CHAPTER 5

Development and Adoption of Low Cost Housing Technology

Introduction

In recent years, there has been considerable debate over the definition of low cost housing. Without falling into any further debate on the issue, in plain terms, low cost housing may be defined as provision of housing which caters to the minimum requirements of masses within their income capabilities, without sacrificing the quality of construction.

Most of the developing countries in Asia, Africa and Latin America share the problems of poverty, large population growth and acute housing shortage alike. The formidable challenge of providing housing to masses at affordable cost is a colossal task which most of the governments in these countries are hardly in a position to cope with. Meagre economic resources of such countries necessitate adopting appropriate building technology which could lead to economy as well as speed in construction. Prefabrication is the obvious choice to meet the ever-increasing demand of housing in these countries. However, because of the prohibitive initial capital investments, total pre-fabrication does not sound to be a pragmatic proposition in majority of the developing countries. For ensuring speed and economy in construction, the only practical solution to the problem of meeting housing requirements of masses in the present context will be go in for adoption of appropriate low-cost construction techniques involving adoption of partial prefabrication employing the use of prefabricated building components of such size and weight which could be fabricated at construction sites or in industrial production units; economical walling systems and single stack system of plumbing, etc.

Premier R&D institutions engaged in the field of building technology like the Central Building Research Institute (CBRI), Roorkee; the Structural Engineering Research Centre (SERC), Madras; the National Council for Cement and Building Materials (NCB), Ballabhgarh; and the Regional Research Laborataries, etc. have played important role in the development of cost-effective construction techniques and materials. On the other hand, organisations like the National Buildings Organisation (NBO), New Delhi; the Building Materials and Technology Promotion Council (BMTPC), New Delhi; HUDCO, and the national network of Nirmiti Kendras (Building Centres) have been instrumental in the promotion of the innovative construction techniques evolved by the aforesaid research institutions in the country.

Adoption of Innovative Cost-effective Construction Techniques

In order to convert the 'know-how' of the research labs to 'show- how' in the field, and Experimental Housing Scheme was initiated under the aegies of the NBO by the Government of India in 1962. Under the scheme, innovative construction techniques and improved building materials, which were evolved as product of basic and applied research, were tried out under field conditions in prototype experimental buildings for their technical and economic evaluation. Successful techniques were subsequently propagated for wider adoption. Under this scheme, construction departments sponsored projects for putting up of 40 to 50 houses incorporating new technologies, design concepts and materials etc. The NBO provided grant-in-aid to the sponsoring construction departments/agencies upto the extent of 100% of the cost of new construction items. Beneficiaries of the scheme included the Central/State Government Construction Departments, Housing Boards, Technical Universities. Research Institutions, Public Sector undertakings of the Government of India and Semi-Government/Autonomous Bodies have sponsored demonstration projects under the Experimental Scheme. In all, 59 experimental projects were sponsored by as many as 42 construction departments/agencies in different geo-climatic regions of the country in which 60 innovative cost-effective construction techniques and materials were successfully tried out (Annexure I).

Adoption of Precast Elements in Partial Prefabrication

Brief details of some of the popular precast building components, namely, precast RC roofing/flooring elements, precast thin RC lintels, precast RC door and window frames, which have been successfully tried out under the NBO experimental projects and their subsequent large-scale utilisation in several housing projects undertaken by various construction departments/agencies in India, are mentioned below.

Precast Roofing Systems

Roofing accounts for up to 25% of cost of construction of a house. By using precast roofing components, 20 to 30% economy could be achieved in the cost of roof construction. Some of the popular precast roofing/flooring techniques promoted by the NBO, which have manifold advantages of saving in cost, consumption of cement and steel and increased pace of construction, are described below. All these systems make use of components which are fabricated on the ground, ready in all respect for erection in building. In-situ concreting, work is minimised in these systems so that the speed of construction is not affected. The necessity for putting up centering and shuttering as in the case of cast-in-situ reinforced concrete (RC slab completely) is eliminated under these roofing systems. The provision of centering and shuttering is a time-consuming process and elimination of the same leads to considerable saving in erection time.

Precast RC Channel Units

Present channel units (Fig. 5.1 to 5.4) are reinforced concrete structural members which possess a channel or trough shape. The sides of the unit are corrugated and grooved at the ends to provide shear key action between the adjacent units. The nominal width of the units is 300 or 600 mm and the depth is 130 mm. The length of the unit will depend upon the span to be covered and is generally kept between 2.5 m to 4.2 m. The units have a minimum flange/web thickness of 25 mm and weight about 36 kg/m length for a width of 300 mm and about 54 kg/m length for width of 600 mm.

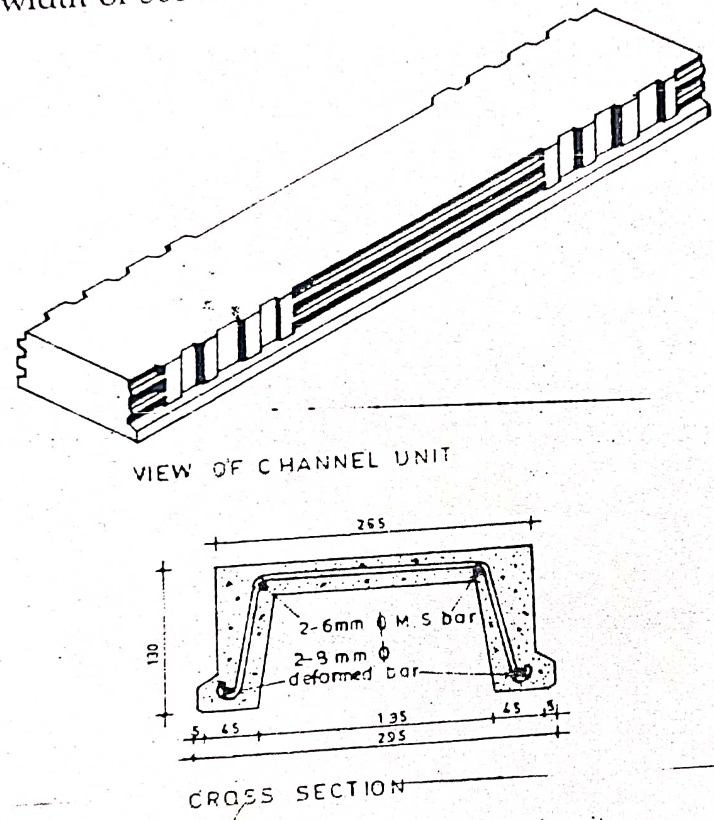


Fig. 5.1 Precast RC channel unit

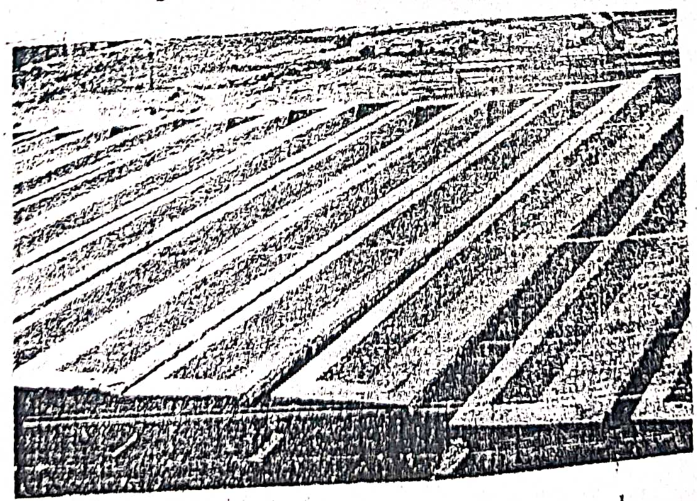


Fig. 5.2 R.C channel units in casting yard

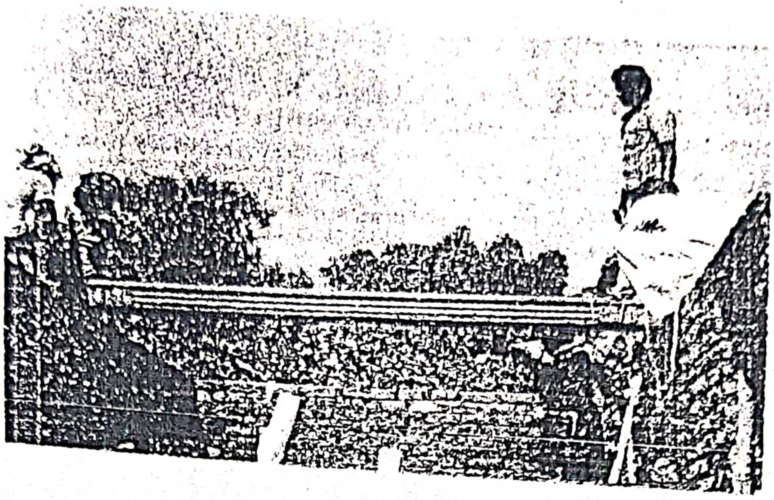


Fig. 5.3 Precast R.C. channel unit being placed in position

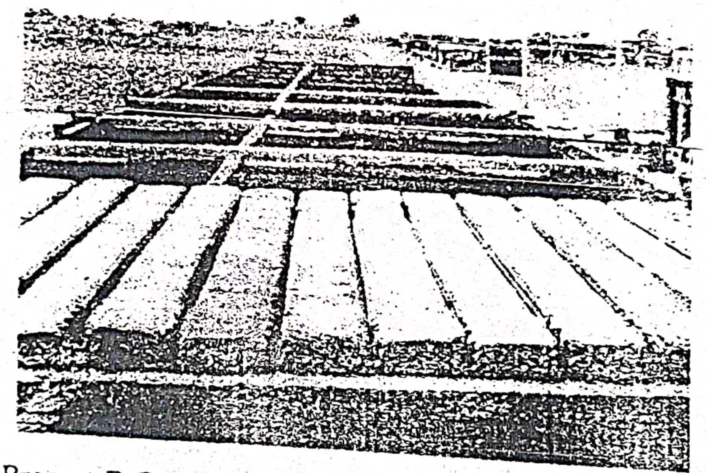


Fig. 5.4 Precast R.C. channel units placed across load-bearing walls

These units are cast in well-seasoned timber moulds with M-15 concrete with 10 mm and down aggregate. The concrete is consolidated using plate vibrator to prevent any honeycombing. The units are cured for 14 days keeping the trough filled with water and then air cured for another 14 days before placing it in position. The units are then placed side by side on the wall and joints are filled with M-15 concrete which is compacted properly. Negative reinforcement is placed in the continuous spans before filling the joints between the units. Electrical conduits, fan hooks, etc., are embedded in the cast-in-situ joint concrete. The system provides an overall saving to the extent of 20% over the traditional RC slab. With this system of roofing, there is as well saving in construction time which is generally of the order of 20%.

Channel units have been adopted in a large number of experimental projects. Construction of 16 type-II quarters for Military Engineering Services (MES) in New Delhi, 200 low cost houses at Neyveli (Tamil Nadu), 198 houses for the Low Income Group (LIG) and 50 houses for the EWS at Faridabad by the Haryana Housing Board, and 20 residential units at

Nagpur by the Western Coalfields Ltd. has been undertaken under the NBO Experimental Housing Scheme. Examples of large-scale utilisation of such units by the Construction Department/agencies in different regions of the country include projects involving construction of 2,000 primary schools in Uttar Pradesh (U.P); 400 staff quarters in Madhya Pradesh by the State P.W.D.; Kendriya Vidyalaya, New Delhi, 304 LIG and 84 EWS houses at Madurai by the Tamil Nadu. Housing Board; 500 MIG and 800 LIG houses at Sheikhpet by the Group Housing Society sponsored by Hyderabad Urban Development Authority (HUDA), and 350 MIG (Middle Income Group) and 730 EWS houses at Velungudi and 124 LIG houses at Palayankattai by the Tamil Nadu Housing Board. Recently, 518 LIG houses have been constructed at Erode (Tamil Nadu) using channel units.

Precast RC Plank and Joist System

This system of roofing (Fig. 5.5 to 5.7) is based on the use of precast RC planks and partially precast RC joists. Planks are 60 mm thick in the centre and 30 mm thick at edges. The size of the planks will depend upon the size of the room. However, the maximum size of the plank is restricted to 1500 mm × 300 mm with 3 number of 6 mm dia. bars as main reinforcement. The planks are placed on partially precast RC joists of size 1500 mm × 150 mm. Cast-in-situ concrete laid over the joists and haunches of the plank after placing 6 mm dia. bars in both directions to make a monolithic structure. Fig. 5.5(b) illustrates connection of precast RC plank and precast brick

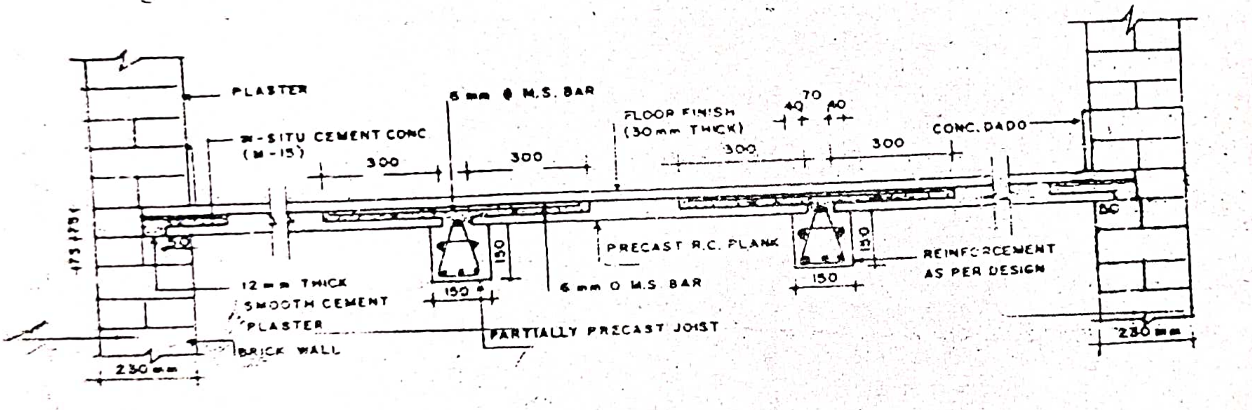


Fig. 5.5(a) Precast RC plank and joist

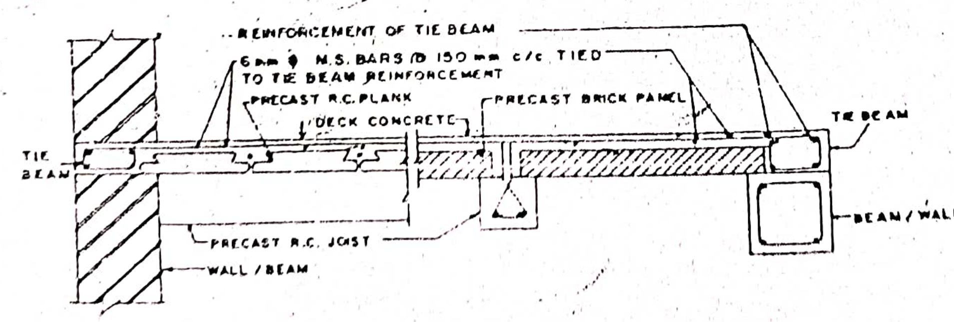


Fig. 5.5(b) Connection of precast RC plank and precast brick panel floor/roof (with deck concrete) with tie beam

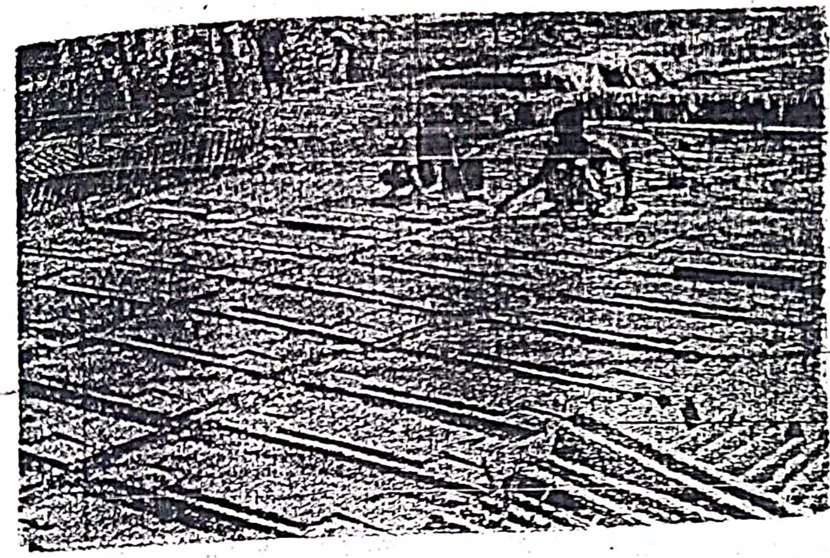


Fig. 5.6 Casting of RC solid planks at the casting yard

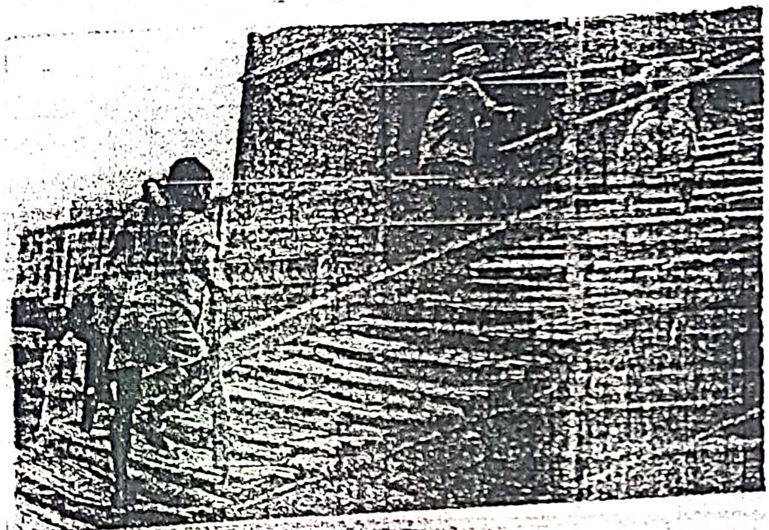


Fig. 5.7 (a) Manual carriage of RC joist, (b) Manual carrage of precast RC solid plank on the roof comprising of RC plank and joist system

panel floor/roof with tie beam. Provision of tie beam helps ensure structural stability in the event of earthquakes. Such beam extends to the depth of the precast components plus the thickness of structural deck concrete.

The planks and joists are cast either in well-seasoned good quality timber moulds or steel moulds. Curing is done for 14 days before they are laid.

This system results in saving of the material and costs to the extent of 20 to 25% in comparison to traditional RC roof. There is also a saving in construction time of the order of about 25% in laying such roof as compared to the conventional in-situ RC slab.

Under the NBO Experimental Housing Scheme, 44 LIG and 24 EWS houses have been constructed using this technique at Ludhiana by the Punjab Housing Development Board. Another 80 houses have been constructed at Lucknow by the U.P. P.W.D., 348 staff quarters constructed at New Delhi by the All India Institute of Medical Sciences, and 48 houses constructed at the Indian Institute of Technology (IIT), New Delhi.

Apart from the experimental projects, this technique has been adopted for construction on mass scale by several construction agencies in the country. Utilising this system of roofing, 13,000 houses have been constructed in Andhra Pradesh, 600 houses in Bombay, 850 houses in Madhya Pradesh, 100 houses Kalyani in West Bengal, and 500 houses in Ghaziabad. Recently, 14,000 houses using precast RC solid planks and joists have been constructed in different parts of Rajasthan.

Precast Brick Panel System

The system (Fig. 5.8 to 5.10) comprises of prefab brickbased components and partially precast RC joists. Panels are laid over the partially precast RC

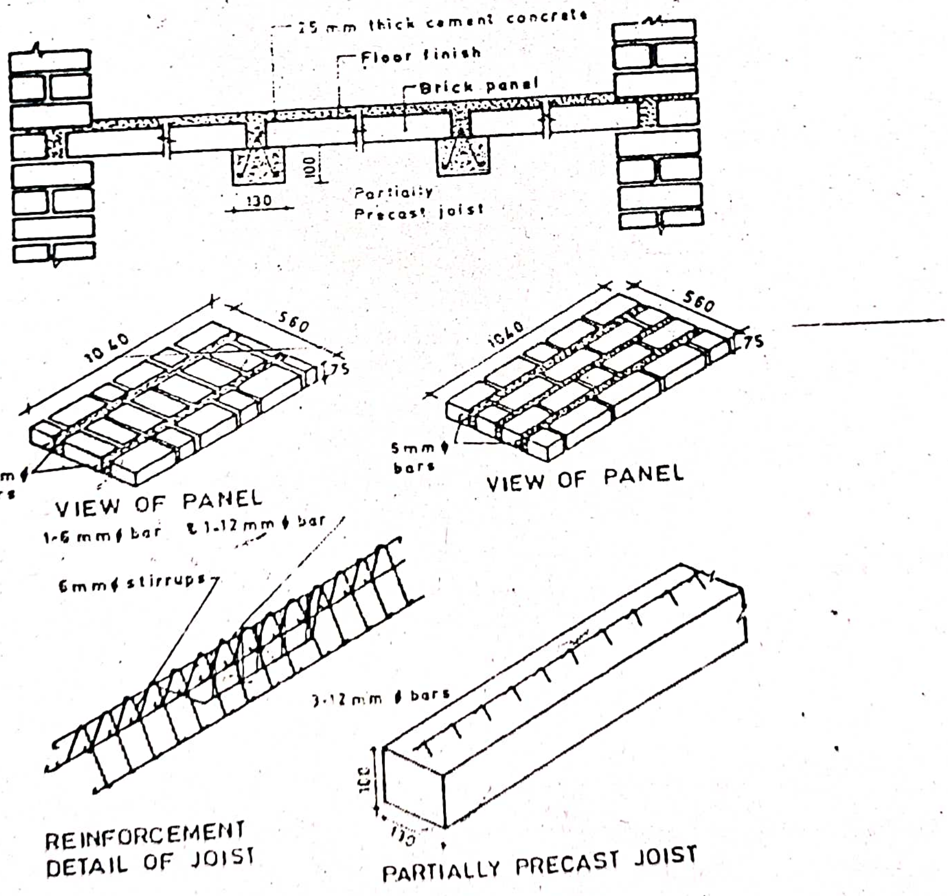


Fig. 5.8 Brick panel roofing system

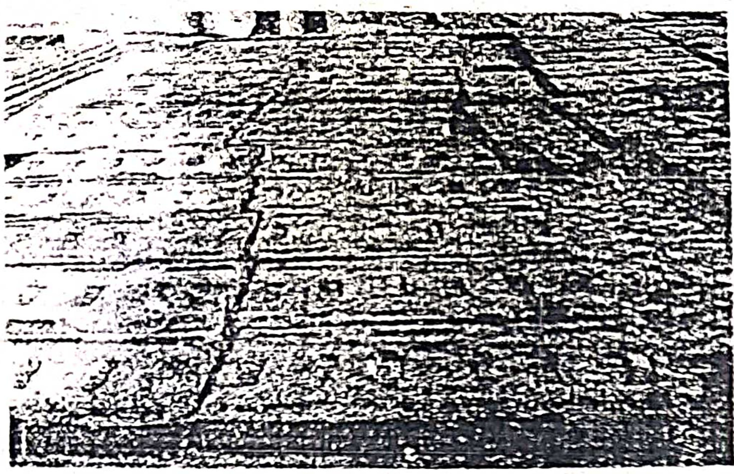


Fig. 5.9 Precast reinforced brick panels at casting yard

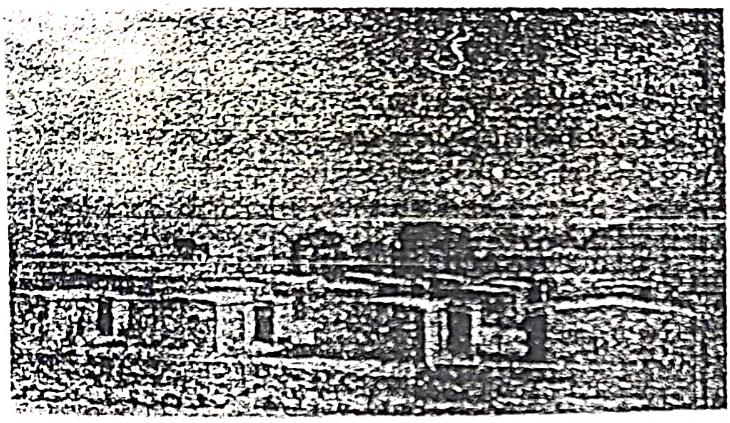


Fig. 5.10 Houses made of precast brick panel system in rural Punjab

joists. A typical size of the brick panel is 1040 mm x 640 mm in which 16 bricks, two bars of 6 mm dia. and M-15 concrete are used. The partially precast joists are 130 mm × 100 mm in section and their reinforcement will depend upon the span. After proper curing and drying, the panels are placed over the partially precast joists over which concrete is laid in normal manner. The panels are cast in well-seasoned timber moulds over casting platform and it does not require high degree of skill. Weight of a brick panel is only 75 Kg, which facilitates its handling manually. At the time of roof assembly, partially precast joists are kept propped till the deck concrete and the concrete over the joists have attained strength. The thickness of deck concrete over the panels is kept as 30 mm. Deck concrete is laid after placing 6 mm dia. mild steel bars, one bar on each panel in both directions. The savings in materials and cost as compared to the traditional RC slab are of the order of about 30 percent.

More than 40,000 houses have been constructed utilising brick panel roofing system in India. This includes 30,000 houses in rural areas of Punjab, 200 EWS houses at NOIDA (U.P), 3500 houses at Ghaziabad, 200 houses at Lucknow, 1000 houses at Cochin, and 200 EWS at Bhopal and 600 houses for the Sri Lankan repatriates.

Thin Precast RC Lintel

Normally, in building construction, 15 cm thick RC lintels are provided over door/window openings. Lintels can be as well designed as a composite member consisting of 75 mm thick RC lintel with the masonry on top. The precast thin lintel (Fig. 5.11) 75 mm thick, and 230 mm wide with 3 numbers of mm dia M.S. bars could be used for opening upto 1.8 m provided bricks used have minimum crushing strength of 10N/mm²* and

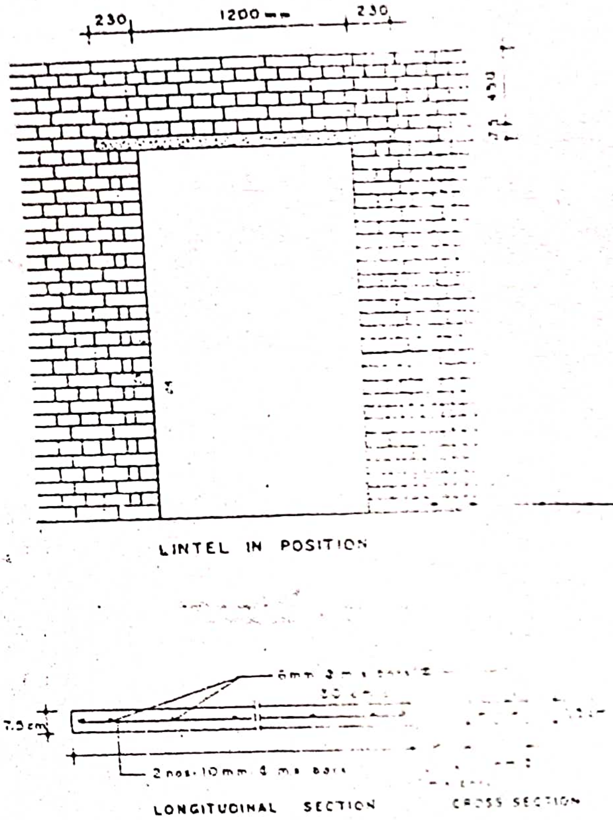


Fig. 5.11(a) Precast thin RC lintel

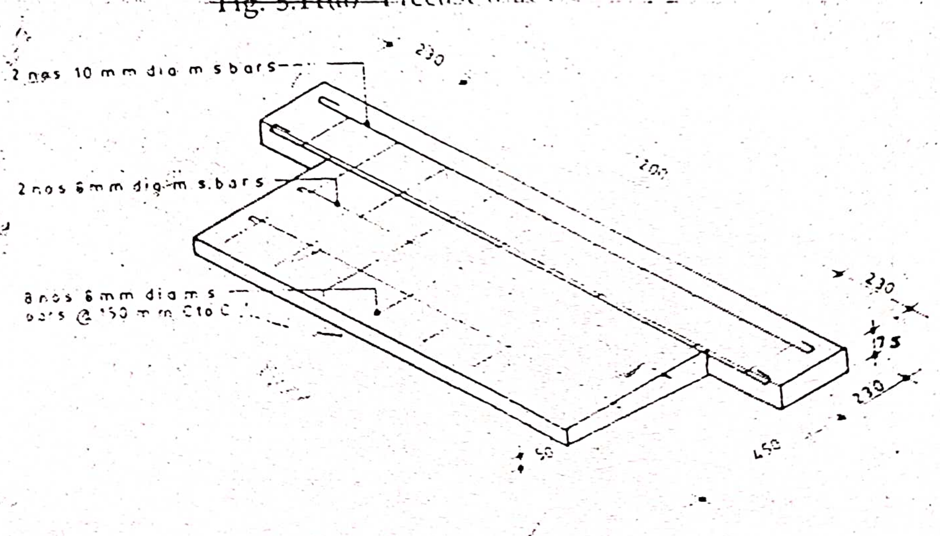


Fig. 5.11(b) Thin precast lintel with chajja

* $1\ N/mm^2 = 10\ kg/cm^2$

mortar is not leaner than 1 : 6 cement-sand and the height of masonry above the lintel is at least 45 cm. Use of precast lintels speeds up the construction of masonry walls besides eliminating shuttering and centering. About 50% saving in material and overall cost is achieved apart from saving in construction time by adoption of precast lintel.

Precast thin lintels have been adopted in a number of Experimental Housing projects. Beside this, such lintels have been used in construction of a large number of houses by the CPWD, MES, Railways, State Housing Boards and the Delhi Development Authority (DDA) and Tamil Nadu Housing Board.

Precast RC Frames for Doors and Windows

With fast depletion of the forest resources timber has now become a scarce material. This has necessitated search for substitute materials for making frames for doors and windows. Reinforced concrete frames provide an answer to the problem. Precast RC frames are alternate to traditional timber frames for doors and windows and economical compared to frames made out of traditional timbers like teak and deodar. They are more suitable than timber frames in wet areas like lavatories, bathrooms and kitchens and are resistant to turmite attack and growth of fungus. The RC frames are better resistant to fire as compared to wooden frames.

Precast RC frames (Fig. 5.12) are recommended for a maximum opening of 2.25 m with cross section 60 × 100 mm or 70 × 75 mm for single shutter doors and 60 × 120 mm for double-shutter doors. Three bars of 6 mm dia. are provided as minimum reinforcement which are firmly held by

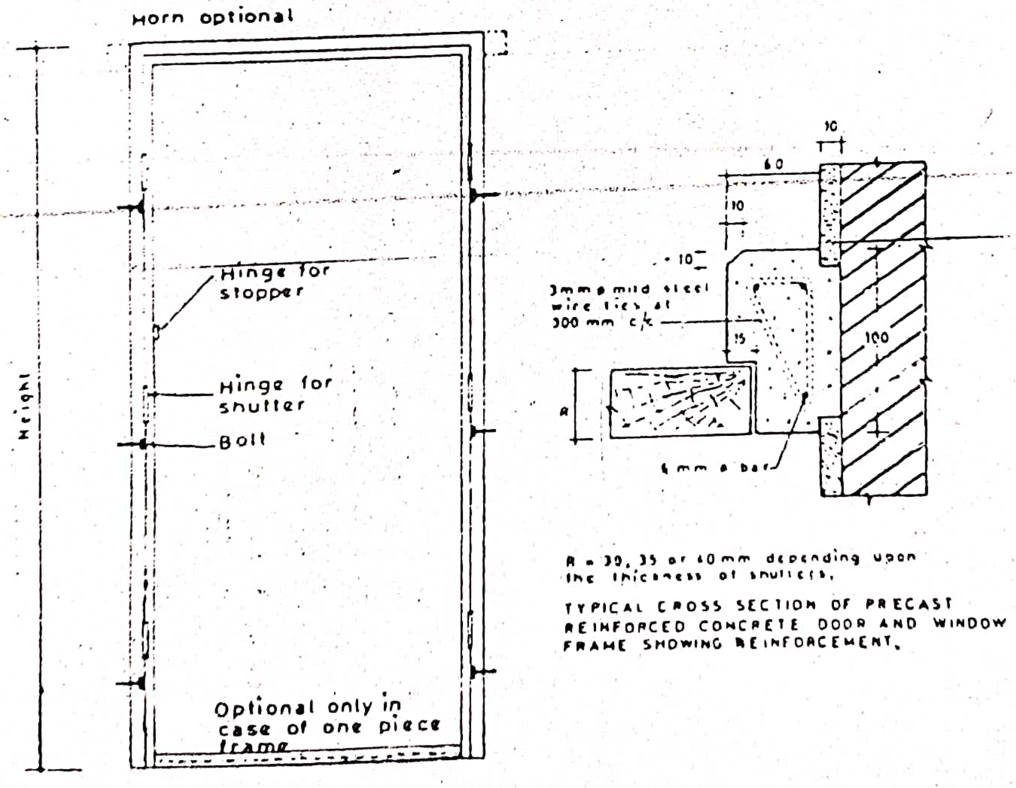


Fig. 5.12 Precast RC frames for doors/windows

means of 3 mm dia. steel bars spaced at not more than 20 cm c/c. The frames are cast in M-15 concrete.

Various methods of fixing shutters to the frames have been tried out. But the most successful and durable method appears to be use nuts running through the frame. Hold fasts, M.S. plates receiving the tower bolt, aluminium sleeves for fixing shutters are embeded in the frame during casting hinges.

Precast RC frames have been tried out in several experimental projects. Under the NBO Experimental Housing Scheme, this technique of construction of frames for doors and windows has been adopted in construction of 10 Asst. Professors' quarters at Patiala (Punjab), 992 prefabricated houses at Delhi by the Municipal Corporation of Delhi (MCD), 16 bed hostel at Roorkee (U.P), 32 staff quarters for Hindustan Housing Factory (now Hindustan Prefab. Ltd.—HPL) at New Delhi, 16 type III quarters at New Delhi by the Army Headquarters, 280 low-cost houses at Neyveli by the Neyveli Lignite Corporation (NLC) and 50 LIG and 48 EWS houses at Faridabad by the Haryana Housing Board. Subsequent to adoption of precast RC door and window frames in the experimental project sponsored by the NLC, the Corporation has since used such frames in construction of 7,000 quarters for its employees.

Adoption of Total Prefabrication for Mass Housing in India

In urban agglomerations, especially in metropolitan centres, where there exists huge backlog of housing, it has become a matter of great urgency to build large number of houses economically at fast rate to wipe out the shortage. Speed in construction could be greatly enhanced with the application of total prefabrication for mass housing programmes. By adoption of total prefabrication, completion time of housing projects could be reduced drastically, to the extent of 40 per cent.

In some advanced countries, appreciable reduction in time taken for house construction has been achieved through adoption of prefabricated method of construction. Building components complete in all respect are prefabricated in housing factories which are subsequently transported to construction sites where only erection and assembly works are undertaken. In the erstwhile USSR, there were as many as 569 prefabrication factories producing prefabricated building components comprising of reinforced cement concrete, prestressed concrete and lightweight concrete. Standard sizes of building components based on modular co-ordination concept of planning are produced in these factories.

In India, too, prefabrication technology for mass housing has come of age. Prefabrication increasingly being adopted for large-scale housing programmes in the country. Brief description of some popular prefabrication systems adopted for mass housing programmes in India is given below.

i) Hindustan Prefab Limited

The Hindustan Prefab. Limited, New Delhi, which is a Government undertaking, established in 1950, has produced a variety of prefabricated building components such as precast beams, columns, floors and roofing elements, and panels etc., and has undertaken a number of mass housing projects in which the prefab. components produced by the said factory have been employed in a big way.

ii) Shirke-Siporex Consortium

M/s Shirke-Siporex Consortium, Pune, manufacture precast hollow columns and beams, lightweight concrete slabs and blocks, and wall panels with the Swedish know-how which have been extensively used in mass housing programmes undertaken by them in different parts of the country. The firm has built over 1,00,000 dwelling units of all categories both in India and overseas. It has also developed anti-corrosion treatment, which has been very effective in preventing the occurrence of corrosion in M.S. reinforcement in Siporex precast concrete components used in the coastal and highly polluted areas like Bombay.

iii) Large Panel Prefabrication

This is an 'on-site' prefabrication system employing precast concrete panels and hollow clay block for external walls and precast concrete and brick panels for internal walls; and precast funnicular shells for roof. Being an on-site prefabrication system, no heavy equipment except a crane is required for handling of precast components. This technique of construction could be employed for construction of residential building upto 4-5 storeys. An experimental housing project sponsored under the Experimental Housing Scheme of NBO which involved construction of 144 flats in six, four-storeyed blocks undertaken by the Tamil Nadu Housing Board at Madras, has successfully employed large-panel prefabrication system under technical guidance from SERC, Madras.

Subsequent to field trial of large-panel prefabrication (Fig. 5.13 and 5.14)) at Madras, totally prefabricated concrete houses were constructed at Vashi (New Bombay) during 1972-74 using large-sized prefabricated wall-panels, floor slabs, bath room units, staircases, etc. All the structural members and cladding components were precast and were erected using a 50-tonne travelling granty crane, especially fabricated for this purpose. The cost of construction compared very favourably with the conventional system. Better utilisation and marginal saving were achieved in the major construction materials such as cement and steel both of which were controlled items at that point of time. The system is also currently being employed in construction of about 3,800 apartments by CIDCO (City and Industrial Development Corporation of Maharashtra Ltd.) in New Bombay.

Large panel precast system has also been adopted in a big way in construction of residential accommodation and office facilities for the Sardar Sarovar Narmada Nigam Ltd. in Gujarat. Experience of application of large panel precast system for mass housing has been very encouraging. It has been possible for the project authorities to construct 20 tenements covering 1,000 sq.m. per day using the aforesaid prefab construction system.

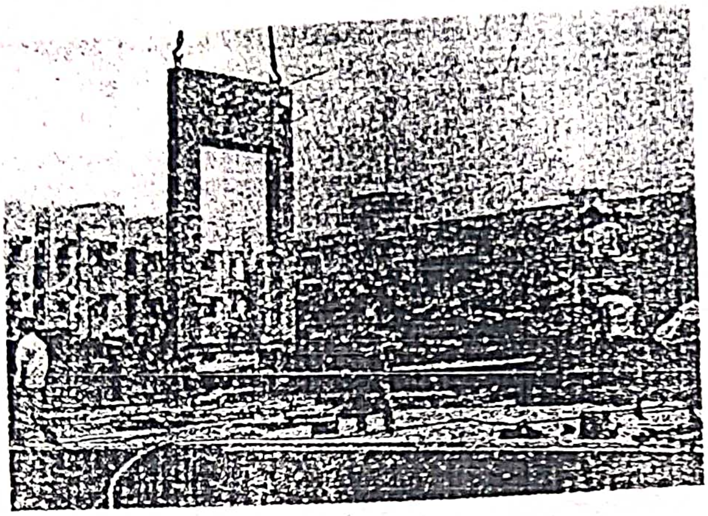


Fig. 5.13 Handling of large sized prefabricated wall panel

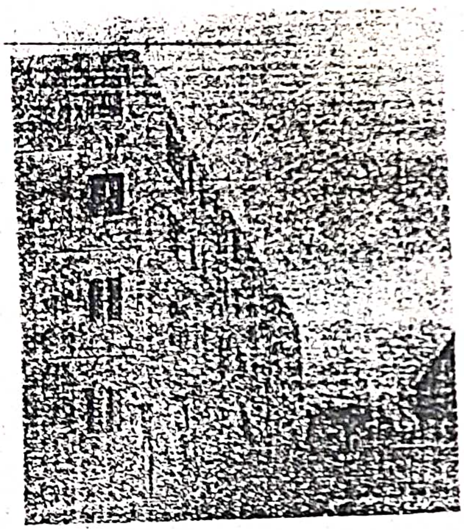


Fig. 5.14 A view of houses made of large-panel prefabrication system

iv) Tunnelform System

In this system of prefabrication for mass housing programmes promoted recently by ECC-Construction Group of L&T (Larsen and Toubro), Bangalore, the reinforced concrete walls and floor slabs are all cast in a continuous pour of the concrete using room sized structural steel framework called 'Tunnel form.' In a broader sense, it is an in-situ construction system like the traditional construction methodologies based on use of brick masonry for walls and RCC for suspended slabs-all expected at site. However, in this system RCC is the only material used for the single operation casting of structurally stable shell of walls and slabs for the houses. The versality of concrete being moulded into any shape of its formwork is better exploited in this mechanised system than the other alternative choices of industrialised constructions, viz, large panel prefabrication or large precast panels for wall supporting standardised prestressed concrete flooring/roofing elements. The structure is cast in such a way that it is totally monolithic and includes load bearing walls, cross walls and slabs. Components like facade, panels, balconies, sunshades, landing staircases, cupboard, kitchen platforms, water tanks, etc., are all prefabricated and integrated into the system. Quick stripping and removal of forms are made possible by accelerated curing using hot air so as to facilitate casting of one or two flats in "One-Day cycle." Accessories like frames of doors and windows, electrical conduits, switch boards, junction boxes, etc., are fixed into the forms along with the reinforcement prior to concreting. After concrete attaining the required strength, the form can be collapsed, withdrawn from the house and then shifted to the next casting. With proper maintenance a tunnel form can be used for 800 or more repetitions. Plastering is totally eliminated and concrete walls and slabs are painted directly under this system of construction.

The basic know-how of the technology was acquired from SPECTRA of France. Some modifications have been incorporated in the original technology to suit the local tradition and living requirements.

With thinner walls (13-15cm), the system provides 5-10% additional carpet area. Elimination of plastering on tunnel formed walls and ceilings saves on labour and materials.

The speed of construction with adoption of this system is claimed to be much faster, providing upto 125 sq.m. of construction per day from one set of formwork operated with one crane.

This technique of construction (Fig. 5.15 and 16) has been employed in the construction of 1,500 dwelling units measuring 75 sq.m. each for the employees of TISCO (Tata Iron and Steel Company Ltd.) at Jamshedpur. The entire construction was completed within a period of only 32 months. Almost 85% monolithic construction was achieved in construction of such

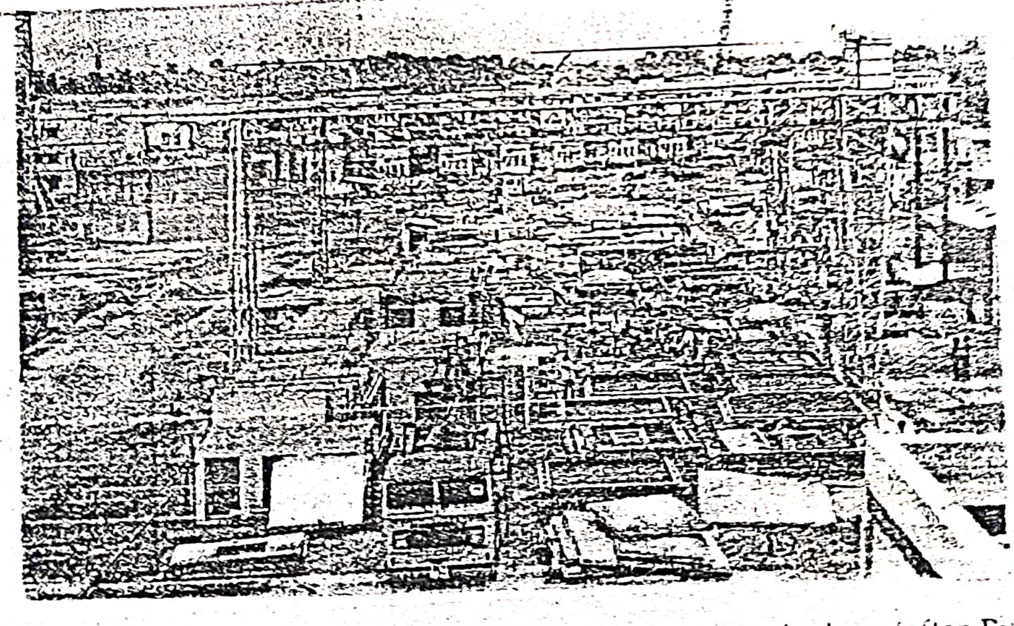


Fig. 5.15 Precasting yard for tunnelform construction at Jamshedpur (after Bi: i. 146 — reproduced with permission from Architecture + Design, New Delhi)

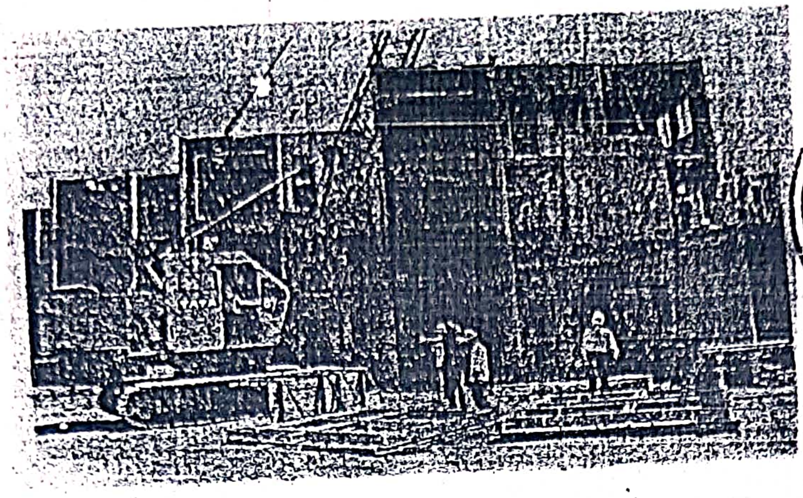


Fig. 5.16 Placement of precast walls under tunnel form construction (after Bibl. 146 — reproduced with permission from Architecture + Design, New Delhi)

residential flats by casting all walls and floor slabs of individual flats in a single pour.

Using this technology blocks upto 20 storeys have since been completed.

v) L&T Form System

This is also promoted by the ECC-Construction Group of L&T, Bangalore. Like the tunnel form system, the walls and slabs in this system also are of reinforced concrete. In this system, the walls are cast using large panel formwork in the first stage, and slabs over walls are cast in the second stage. Since the walls and slabs are cast in two separate stages accelerated curing is avoided in this system of construction.

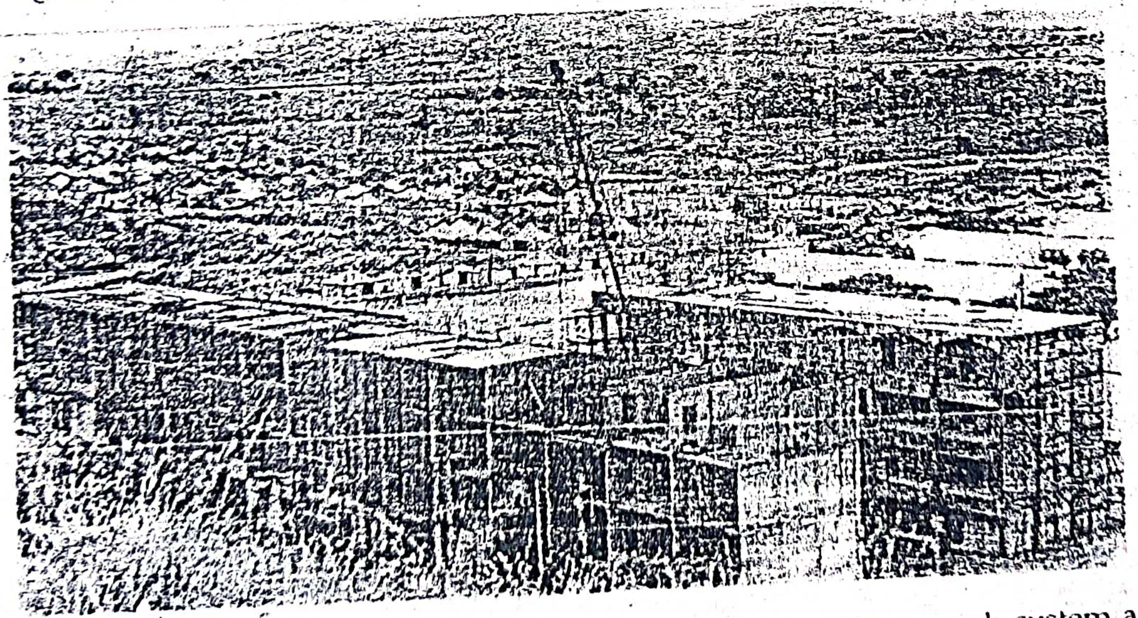


Fig. 5.17 Construction of precast houses employing L&T form work system at Puttaparthy (Andhra Pradesh) (after Bibl. 146 — reproduced with permission from Architecture + Design, New Delhi)

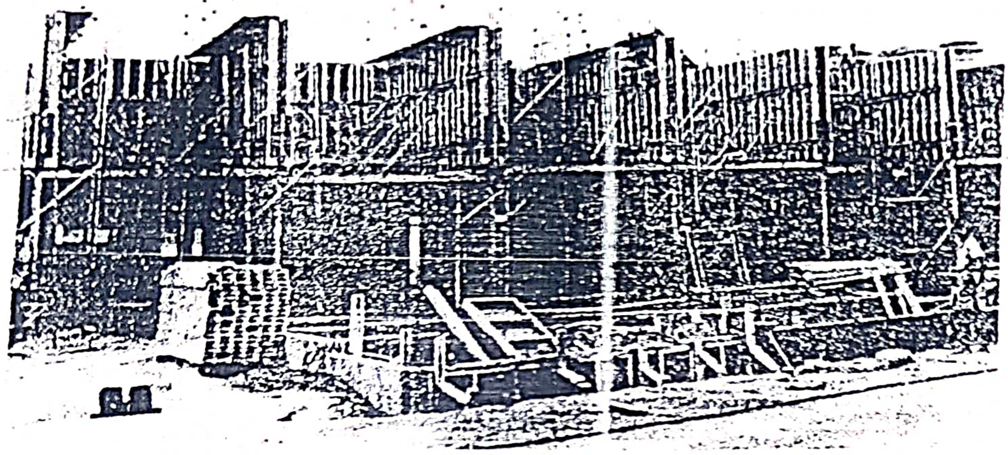


Fig. 5.18 Formwork for walls under L&T formwork system (after Bibl. 146 — reproduced with permission from Architecture + Design, New Delhi)

Accessories like frames of doors and windows are fixed to the formwork prior to concreting or provisions are made for door and window openings at the predetermined positions in the formwork.

The above technique (Fig. 5.17 and 18) has been adopted in construction of 240 community flats for the Shree Satya Sai Central Trust at Puttaparthy (Andhra Pradesh). The flats measuring 42 sq.m. each were built in a record time of 180 days using the L&T form system.

vi) Concrete Hollow Blocks for Walling and Roofing

Concrete hollow blocks (Fig. 5.19 and 20) could be ideal substitute for the conventional clay bricks whose production destroys fertile top soil to the extent of 50,000 acres every year in the country. These blocks are also

Fig. 5.19 Casting of concrete hollow blocks

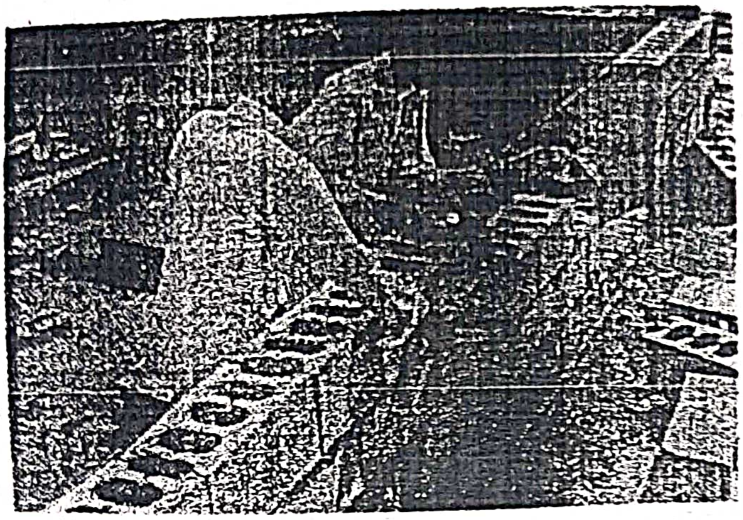


Fig. 5.20 Construction of masonry wall with concrete hollow blocks

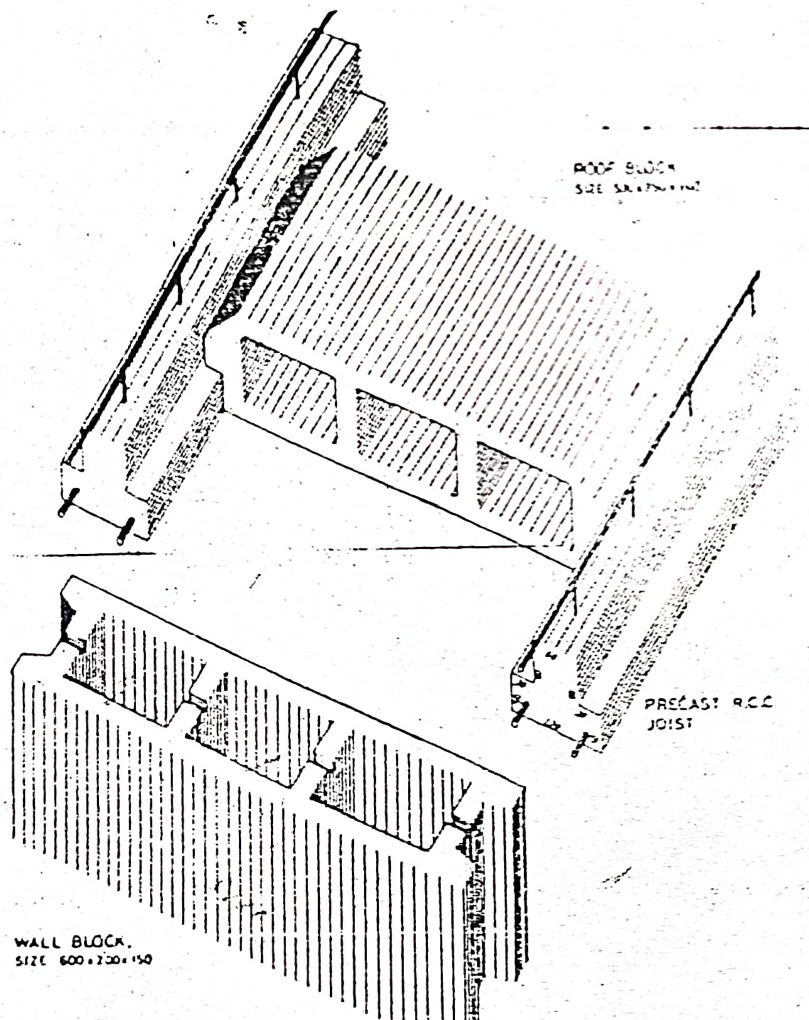


Fig. 5.21 Zip block system — precast elements

ideally suited for the regions like the southern states of the country where soil of requisite grade is not available for manufacture of good quality bricks. In India, a plant for manufacturing concrete hollow blocks was set-up in Madras as early as late '40s. In the USA and Canada, more than 80% of walling is currently done using concrete masonry blocks, and manufacture of concrete masonry units is an established business in these countries. In Europe, too, there has been immense increase in block masonry constructions in recent years. Such blocks have been used for load bearing constructions upto 10 storeys. Concrete masonry unit is a modular concrete product. The reasons for its popularity in the western countries are its various advantages like durability, strength, structural stability, fire resistance, thermal and accoustical characteristics, attractive appearance and, above all, economical and faster construction.

There are, at present, quite a number of manufacturers of hollow block making machines in India, the Minasto Shrike and Gospel to name a few.

The Zipblock system of prefabrication, promoted by M/s CVG Shelters, Madras, utilises precast concrete hollow blocks of 600 × 200 × 150 mm size for walling, and precast 'hourdi' type hollow blocks of 530 × 250 × 140 mm as filler material for roofing with partially precast joints for floor or roof slabs (Fig. 5.21 and 22). Under this system of construction, foundation is not prefabricated. Adoption of piles helps foundation become integral part of the system. The Zipbloc system using 150 mm blocks as load bearing walls could be used for construction of houses upto three storeys. It has

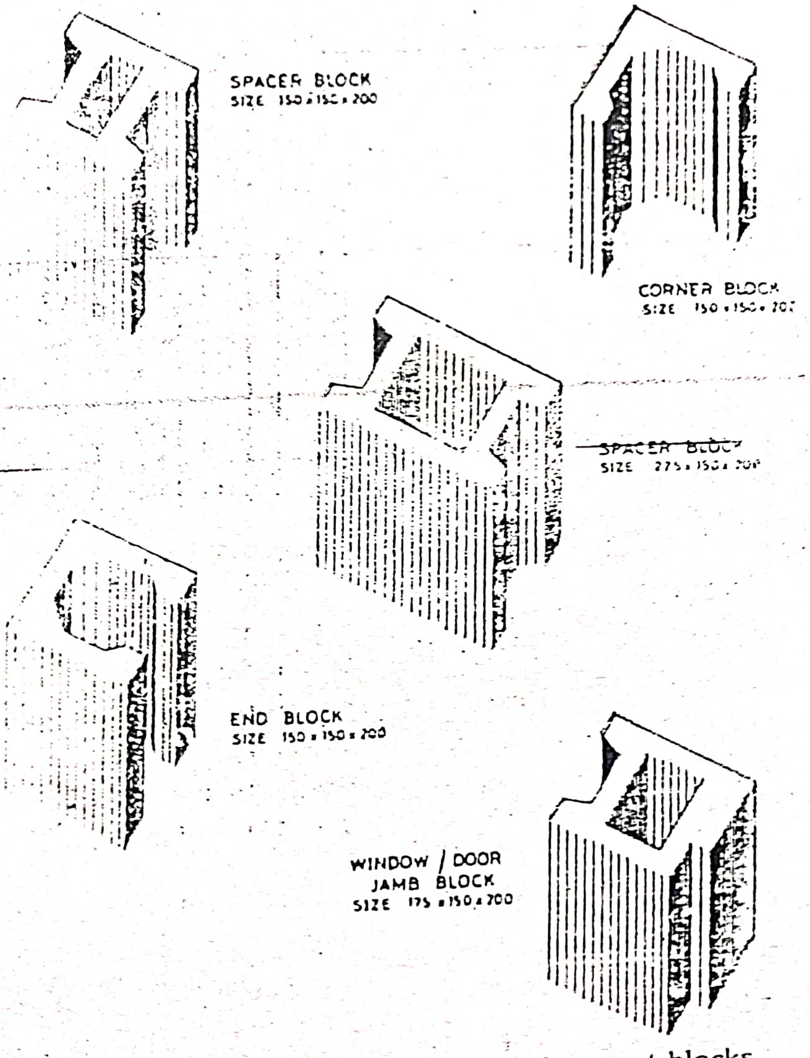


Fig. 5.22 Zipblock system — special precast blocks

already been successfully tried out in the construction of several two storeyed houses in Madras.

Plastering can be avoided by application of this system of construction. Moreover, formwork is eliminated as the zipbloc roofing is supported by partially precast joists, and by utilizing precast lintels and sunshades.

General Remarks on Precast Roofing/Flooring Systems

A few points which are applicable to all the precast roofing/flooring systems so far described deserve special consideration for ensuring their satisfactory performance.

i) First, the planning of the building. It is very important that the building plan should be prepared keeping uniform span for the prefab components. By doing so, precast units of only one size will be required in size as it will reduce the number of sizes of moulds. Building planned on crosswall system is well suited for adoption of precast units.

ii) The moulds for precasting may be manufactured with good quality timber or steel. Steel moulds can be used for a large number of castings and will be economical in the long run. Good timber moulds may be used for 30 to 40 casting operations.

iii) The precast units may be designed by common methods of structural design adopting ultimate load method of design or limit state method as per the codal provisions of relevant Indian standards. Both ordinary mild steel or high strength deformed bars may be used for reinforcement.

iv) Precast units should be adequately cured before they are used in the building. Handling methods should be given particular attention to avoid breakage and damages to the finished surface.

v) Joints are the most critical parts in prefabrication. Their efficiency decides the success or failure of the system. Moreover, the joints of prefabricated elements tend to develop shrinkage cracks. It is, therefore, imperative to take adequate precaution to ensure watertightness of joints and structural integrity of the precast elements. As a precautionary measure, precast elements are required to be transversely connected with reinforcing bars to avoid opening of joints. To overcome the problem of differential shrinkage between the precast element and the cast-in-situ concrete in joints, use of non-shrinking cement grouts and sealants is a positive solution, and contributes to the satisfactory performance of joints.

vi) All openings should be pre-planned and provided for in the moulds so that chipping on breaking of the precast units is completely avoided.

vii) Fan hooks, electrical conduits, etc., should be embedded in the in-situ concrete.

viii) The waterproofing of the roof should be done with great care as number of joists are involved in the precast roof assembly.

ix) The Armenian earthquake (December 1988) had exposed the vulnerability of precast roofing components to the forces of earthquake. Precast concrete frame buildings suffered extensive damage during the said earthquake. Precast large panel buildings, however, gave better performance during the earthquake due to proper bracing. Different parts of such buildings were better tied together than the previously quoted buildings. As such, it becomes necessary to take adequate precautions in design and construction of precast roofing systems. The revised edition of IS : 4326 provides the necessary guidelines regarding suitable strengthening measures to be adopted for design and construction of prefabricated buildings in earthquake prone areas. Moreover, occurrence of the September 1993 Maharashtra earthquake in a zone which is considered to be seismically stable, provides warning with regard to uncertainty of occurrence of earthquake. This necessitates adoption of additional precautions in respect of design and construction of precast constructions. The IS : 4326-1993 (Second Revision) stipulates that all the floors and roofs to be constructed with small precast components shall be provided with tie beams. Such beam runs all round the floor or roof and binds together all the precast components to ensure diaphragm action of the floor/roof. Tie beams shall be made of cement concrete of grade not leaner than M15. They shall be provided on all longitudinal and cross walls.

Economical Walling System

Wall is one of the important structural elements in building and housing construction which, on an average, accounts for 25 to 30% of the cost of construction in civil work. Traditionally, brick masonry and stone masonry are the two most popular walling systems used in building construction in India. Burnt clay brick is one of the predominantly used basic construction materials in the Indo-Gangetic plains while in States like Rajasthan and Gujarat, locally available stone is used as an important building material for wall construction.

As a result of research work undertaken at the CBRI, Roorkee, several innovations in design construction of load bearing brick masonry have been evolved. These innovations have been experimented with under the Experimental Housing Scheme of NBO. These include single brick chick load bearing masonry walls for four-and five-storey construction, nineteen centimetre thick walls (using conventional bricks) for upto two-storey construction, half brick thick walls, fly-ash gypsum brick masonry and precast stone block masonry. Adoption of these systems has not only resulted in economy but also in less consumption of bricks and mortar, utilisation of industrial waste and saving in time.

Single Brick Thick Load Bearing Wall

Till a few decades back, it was in practice to construct two-or three-storeyed buildings and houses as the pressure on urban land then was not as considerable as it is now. Design of load bearing walls was earlier made on empirical methods based on the established experience of architects/engineers. For example, wall thickness for a four-storeyed construction as per the empirical method was kept as 46 cm, 34 cm, 23 cm and 23 cm for ground, first, second and third storeys respectively. Through a rationalised design method, it has now become possible to construct single brick thick load bearing wall in multi-storeyed construction through use of better quality bricks. In present construction practices, single brick thick load bear-ing walls could be adopted for construction of four-and five-storeyed resi-dential buildings provided bricks of good quality having compressive strength of 7–10.5N/mm² (70–105 kg/cm²) are available. Apart from saving in consumption of bricks, cement and steel, such types of load bearing brick structures provide more covered area, resulting in upto 15% economy in cost of construction.

Construction of four-storeyed residential buildings having single brick thick load bearing walls have been extensively adopted by the CPWD and also by various other construction departments such as MES, DDA, ONGC, IDPL, etc. Recently, 400 four-storeyed tenements were constructed with single brick thick load bearing walls in Erode town in Tamil Nadu.

In Calcutta, construction of a block of 50 residential units having storeys with single brick thick load bearing walls on all the floors had been taken up under the NBO Experimental Housing Scheme which resulted in saving 6% the cost of construction. As a follow up of the said experiment construction, a large number of 5-storeyed residential buildings have been put up by different construction of five-storey residential buildings having single brick thick load bearing walls had been undertaken by the CPWD in 1980 (Fig. 5.23.)

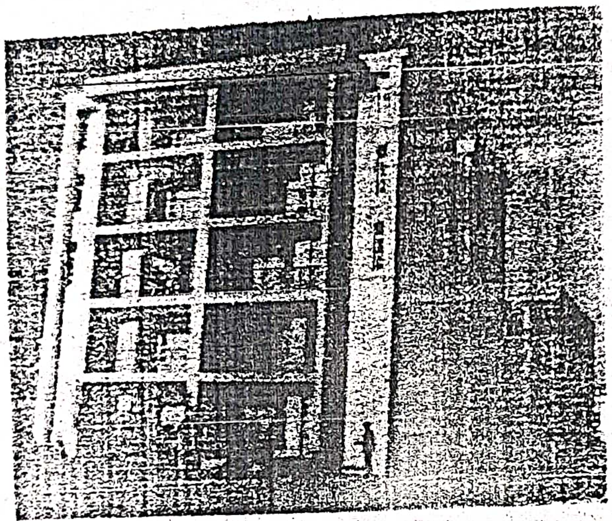
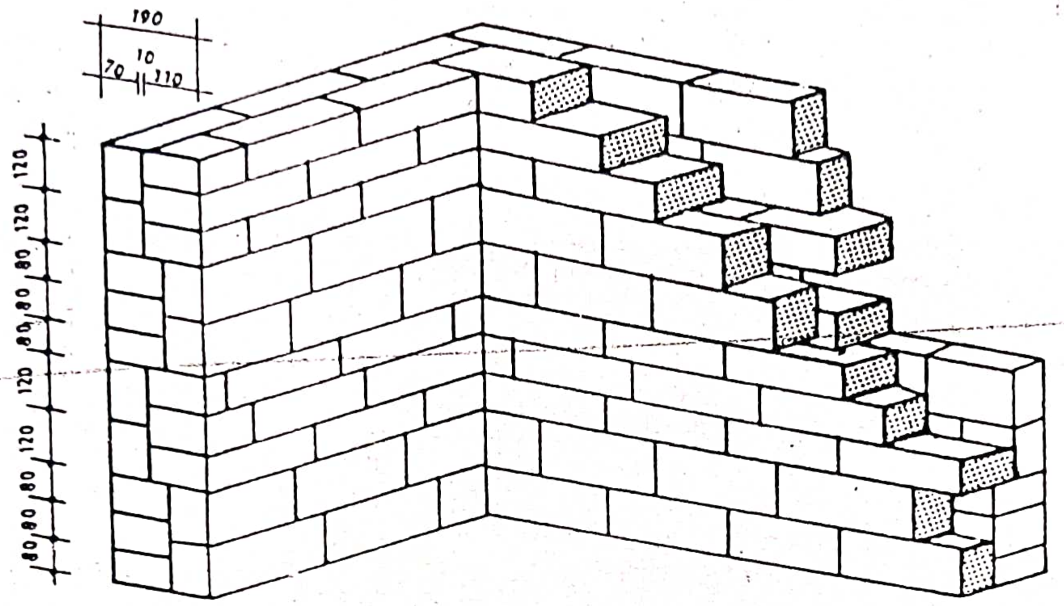


Fig. 5.23 Five-storeyed building having single brick thick load bearing walls in all storeys

Nineteen Centimetre Thick Load Bearing Brick Masonry Walls

It has been a common practice these days to adopt 23 cm thick load bearing walls using conventional bricks for normal house construction. However by a rational design of the structure it is possible to construct 19 cm (7.1/2") thick load bearing walls (Fig. 5.24 and 25) for upto two storeys using burnt clay bricks.

In ordinary brick masonry construction, English Bond and Flemish Bond are generally adopted for getting the required wall thickness. In case of 19 cm thick walls a different type of bond is adopted and construction also differs from the traditional type. Under this technique of



INTERNAL CORNER VIEW

Fig. 5.24 Nineteen centimetre thick land bearing wall

construction, bricks are laid on edge as well as flat. In order to obtain a height of 23 cm, three bricks are placed on bed whereas adjacent to it two bricks are placed on edge. The next 23 cm height is obtained by placing two bricks on edge and three bricks on bed on the same side of the wall. The pattern is then repeated to obtain full height of the wall. Corners and junctions of such walls are also constructed in a different manner to break the continuity of joints.

Such walls can be designed according to the provisions of IS:1905-1980. A saving to the extent of 16% has been achieved in cost of bricks and mortars employing this technique. However, there has not been a saving in the labour component, the reason being that two masons are employed in the construction of such walls as both its sides are to be constructed

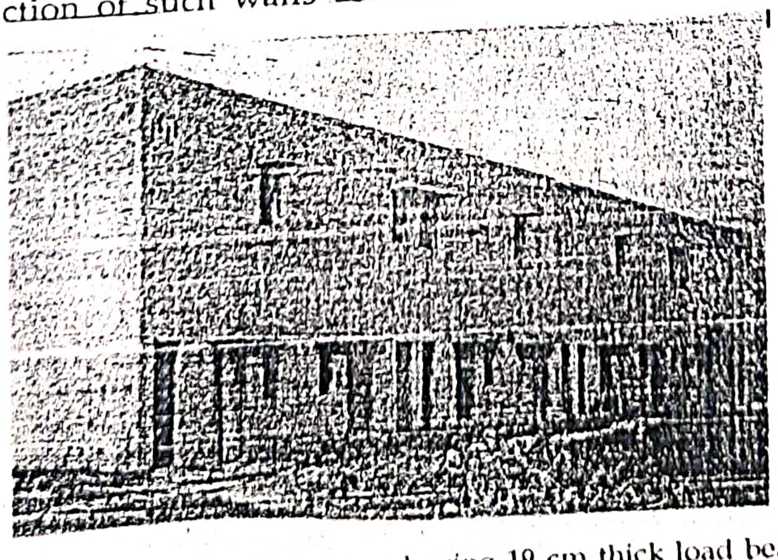


Fig. 5.25 A view of double storey quarters having 19 cm thick load bearing walls at Ludhiana

independently with bricks on edge as well as flat. As masons work on both faces of the wall a smooth face is obtained on each side as a result of which the thickness of plaster required is less. The reduced wall thickness also results in providing the same floor area in a reduced plinth area.

This technique has been tried out under the NBO Experimental Housing Scheme at Ludhiana. Subsequent to this experimentation, a large number of houses have since been constructed adopting this technique in different parts of Punjab.

Half Brick Thick Load Bearing Wall

Generally, half brick thick walls are constructed as non-load bearing walls. But with proper planning, it is possible to put up half brick thick (115 mm) walls behaving as load bearing walls. In construction of such walls,

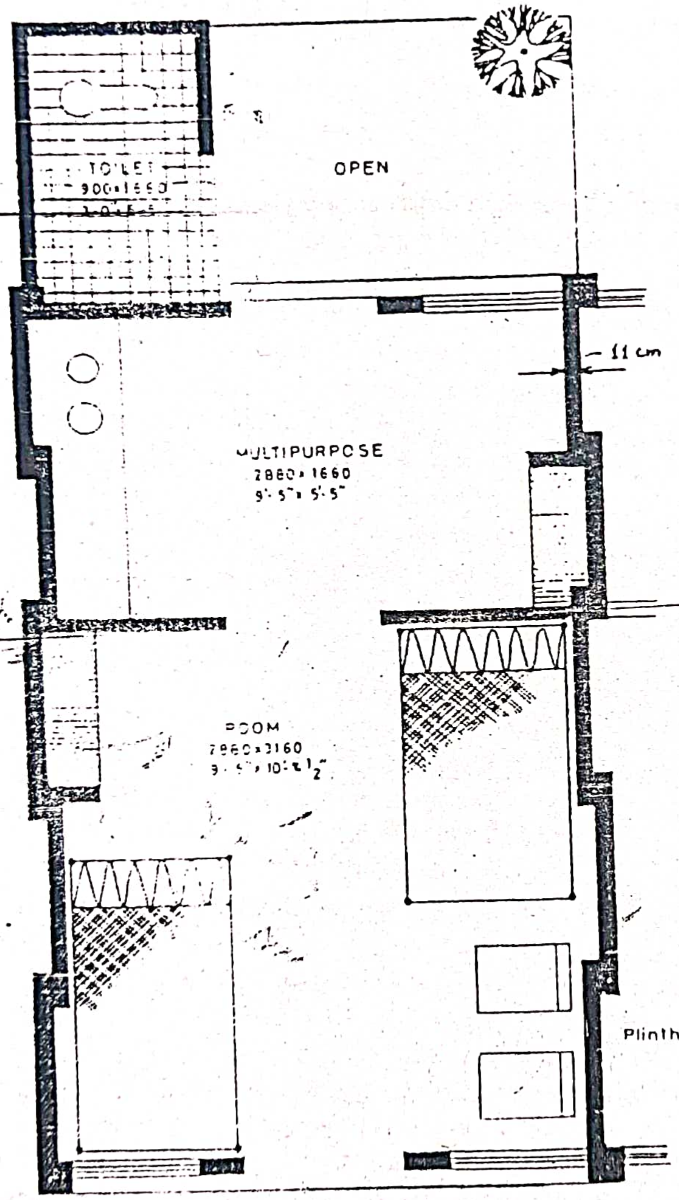


Fig. 5.26 House for the urban poor

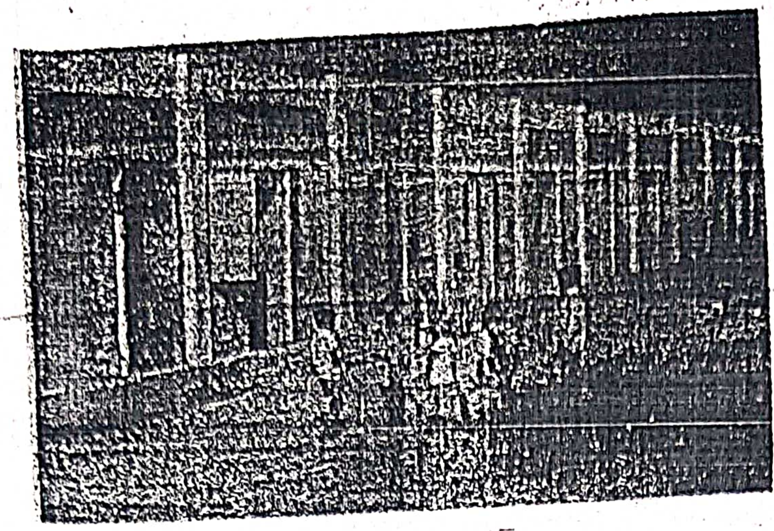


Fig. 5.27 Houses for urban poor having half brick thick load bearing wall

over-lapping of half brick thick walls at regular intervals act as pilasters of 23 cm × 23 cm size (Fig. 5.26 and 27). These pilasters transfer the load of the roofing systems to the foundation.

Masonry work in brick of 10 N/mm^2 strength in cement sand mortar 1:4 is generally adequate for constructing such walls. A ring beam of 23 cm width and 7.5 cm depth with 10 mm. dia. MS bars is required to provide bearing for the roof. Saving to the extent of 15% is achieved when compared with the traditional 23 cm thick load bearing walls.

This technique of wall construction was utilised in construction of a block of 12 single-storeyed tenements at a resettlement colony of the DDA in 1978. Precast RC channel units were used for roofing in this project. The Maharashtra Housing and Area Development Authority (MAHADA) has adopted this technique on a large scale. The technique has also been tried for construction of 200 EWS houses at Bhopal.

Flyash Gypsum Bricks for Masonry

Common burnt clay bricks can be manufactured from those soils which have got standard percentage of clay, sand, etc., within variable limits. However, there are areas especially in central and southern India where good quality soil for manufacture of burnt clay bricks is not available.

Flyash gypsum bricks are a good substitute for burnt clay bricks for the areas in which flyash is readily available. These bricks can be manufactured with a composition of 92% flyash, 4.5% powdered kankar lime and 3.5% gypsum in volumetric proportion. A compressive strength of 5-6 N/mm^2 (50-60 kg/cm^2) is expected to be achieved from these bricks. They also have good insulation properties and consequently provide better thermal comfort to the occupants in comparison with the common bricks.

The method of manufacture of these bricks is very simple and does not require elaborate arrangements. Flyash kankar lime and gypsum are powdered and mixed in the desired proportion volumetrically in dry state. A measured quantity of water is then added and mixing is done in a pan till the mixture forms a stiff paste. The paste is poured into the steel moulds. The mould is released when the mix has hardened sufficiently. The bricks are then cured for at least 10 days by stacking them properly and occasionally sprinkling water in order to keep them wet. The bricks are subsequently subjected to curing by air for about a fortnight. These bricks do not require to be burnt in a kiln.

Flyash gypsum bricks have been used at Neyveli by the Neyveli Lignite Corporation under the Experimental Housing Scheme of NBO using flyash from the Neyveli thermal power plant which complains high percentage of lime.

Stone Block Masonry

The precast stone block masonry (Fig. 5.28) is an improvement over the traditional stone masonry which requires excessive materials and more skilled labour and is time-consuming. The precast blocks can be easily produced at factory or at site with semi-skilled workers without any special equipment.

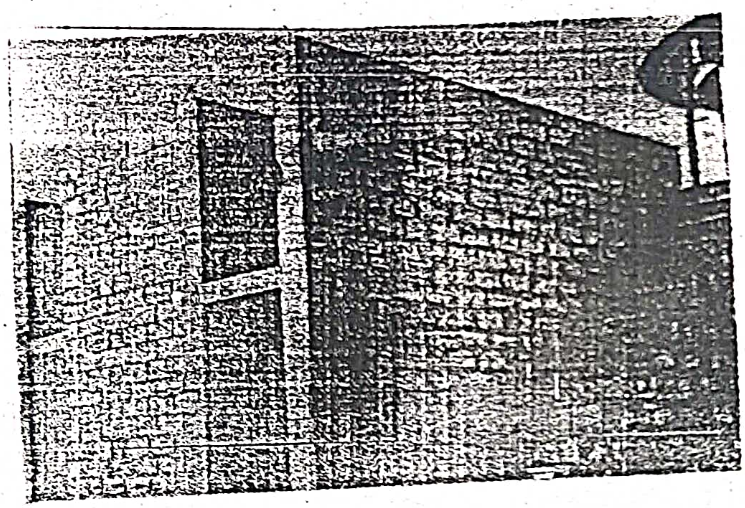


Fig. 5.28 A view of house with precast stone block masonry

Considering the ease in handling and other requirements the nominal length and height of the block are kept 30 cm and 15 cm, respectively, with three widths 20 cm, 15 cm and 10 cm The actual block dimensions are short by 1 cm to accommodate mortar joint thickness. These blocks weigh from 9 to 18 kg. To get a stone texture on the outer face of wall, the blocks are cast so that the bottom face during casting forms the exposed face when laid in wall.

The blocks are cast either in individual steel moulds of fixed type or split type or gang moulds of six blocks (Fig. 5.29). These moulds are made of 4 mm thick M.S. sheet and are welded from outside so that the internal edges are sharp and free from welding flux.

A smooth level and hard surface is required for casting the blocks. The casting platform may consist of 30 mm thick 1:3:6 cement concrete finished

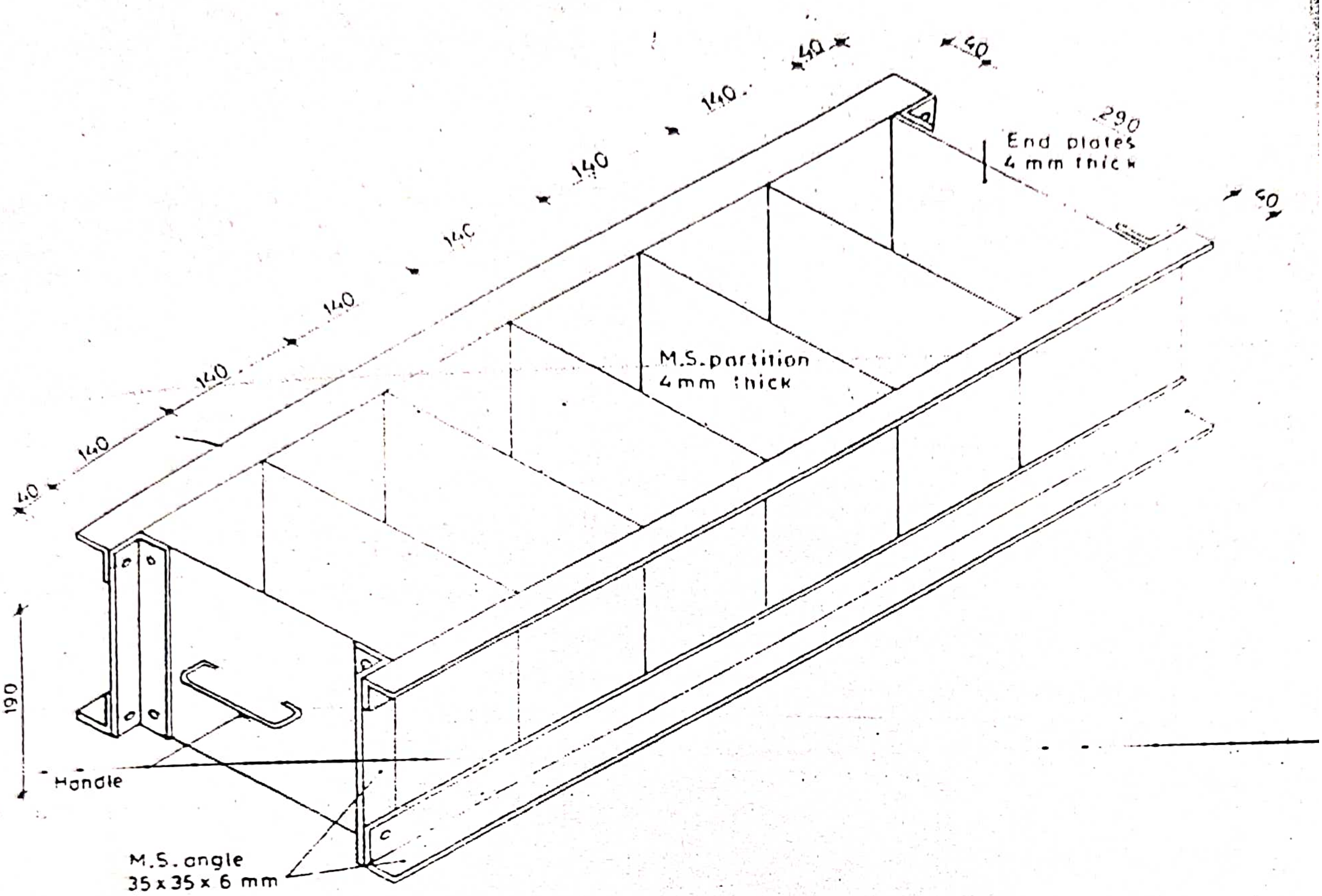


Fig. 5.29 Moulds for stone block masonry

smooth with neat cement. For production rate of 500 blocks per day a casting area of 80 sq.m. is required.

The stone masonry blocks are made of large size stone pieces bonded together with lean-cement-concrete mix of 1:5:8 (cement:sand:stone aggregate 10 mm and less). The stone pieces used are as large as can be accommodated in the mould. These can be from 5 to 26 cm in size and obtained either from quarry or breaking the river boulders. This will result in a good ~~flat stone~~ texture.

These blocks are used both for load bearing as well as non-load bearing walls. The thickness of the wall depends upon the load coming over it. This construction system provides an economy of the order of 15 to 20% in the walling cost against the conventional method of construction, viz., random rubble masonry. Stone block masonry provides finishing of brick masonry on both sides of the masonry wall.

These blocks have been used in an NBO experimental project at Bhopal sponsored by the Bhopal Development Authority. Over 25,000 houses have been constructed with stone masonry blocks in different parts of the country. In Andhra Pradesh and West Bengal, prefab factories have come up which supply these blocks. At Dehradun (U.P.), 330 residential quarters have been constructed using such blocks. They have also been use in construction of 8 educational institutions and 1,000 residential quarters in Rajasthan where 8 million blocks were used in place of 40 million and more of Nirmiti Kendras (Building Centres) in different parts of the country would be an effective step in this direction. The existing Building Centres at Quilon, Jaipur and Nizamuddin (New Delhi) have set examples for excellence in imparting training to masons in respect of skill upgradation.

ix) The various I.S. codes on different topics (Annexure II) related to low cost housing (Annexure II) as brought out by the BIS could play a major role in promotion of low cost housing technology in the country.

x) Taking recourse to modern construction management practices such as PERT (Programme Evaluation and Review Technique) and CPM (Critical Path Method) could lead to avoidance of time and cost overruns as has been experienced in some of the NBO experimental projects (See Case Study).

xi) Due attention should be given to the spatial planning in any housing project. The size and shape of the building have bearing on the cost of construction. Irregular shapes require more design efforts and will hence result in greater cost of construction.

Case Study: Adoption of Precast RC Plank and Joist System for Roof/Floor in the AIIMS Project (after Bibl. 103)

The National Buildings Organisation was approached by the All-India Institute of Medical Science (AIIMS) to suggest ways and means for undertaking a large scale housing project at lowest possible cost and within shortest possible time of completion. The project comprised of construction of 328 house for Doctors/Nurses of AIIMS, New Delhi.

The project was completed in two phases. In first phase 160 double-storeyed quarters were started in January, 1980 and were completed in six months' time through application of modern construction management practices — CPM.

In the second phase 168 quarters were constructed in three storeyes. ~~All the 328 quarters are under~~ occupation at present.

The following innovative design concepts, new construction techniques and materials were adopted in this project

i) Modular concept in planning, designing and construction based on 3M (300mm) grid to establish dimensional co-ordination.

ii) Precast RC roof/floor system comprising of precast joists and planks to achieve saving in consumption of cement and steel and also speed in construction.

iii) Lower ceiling height of 2.8 metres to reduce cost of construction.

iv) Cement lime composite mortar for masonry and plastering to effect saving in consumption of cement

v) Single stack system of plumbing to reduce cost of plumbing

vi) PVC pipes for cold water supply to replace GI pipes which are costly

vii) Secondary species of timber for joinery work to replace primary species of timber which are scarce and costly

viii) Common staircase to serve eight dwelling units in two storeyed construction to reduce area for vertical travel, and

ix) Ferrocement overhead tanks for water supply which are lighter and cheaper.

Fig. 5.38 shows the lay out plan. Specifications adopted in construction area indicated at Annexure III.

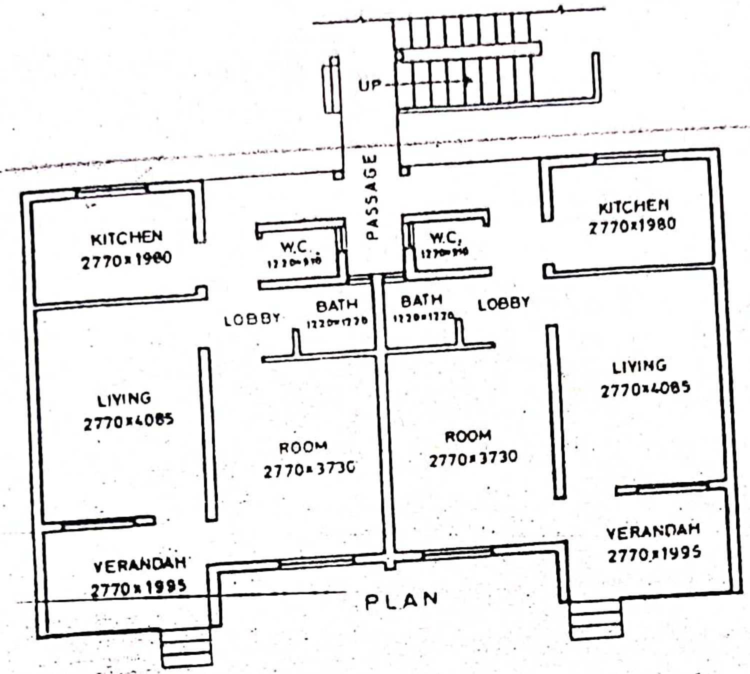


Fig. 5.38 A.I.I.M.S. housing project for doctors and nurses

Assessment of Savings

The cost per unit with experimental specifications, excluding electrical services, was Rs. 20,768 (1979-80 price). The cost of corresponding conventional construction would have been Rs. 22,117 per unit. There was thus an overall saving of 1,348 in the construction of each quarter, itemwise comparison of experimental and conventional construction is given at Annexure IV.

As compared to the plinth ~~area rate~~ of Rs. 435.80 ~~per sq.m.~~ of conventional type of constructions, a plinth area rate of Rs. 409.25 (1979-80) was achieved by incorporating new design concepts, cost-effective construction techniques and materials and modern construction management practice.

As a result of adoption of innovative specifications and techniques in this project, there was a saving of 36.7% in cement and 20.3% in steel. The saving of cement and steel in each item is given at Annexure V. An overall saving of 6.09% was achieved in this project.

Annexure I

Cost-effective Techniques and Alternate Building Materials Adopted in NBO Experimental Projects

A. Foundation

1. Under reamed pile foundation.
2. Hyperbolic paraboloid footings.
3. Leaner cement concrete (1 : 8 : 16) for foundation.
4. Pocket connections for foundations.

B. Superstructure Walls

5. Brick cavity walls.
6. Single thickness load bearing walls for 4 and 5 storeyed buildings.
7. Load bearing concrete panels for walls.
8. Use of modular bricks.
9. Use of improved methods of brick laying and plastering.
10. Polyethylene D.P.C.
11. Light weight aggregate concrete blocks for masonry in partition.
12. Hollow cinder blocks for masonry.
13. Damp proof course in cement mortar 1 : 4 with air entraining agent.
14. Large composite cement concrete panels using hollow blocks and solid bricks.
15. Flyash-lime-gypsum bricks for masonry.
16. Nineteen cm walls for superstructure masonry.
17. Stone block masonry.
18. Rat Trap Bond for Masonry walls.

C. Doors and Windows

19. Precast RC frames for doors and windows.
20. Particle board for shutters of doors/windows.
21. Steel frames for doors/windows.
22. Frameless doors.
23. Coal tar drum sheets for door shutters.
24. Red mud shutters for doord and windows.

D. Roofing/Flooring Slabs

25. Precast channel units for roofing/flooring.
26. Prestressed channel units.
27. Precast cored units for rooring/flooring.
28. Precast cellular units for rooring/flooring.
29. Precast waffle units for roofing/flooring.
30. Doubly curved tile roofing system.
31. Batten and hollow block construction for roofing.
32. Precast concrete folded plate roofing.
33. Precast hyperbolic shell units for roofing.

34. Precast RC 'T-Beam' unit for roofing.
35. Precast RC planks and joists for roof/flooring.
36. Precast 'L' pan roofing.
37. Precast panels with earthen 'kulhars'.
38. Thin RC ribbed slab for floors/roofs.

E. Flooring

39. Stabilised soil cement base for floors.
40. Magnesium Oxychloride flooring.
41. Floor base of 1 : 20 : 40 cement : flyash : sand.
42. Reduced floor thickness.

F. Structural Members (Beam, Columns, etc.)

43. Hollow beams.
44. Precast RC columns and beams.
45. Precast concrete staircase elements.

G. New Materials

46. Use of deformed bars.
47. Partial replacement of cement by flyash.
48. Hydrated lime.
49. Blending of Badarpur sand with Jamuna sand in mortar.
50. Plastic stays.
51. Plastic wash and hand basins and other fittings.
52. Secondary species of timber for doors/windows.
53. Reactive clay pozzolana.

H. Services (Sanitary, Water Supply)

54. PVC pipes for water supply.
55. Single stack system of plumbing.
56. Evaporative roof cooling system.

I. Architectural Planning and Structural Designs

57. Lower ceiling height.
58. Precast lintels.
59. Design based on ultimate load theory.
60. Design for solar energy utilisation.