation of the Code a number of points have arisen which can themselves be taken as case studies in so far as they have direct bearing on construction costs. A few important cases are enumerated below:

The building Bye-laws in metropolitan cities of the country, reveal wide divergencies with regard to provision of open spaces around and outside the building. The bye-laws generally cover three cases of residential buildings (row housing, semi-detached and detached housing). Hence unification of open space requirements in Building bye-laws of a number of municipal corporations leading to considerable saving in land usage has been incorporated in the National Building Code.

In Indian bye-laws, while dealing with floor area according to fire resistivity, importance has not been given to the type of construction or grading of structure. These aspects have been stressed in the National Building Code (24).

A critical examination of structural design concept in various bye-laws in the country and standards laid down by codes of practices (12,13,14,15) indicated wide variations particularly regarding minimum thickness of brick walls. This has been rationalized by the National Building Code by the inclusion of suitable Nomograms which give the minimum thickness of walls of single and multi-storied buildings for given storey heights.

CONCLUSION

Every effort is being taken up to reduce the cost of construction in India (especially for the major housing schemes envisaged in the Fourth Five Year Plan) by the Government and non-Government organizations. The report presented above strives to explain the various methods and techniques adopted in the Low Cost Housing Projects in India. The work of National Building Organization in promoting the Experimental Housing Schemes for effecting economy in building construction and the efforts taken by the Indian Standards Institution in bringing out the National Building Code to rationalize the methods adopted have been briefly explained.

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