Demonstrating Cost Effective Technologies

(A Case Study of Bawana Industrial Workers Housing Project)

bmtpc

Building Materials & Technology Promotion Council
Ministry of Housing and Urban Poverty Alleviation
Government of India.

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FOREWORD

Building Materials & Technology Promotion Council since its inception in 1990 has been toiling hard to implement cost effective, energy efficient & eco-friendly building materials & technologies at gross root level. There have been number of success stories, however, the single largest project executed in India using these technologies has been by Delhi State Infrastructure & Industrial Development Corporation (DSIIDC) for industrial workers. Later the same concept was repeated for EWS housing projects by DSIIDC. These projects have been documented by Shri Promod Adlakha, Consultant & Architect, under one of the BMTPC's sponsored study so as to bring the entire gamut of these technologies right from implementation to cost-economics to construction management & quality control for the engineers & architects who are willing to adopt them for ensuing projects.

The technologies used are simple & rudimentary i.e. load bearing construction using modular bricks with cement-flyash blended mortar for structural framing, precast RC planks & joist for roofing & flooring. Also, ferrocement staircase treader–riser units, precast ferrocement sunshades, kitchen platform & precast ferrocement water tanks are used as an alternate to common conventional systems. It has been shown that there is overall saving of more than 20% over conventional construction in civil works. The single stack system for plumbing & sanitation has been used as a digression from the conventional dual stack system giving overall saving of more than 30% in plumbing services. There is also considerable saving of cement & steel which are energy intensive materials and based on natural resources which are finite in nature. Through this real time project, it has also been shown that there is considerable saving in time of construction. The publication presents all the details including cost analysis. It is also equally important to draw a strict QC/QA plan while implementing any new/alternate construction methodology/system. The entire chapter is devoted on these aspects in the publication. In light of Housing for All Mission launched by Govt. of India, it is hoped that this document will become a reference document for professionals and go a long way in BMTPC's mission to mainstream alternate materials & technologies.

The BMTPC's team of Shri Sharad Gupta and Shri Dalip Kumar also deserve a special mention for bringing the document to presentable form in time-bound manner.

It is high time for architects & engineers to bring innovations in clichéd conventional building construction.

Dr. Shailesh Kr. Agrawal
Executive Director
BMTPC

PREFACE

This document describes the Architectural and Structural methodologies adopted keeping in mind the cultural, social & economic needs of the urban poor. Optimizing on cost with respect to housing blocks and layout, use of appropriate cost effective alternative materials & technologies were incorporated in the project with technical support of Building Materials & Technology Promotion Council (BMTPC) and Central Building Research Institute (CBRI).

This document shall play an important role to economize the cost of construction without affecting functional behavior and ensuring reliable and durable “Built Environment”.

This document shall be useful to all planners, Architects, Engineers, Administrators, Builders & Developers, Housing Boards, Development Authorities, Teaching & Training Institutes and Professionals of Government Departments.

Promod Adlakha
Adlakha Associates Pvt. Ltd.

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Chapter 1 : INTRODUCTION

1.1 Preamble

In order to decongest the City of Delhi, it was decided to shift the industries from Delhi's non-confirming areas to the outskirts. DSIIDC was entrusted with this gigantic task of shifting about 28,000 industrial units. For the purpose, 1865 acres of land was acquired, in North West Delhi at Bawana and surrounding areas.

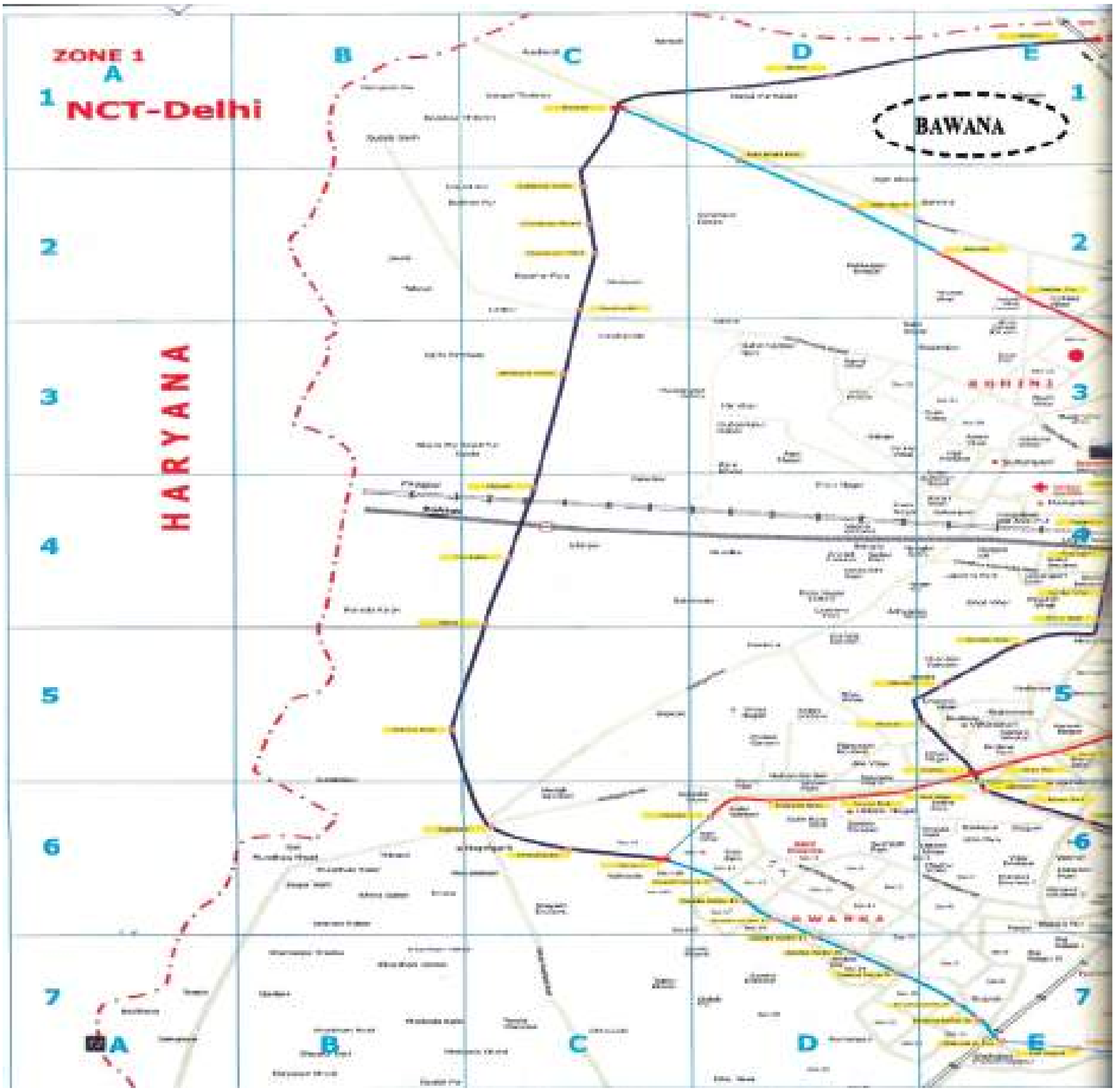


Fig. 1.1: Location of Bawana in Map of Delhi & proposed Metro Connectivity

Bawana Industrial Estate, the largest Industrial Relocation Scheme in Asia, was expected to benefit a work-force of about 2,50,000 persons. The Industrial Estate was also to provide; whole-sale market, raw material market, workshops, warehouses, godowns, offices etc.

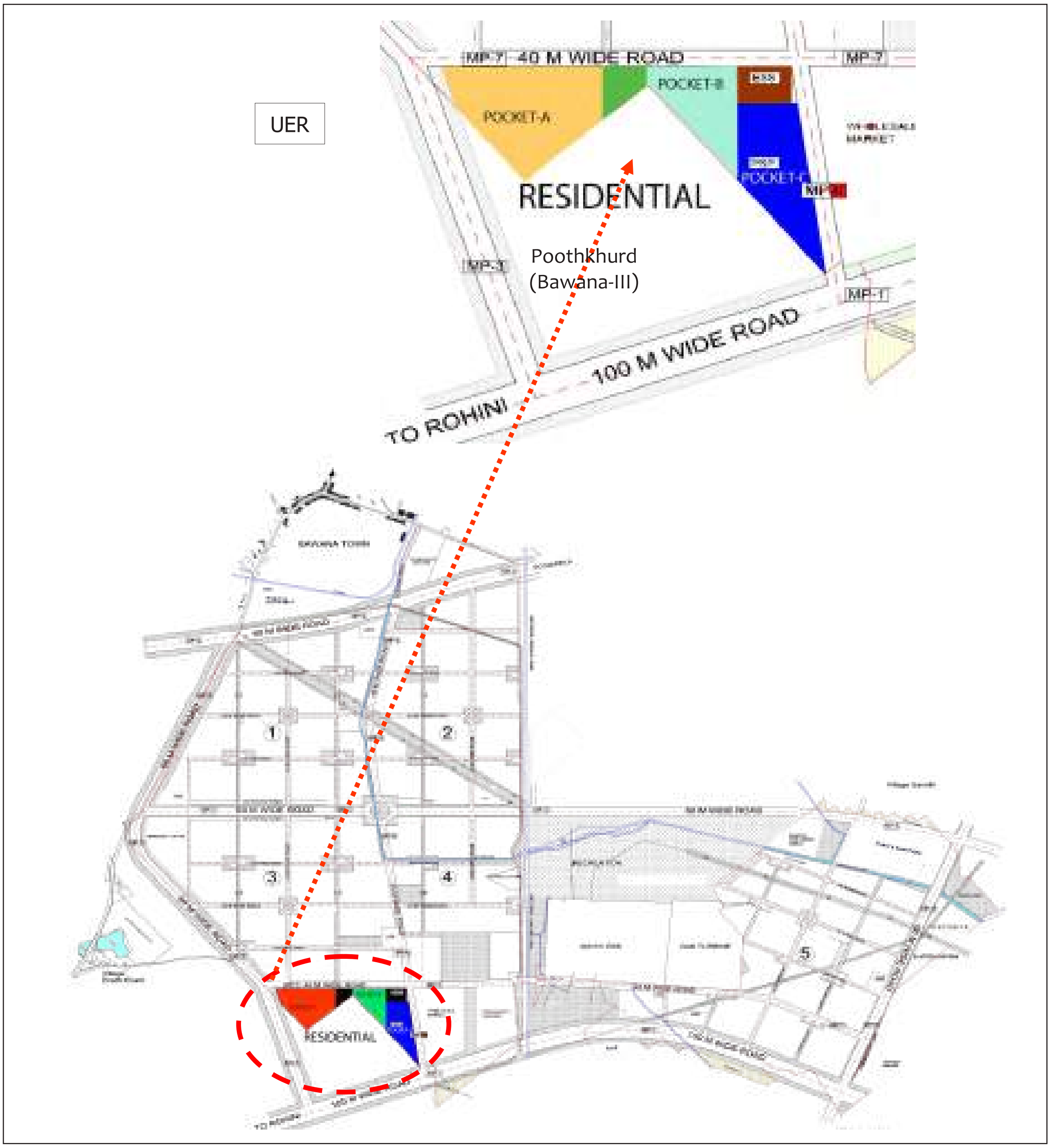


Fig.1.2: Layout Plan of Bawana Industrial Complex (Showing Residential Pocket)

1.2 Rajiv Gandhi Housing Project

Bawana Industrial Estate was also required to provide proper living accommodation for the workers. Accordingly, DSIIDC launched a housing scheme for Industrial Workers at Bawana Industrial Estate. The DSIIDC took upon the responsibility of providing accommodation to industrial workers catering to the relocated industries in this new industrial township. In order to achieve this it has played a leading role in the planning and implementation of this project.

This scheme was meant primarily for providing shelter for poor industrial workers near to their work place so that they were not required to travel long distances. The project was to facilitate economic upliftment of the workers and to reduce time consumed to travel from place of living to place of work and vice – versa so that they have adequate time for relaxing, socializing and looking after their families.

Part of "The Rajiv Gandhi Housing Project" at Bawana has been implemented and dedicated to the people on 19th November, 2006 by the then Hon'ble Chief Minister of Delhi. The project is a good example of effective use of time tested materials along with the use of alternative technologies.

1.3 Project Philosophy and Realization

The Housing Project at Bawana has been evolved on the philosophy of providing a dream home for the poor within the affordable costs without compromising on the quality and creating a living environment congenial to their lifestyle and culture. The aspect of affordability was of prime consideration.

The objectives of the philosophy behind the project had to be achieved while keeping in mind the following:-

- Low Income Housing Norms
- Planning and Design Concept
- Built Environment
- Efficient Infrastructure Development
- Appropriate Specifications
- Optimum Structural Design
- Cost Effective Construction Techniques
- Fast Track Construction
- Efficient Construction Management and Quality Control
- Aesthetic
- Functionality
- Social-acceptance
- Environmental issues
- Sense of togetherness (neighborhood concept)
- Thus the overall concept of the project was evolved.

1.4 Low Income Housing Norms

Since the houses in the project primarily belong to the low income segment, the norms on low income housing as contained in the National Building Code of India have been kept in mind while finalizing the design of the houses. The NBC norms are as under :

- In case of one room house, the size of multi-purpose room including space for cooking shall not be less than 12.5 sqm with a minimum width of 2.5 m.
- In case of a two roomed house, the size of 2nd room shall not be less than 6.5 sqm with a minimum width of 2.1m, provided the total area of both the rooms is not less than 15.5 sqm. In the case of incremental housing to be developed as a future two room house, the bigger room shall always be the first room.
- The minimum size of independent W.C. shall be 0.9 x 1.0 m.
- The minimum size of independent bath shall be 1.2 x 1.0 m.
- The minimum size of combined bath & W.C. shall be 1.80 x 1.0 m.
- The size of a cooking alcove serving as cooking space shall not be less than 2.4 sqm with min. width of 1.2 m. The size of individual kitchen provided in a two roomed house shall not be less than 3.3 sqm with min. width of 1.5 m.
- Minimum height of habitable room 2.6 m, kitchen 2.6 m, Bath/W.C. 2.1 m.
- Minimum width of staircase upto 4 storeyed constructions should be 1 m, risers a maximum of 20 cm and tread a minimum of 25 cm.
- The minimum clear head room shall be 2.1 m.

Beside NBC norms the living habits of the occupants, climatic considerations of Delhi, affordability levels of the class have been taken into account.

1.5 Planning and Design Concepts

1.5.1 Design Considerations

The prime objective of the project as defined already was to create an integrated human habitat suited to the lifestyle and cultural background of the workers. This was to be achieved efficiently to match the affordability of the users. The unit size, type of housing, level of infrastructure etc. to be provided were areas of concern to achieve scalability vis-a-vis affordability and marketability.

Depending on the land cost, land development cost, affordable density, conducive to the overall goal of affordable housing, the desirable design considerations were compiled at dwelling level, cluster level and the sector level. The basic considerations were to reflect economic planning. Self-financing approach was adopted to ensure viability of the project. The development is built at a high density of 300 dwelling units per hectare. The built form reflects the local characteristics and aspirations of the people.

All basic community and institutional facilities and services including basic social services like education, health, recreational areas, essential infrastructure and amenities like water supply, sewerage, storm water drainage, roads, electricity and activities like commercial and other services establishments have been taken care of in the project.

The project has been designed on the basis of a ‘creative’ form:

- The Urban form for maintaining the traditional living pattern of the inhabitants.
- The Design is Socio-culturally sensitive with a strong sense of interaction and unity & identity.
- The design is adaptable to local life-styles and space requirements
- Fostering social interaction and inter-relationship by grouping of the inhabitants.
- The design respects the existing social hierarchies and resultant morphologies in terms of layout, accessibility, proximity and interrelationship.

Providing amenities like community halls, kiosks, schools, women welfare centre, dispensary, tot lots, cycle tracks which serve not only as a functional public node, but also reflect the identity of the inhabitants and their aspirations.

1.5.2: Planning Concepts

The site is broadly divided into 11 Sectors so that the construction sequence is well managed and phased out with the required infrastructure. Each sector works as an independent “Block of Units”. The water supply and sewerage systems have been designed, so that the residents can be allotted the dwelling units in ‘phase’ and that they can move into a cluster even while construction is going on for other clusters. This has helped in easy and efficient implementation of the project.

The development of the project was conceptualized with a focus that Pocket/Sector ‘A’ shall have only Type II houses in G+3 *(Fig.1.3)* and that Pocket/ Sector ‘B’ shall have only Type I houses in G+2 *(Fig.1.4)*.

Fig. 1.3: Pocket A

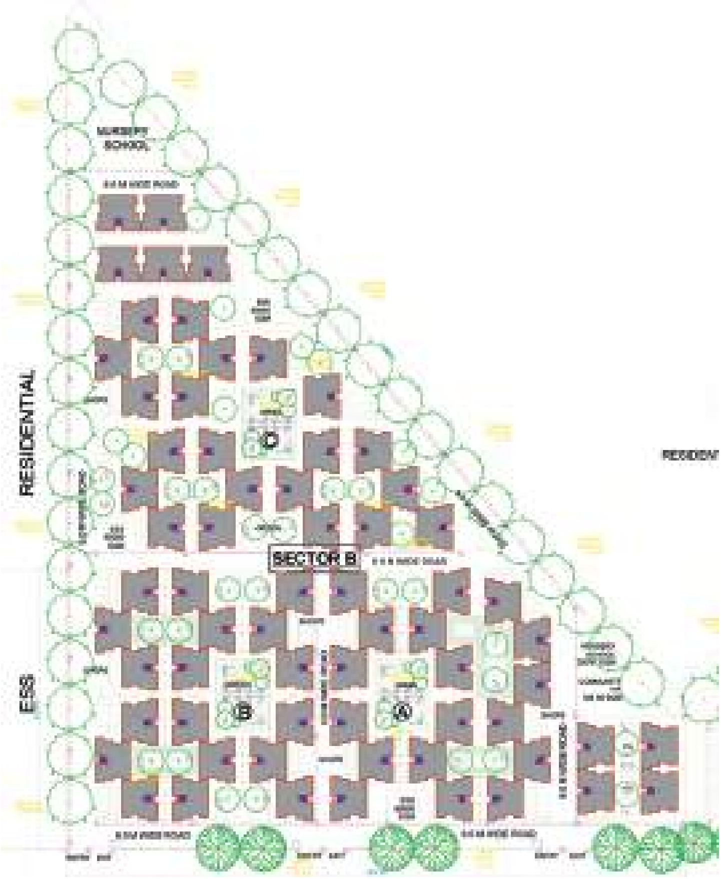


Fig. 1.4: Pocket B

The cluster were planned in a grid pattern with hierarchy of Roads along all sides of a cluster tangential to the front road (MP-7) and parallel to the sides of triangular plot.

Fig. 1.5 shows a typical cluster with blocks of G+3 in Pocket/Sector A.

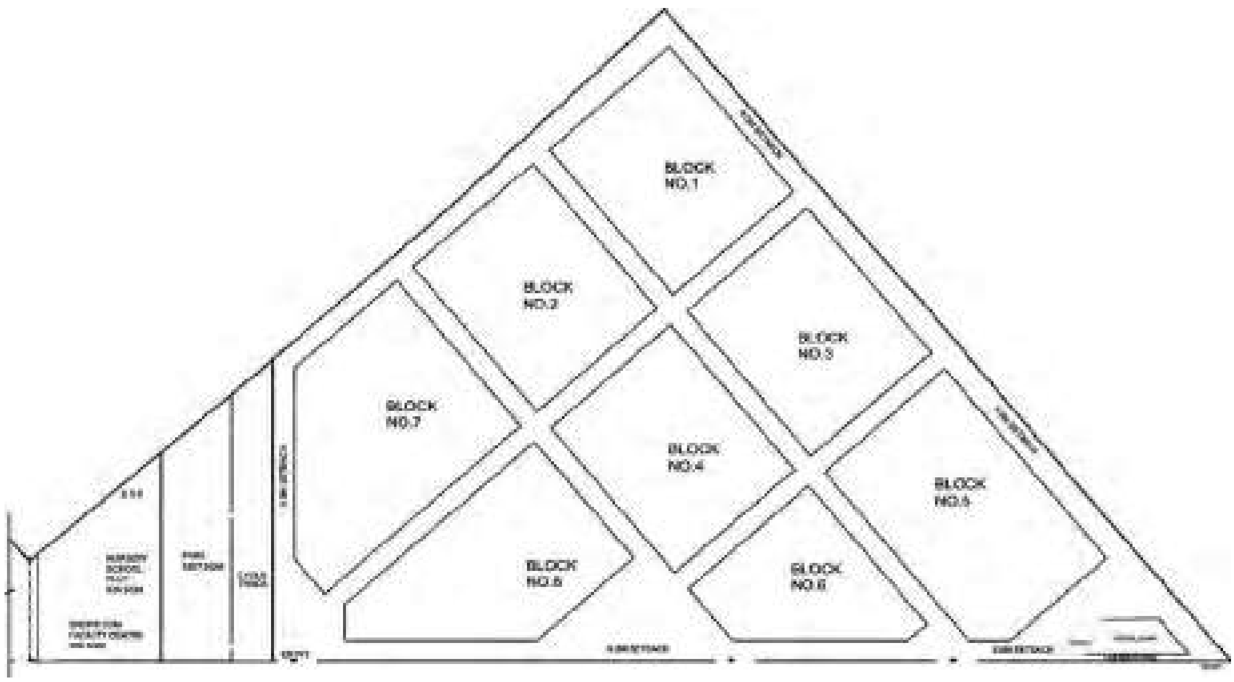


Fig. 1.5: Layout Grid Plan

On the advice of Delhi Urban Art Commission, the entire layout as well as the 'block' dwelling unit plan were modified on the following lines:

i. The separate sectors/pockets for Type I and Type II defeat the purpose of social living.
ii. The large complex should create variation in skyline. Intermixing of both Type I (G+2) and Type II (G+3) would create an interesting skyline.

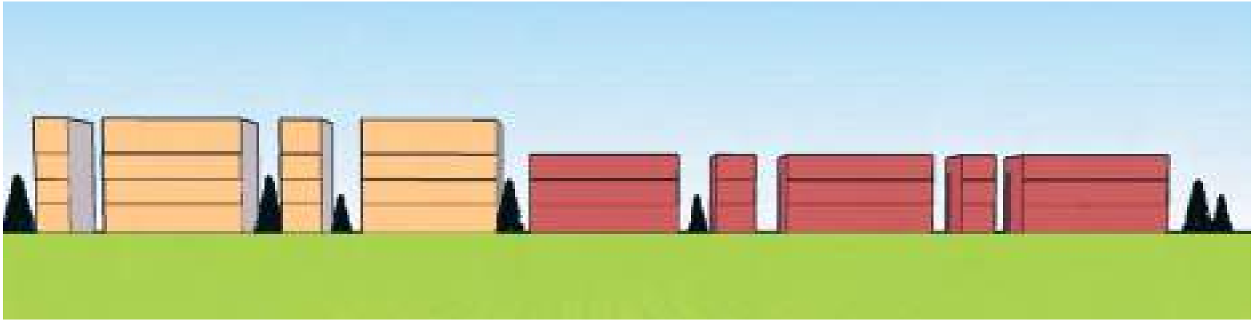


Fig. 1.6: Shows the proposed skyline

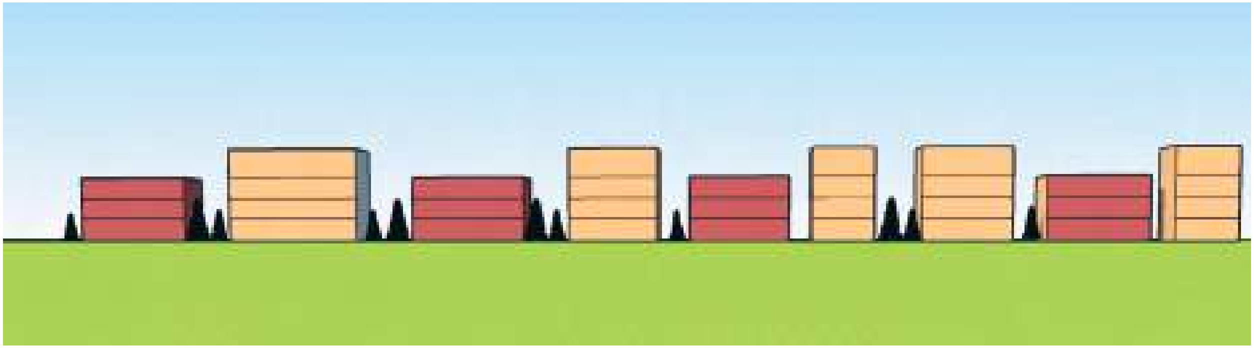


Fig. 1.7: Shows the skyline as per modified plan

iii. The parks were small and scattered like tot lots, which eventually would invite the residents to encroach upon.

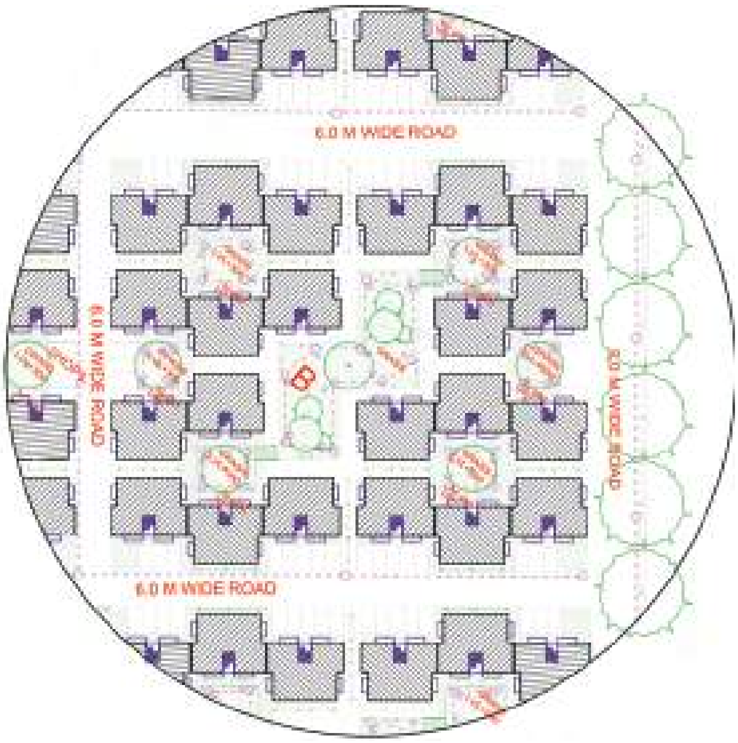


Fig. 1.8

The modified layout plan was worked out on the similar pattern of road network but with intermixing of Type I (G+2) and Type II (G+3) blocks. As per Delhi Master Plan – 2001 the maximum density allowed is 300 DU/ hectare. This could be efficiently planned as a low-rise high density concept with walkable structures. This also prompted to use load bearing concept instead of a framed structure. The modified layout plan is shown as *Fig. 1.9*. A modified cluster plan is shown as *Fig. 1.10*. The cluster has a bigger green court / Park with blocks around the court in a "swastik" pattern.

Fig. 1.9

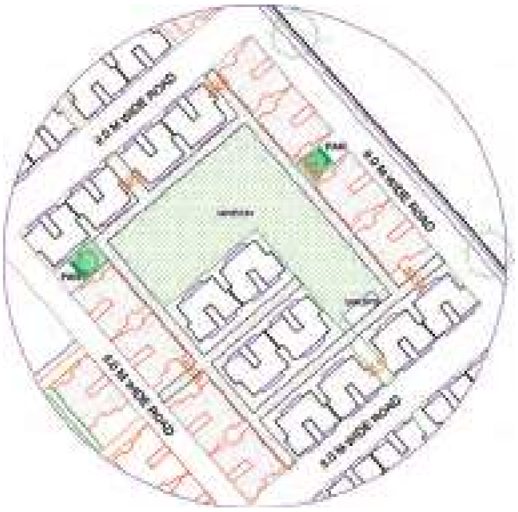


Fig. 1.10

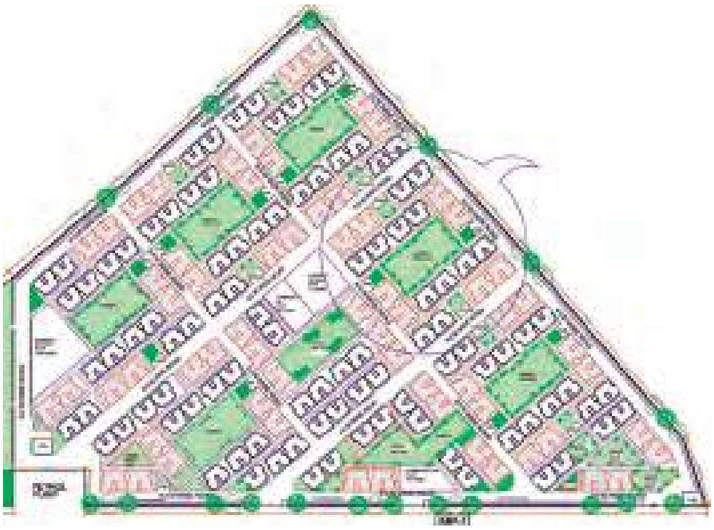


Fig. 1.11

Fig. 1.12

It was further modified with a cluster comprising of combination of twin blocks (*Fig. 1.11*) and *Fig. 1.12* shows a typical cluster.

The layout plan was further modified by merging the small parks with the central large park *(Fig. 1.13)*, thereby creating a wind flow across the cluster *(Fig. 1.14)*. Thus the central green provide a cooling effect in the harsh weather of Delhi.

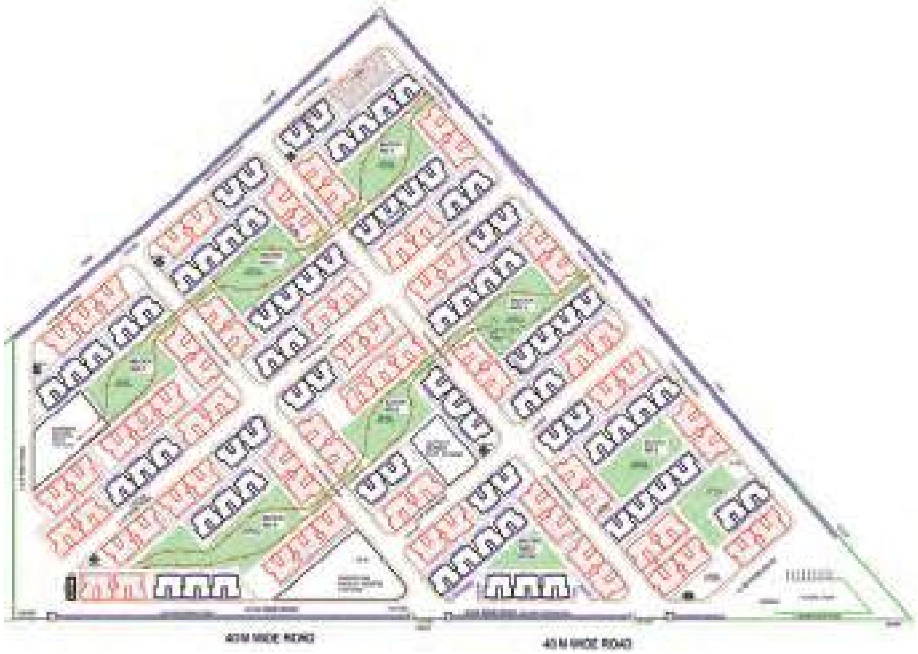


Fig. 1.13

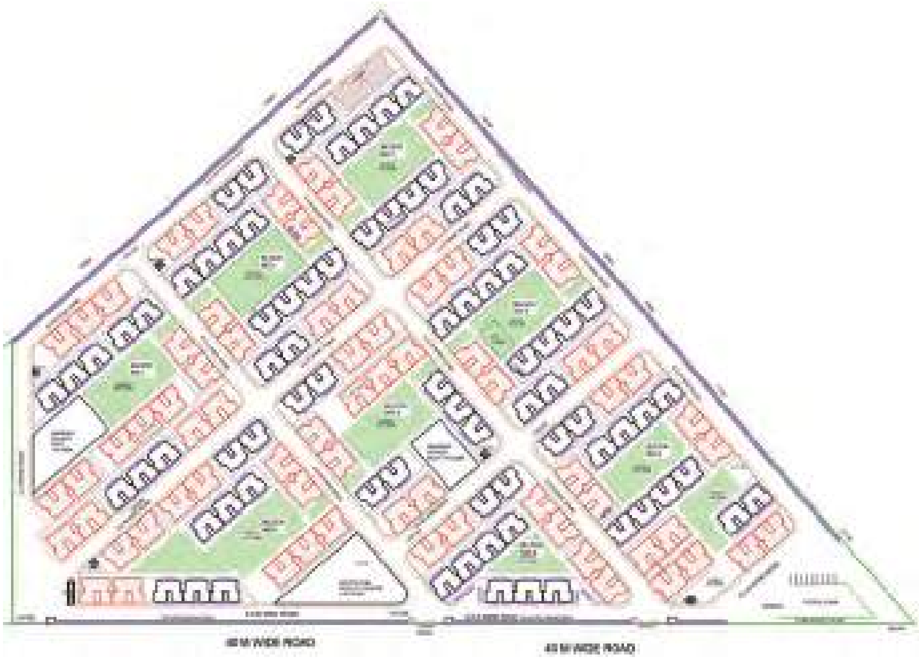


Fig. 1.14

1.5.3 Planning at Sector (Pocket) Level

- To maintain contact with land and greenery.
- To reflect the local characteristics in the built form.
- To encourage interactions and integration amongst the various social groups.
- To segregate pedestrian and vehicular movements.
- To optimize land use, roads and other infrastructure.
- To provide a sense of security.
- To provide daily need facilities within easy reach.
- To provide well-ordered hierarchy open spaces for various activities.
- To provide defined entry points and discourage through vehicular traffic.
- To suit self-financing approach.

1.5.4 Planning at Cluster Level

The design considerations at the cluster level include :

- To promote person to person contact through cluster of human scale.
- To provide an individual character to each cluster.
- To create a functional and pleasing street environment.
- To provide spaces for social & religious activities.
- To provide basic essential amenities and utilities to every cluster.

The cluster is the form of a group which helps in fostering a sense of community, a concept similar to the 'Mohallas' found in traditional towns. The open green square & pathways "Streets" promote person-to-person contact. This is also achieved by giving a sense of boundary and a sense of identity to each cluster. The built form of cluster is in relation to the human scale. The cluster boundaries have been defined by access roads, around the clusters. The small green squares and pedestrian walkways around, not only provide access to various infrastructure to each house but also become focal points for social brotherhood. The green squares act as safe play areas for children and provide for social and domestic get together.

1.5.5 Planning at Dwelling Level

For the house design, a range of options/designs were evolved. The Architectural planning of dwelling units was done with the following parameters :

- To make the dwellings sensitive to the life styles and daily needs of the people.
- To give the dwelling a rich and unique identity.
- To integrate the spaces within and outside the dwellings.
- To maintain privacy within and from outside.
- To consider light, ventilation, climate control.
- To study efficiency of dwelling units w.r.t. internal circulation.
- To use appropriate materials and construction Technologies.
- To make the dwellings simple and economical.
- To propose economic planning of services, structure and substructure.

1.6 Built Environment

Built environment are of two types, viz. measurable & non-measurable. Measurable functions are necessary from the considerations of economy whereas non-measurable functions are important from the considerations of aesthetics, quality of life etc.

The concept of Built Environment involves issues relating to anthropometrics, ecology and environment spaces, building and plumbing services, sustainable development, construction management and economy.

While designing this "Rajiv Gandhi Housing Project" efforts were made to keep above cited parameter in mind for creating an efficient Built Environment in the project. It was observed that a low–rise built form would be more suitable. In case of low rise development the habitants are more in touch with the Mother Earth and the Mother Nature, which provides a sense of comfort.

Protection of outdoor spaces by mutual shading of external walls, shelter from the winds during hot summer and cold seasons, shelter from the dust and reduction of surfaces exposed to solar radiation are some of the other important aspects which have been given considerations for the Built Environment.

1.7 Compliance to Standards and Specifications

Following Standards were followed for Design & Execution :-

- MCD Byelaws
- DDA Byelaws
- BIS Codes
- CPWD Specifications
- BMTPC Specifications
- CBRI Technical Notes
- IRC Standards
- HUDCO Technical Services
- IBC Publications
- National Building Code
- National Electrical Code

1.8 Orientation

Delhi climate requires an orientation of the longer sides of building towards North – South as this ensures less radiation on built form during summer months. Although it is not possible to meet the desired objective for all in a cluster form, yet most of the houses have the desired orientation. Wherever, possible care was taken that most of the houses had the opening facing the prevailing breeze, so as to utilize its cooling effect.

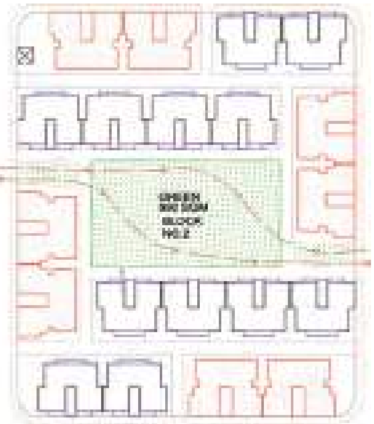


Fig. 1.15: Wind Flow Diagram

1.8.1 Courtyard Living Concept

The problem associated with the low cost housing schemes is that the low cost housing projects lack quality and variety of open spaces. The bias of economics in planning such schemes typically ignore the social aspects and needs while designing.

The problem has been addressed in this project technically by providing blocks in cluster court concepts whereby the "organized" open spaces have been formed to create intimate family links like an enclosed form and expression of a public square.

The courtyard type of built form is very suitable, as the open courtyards are excellent thermal regulators. Deciduous trees & plants provide shade in summer and allow the low sun in winters.

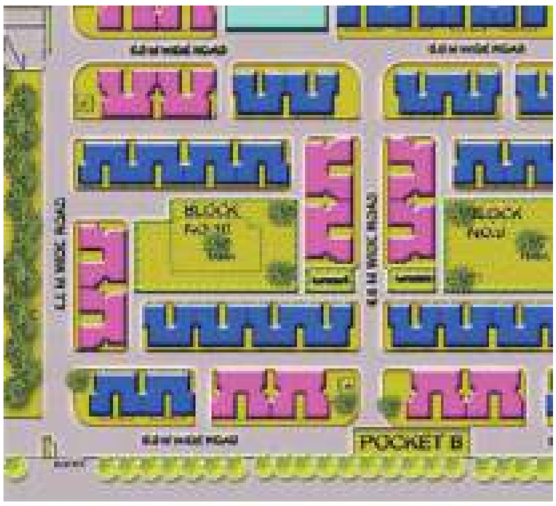


Fig. 1.16: Courtyard Concept Image

Fig. 1.17

1.8.2: Public squares spreaded with large trees located in the centre or at a corner of the squares are a common feature for meeting of the habitants. The space beneath such shady trees is used as an outdoor meeting place, work place and porches.

1.8.3: Similar meeting places have been created around the trees planted along the periphery of the settlement and in other green spaces.

Fig. 1.18

Fig. 1.19: Sit Outs

1.8.4 Automobile traffic in low income housing settlements is limited. This does not mean, however, that there is no vehicular traffic in the area but its conglomeration may be different. There are smaller vehicles in lower income housing than the conventional housing. The smaller vehicles include bicycles, mopeds, motor rickshaws, auto-rickshaws. It is a mindset of people to park the vehicles closer to the house, than in specified parking spaces.

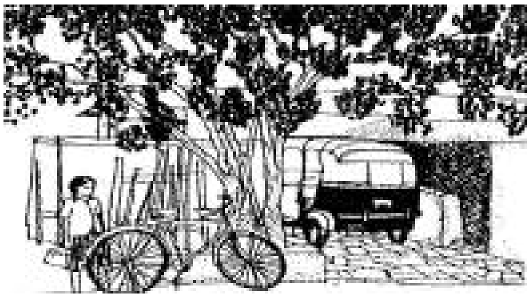


Fig. 1.20

1.8.5 The layout is done such that these specified spaces are closest to each block of houses. Parking spaces have been created in each cluster and the access ways between the blocks are wide to accommodate such vehicles, wherever required.

Fig. 1.21 – Pathway

Fig. 1.22 – Parking lot

1.8.6 In informal settlement, streets are generally narrower than functionally required. In this project, the pathways are 2.5 to 4m wide. The vehicular access streets/roads are 9m wide (Right of way) and thus houses set-backs are minimum 9m across the road.

Fig. 1.23: Showing Pathway & Road

1.9 The Neighbourhood

The neighbourhood, commonly defined as community living & its coherence found in villages as the social pattern of living in the countryside, is of fundamental importance to this scheme in order to provide a feeling of togetherness.

The Universal needs of a family life are basically same; where in basic instincts of a human being govern the needs with some variations as a result of social, climatic and geographical effects. The neighbourhood system if available is applicable and acceptable in both urban and rural areas equally.

The framework of a model community is a distinct identity classified under the following :-

- Residential Environment
- Elementary Schooling
- Small parks and play grounds
- Local Shops / Kiosks
- Facility Centres

1.9.1 Under the term 'residential environment' is included the quality of architecture, the layout of roads, and pathways/streets, the plantation along ends of corner blocks, the arrangement and setbacks of buildings and their linkage to the meeting places. The commercial links to the dwelling places – all the elements, put together create an environment and constitute a worth living characteristic atmosphere.

1.9.2 Small Shops / Kiosks have been planned in addition to formal markets / shopping areas. These kiosks by the nature of their commerce are exclusively oriented to local needs, and their intimate proximity to the home and along main roads around cluster corners in open spaces. Without the organized small shops, the houses at ground floor, facing the roads normally become commercial centre and as such are not desirable. *(Fig. 1.24 & 1.25)*

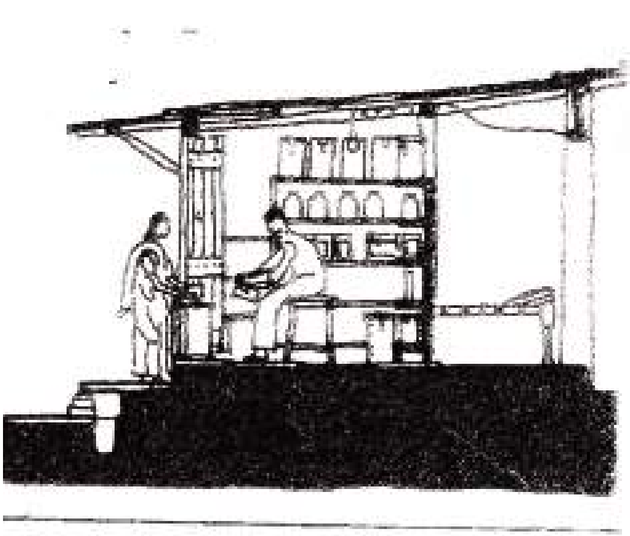


Fig. 1.24: Temporary unauthorized structure for shops (Undesirable)

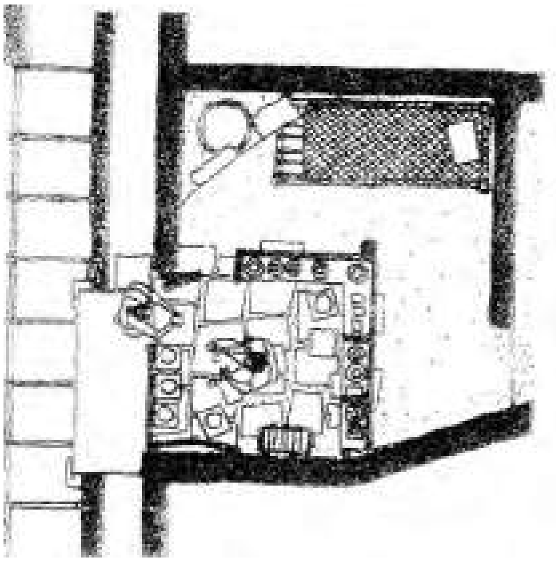


Fig. 1.25: Shop opened in houses (Undesirable)

Fig. 1.26

1.10 Distribution of Open Spaces

At the cluster level as well as at Sector/Pocket level, the open spaces have been organized in a linear fashion so as to lend continuity. The pedestrian pathways along the open spaces short circuit the formal road pattern. The green area divided into each cluster has been linked with clusters through small green areas. The pattern and distribution of open spaces has been linked with location of various facilities, amenities and the road network, so as to evolve a compact network for the colony.

Informal day to day shopping through kiosks has been provided along the green spaces to form public squares. Thus the land has been put to optimum use without loss of spaciousness. Due to the location of social facilities in open spaces, there are better chances of these spaces being used, maintained and self-policed against illegal encroachment.

1.11 Social Facilities and Amenities

The facilities and amenities provided in the colony are given in table below. Each sector / pocket has been organized to incorporate the required facilities and amenities so as to sustain a viable community. The amenities include primary schools, kiosks, community centre, facility centre, petrol pump, rickshaw stand, informal weekly market, Elect. Substations, mother dairy booth, crèche, library, dispensary, essential shops.

Community activities have also been combined with open spaces, thus promoting multiple use. The boundaries have also been demarcated for social facilities.

1.12 Landscape Design

1.12.1 In most conventional housing projects, landscaping is considered as a frill. In Bawana Housing Project, Landscaping and tree planting has been considered as integral part of the planning process. The trees have a strong significance in low-income areas as various social, domestic and work activities are performed beneath trees. Trees become focal points. They modulate spaces and enhance the quality of living environment. The plantation of trees, grass and shrubs has been done for unbuilt open areas in squares. Plantation of hardy plants has been emphasized.

Another important aspect of the tree plantation exercise was to carry out at an early stage of land development, so that by the time, the township is ready for occupation, the vegetation would reach a stage of maturity and could serve its purpose. This step had been taken up right at the beginning to create a habitable environment.

1.12.2 Plant Selection

Plants are an important component of landscape. Following factors have been kept in mind while deciding the nature of plants to be put in the project :

- Ecology
- Botany
- Horticulture
- Aesthetics
- Growth & survival
- Environmental function
- Maintenance

1. Emphasis has been laid on branching and flowering pattern at corners of the lawns.
2. Trees have been planted along the boundary wall with tree guards in exposed brick and Kota stone in order to enable these spaces to be utilized for sitting under the shade.
3. Being low rise structure, emphasis has been made for using medium size trees.
4. Situated in an industrial area and along the 40m road, vegetation buffers have been provided along the boundary wall which acts as pollution sinks, as the leaves absorb pollutants.
5. Small green areas / small parks have pipe railing in orange colour provide the protection from misuse of the park.
6. The multi coloured Concrete Park railings add to the aesthetics besides providing privacy protection & identity.

Photo 1: A few landscaped features

1.12.3 Construction details, specification and methods used for the landscape elements include.

- Paved areas as 'soft' areas for pedestrian use with interlocking pavers, which are porous and minimize the heat island effect.
- Edges, kerbs, bumper stops, ramps, steps, planters, railings and other protection devices.
- Boundary wall, fencing and retaining walls.
- Tree gratings with exposed brick & kota stone finish as street furniture.
- Low level park boundaries with kota stone top finish as street furniture.
- Structures in landscapes such as gate houses, kiosks.
- Site utilities such as saucer drains, storm water drains, manholes, catch basins, outdoor lighting fixtures, electrical feeder pillars, all provide aesthetics merged with parks.
- Outdoor signage.
- Provision for handicapped wheel chair access and movement.

Photo 2

1.13 Land use Pattern

The land use pattern has been evolved in a manner to achieve a net density of 300 D.U./Ha., the other details are as follows :

		Pocket A, B & C
• Total Plot area (Pocket A,B,C)	=	1,50,000 sqm (15 Ha)
	=	37 Acres (approx.)
• G.F. coverage achieved	=	29.91%
• Area under Roads & Parking	=	27%
• Area under Pathways of soft areas	=	10%
• Area under green tot-lots/parks	=	20%
• Total FAR achieved	=	105

Community Facilities

- Primary School = 4 Nos.
- Kiosks = 21 Nos.
- Community Centre / Facility Centre = 4 Nos.
- Local Shopping cum Facility Centre = 1 Nos.
- Women's, Welfare Centre = 1 Nos.
- Security Check posts = 5 Nos.
- Rickshaw Stand = 1 No.
- Informal market = 1 No.

Table 1

Category	Plinth Area (sqm)	Carpet Area (sqm)	No. of Storeyes	No. of DUs	No. of blocks
Type I	31.60	24.47	G + 2	1500	125
Type II	37.73	27.61	G + 3	1664	104
Type III	39.96	28.92	G + 3	1184	74
Total				4348	303

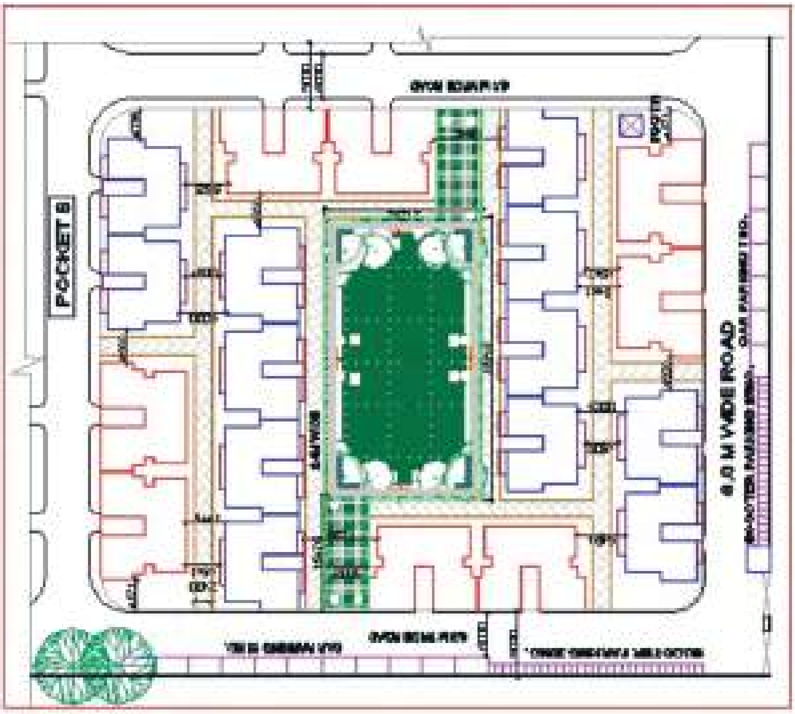


Fig. 1.27: A Typical Cluster

The ground coverage has been limited to 30% and low rise (3 & 4 storeyed) structures have been provided so as to have desired open areas. The organised green areas e.g. Parks and Tot lots are about 20% besides the other green patches which further accounts for approximately 5%.

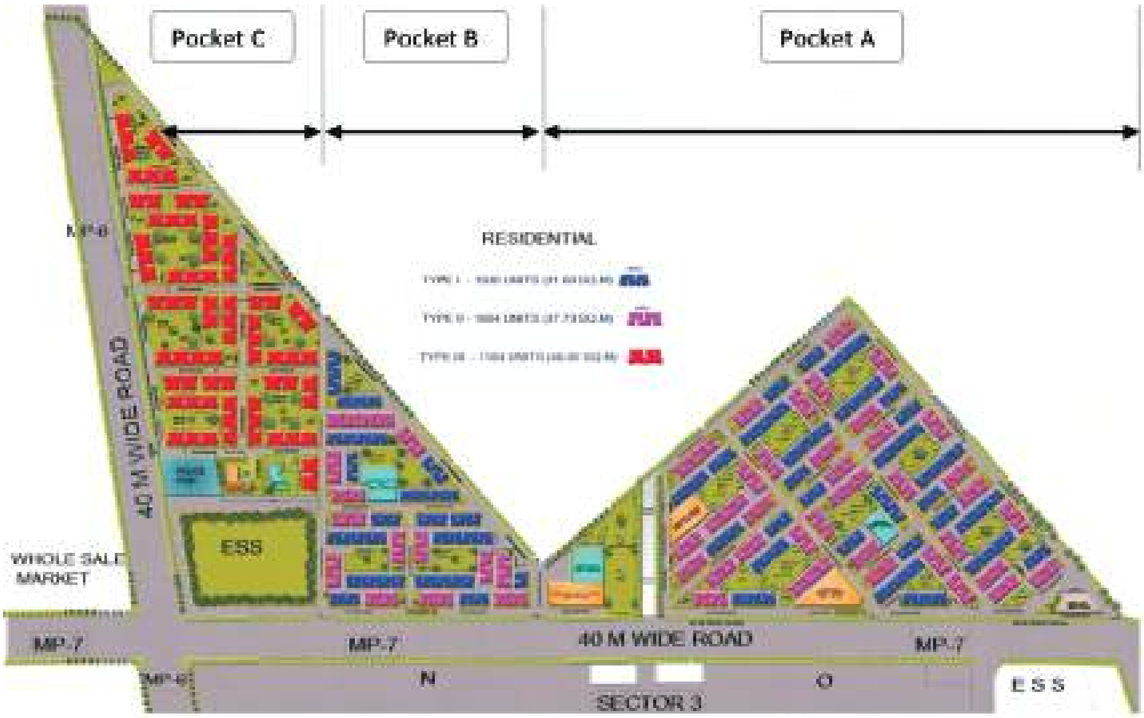


Fig. 1.28: Layout Plan

1.14 Traffic Planning, Road Network and Blocks Articulation

The blocks have been planned to give better and equal relationship of green space, parking and approach. The blocks offer privacy, natural light and ventilation to all the flats. From the point of view of articulation of the building blocks and open spaces, relationship of fenestration's, road pattern, and parking layout have been provided in such a manner that central green area merges with the parks, improves the environment and livability of the inhabitants of the complex.

While designing an appropriate circulation network, the various elements of the habitation have been taken into account. The grid pattern has been principally adopted. Through traffic has been excluded. The system of road network follows a clear hierarchy in terms of width. The street pattern within the cluster has clear identity to the streets which has created a functionally sympathetic and aesthetically pleasing street environment. Forming cluster around green squares also helped in providing economic infrastructure and easy access from the streets. The strips of land 1.5m wide on either side of the road earmarks a transition zones from where the housing activity starts.

The road network has three hierarchies :

- Access road 40m wide
- Internal Roads 9m wide
- Pathways 3.5m wide

There are no dead ends, thus facilitating smooth vehicular traffic.

The access to each Sector/Pocket has been controlled by limited entry points, which enhances the domain of the neighborhood. The central open space of each cluster is free from vehicular movement or parking areas, whereby this open space can be effectively used as community activity space too, for small children

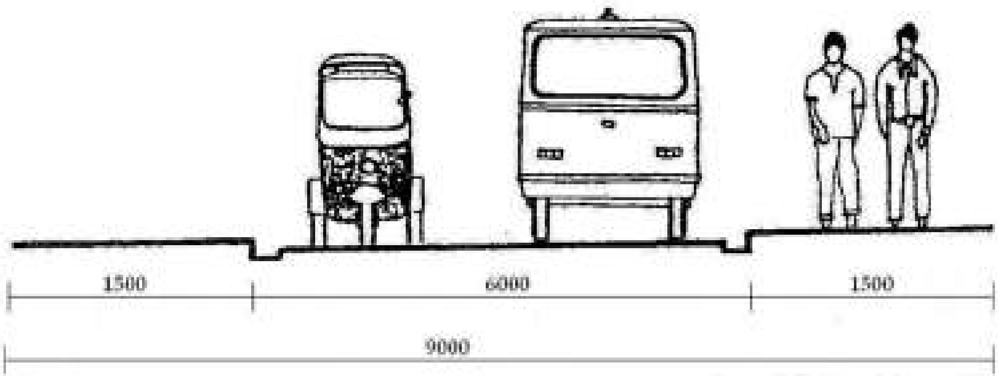


Fig. 1.29: Road Section (Pathways for pedestrians along road)

to play, while their parents can keep a watch overlooking them. The green tot lots spaces can be used for family functions also.

Another concept in the road network is the secondary linkage with pathways in each cluster. These pedestrian pathways cut through the access roads and join the other clusters pathways. Properly landscaped public spaces are located around these pathways. Continuous pedestrian flow with centralized green linkage is an important feature of the project. At nodal points, that is intersection of roads, 'kiosks' have been planned in each cluster.

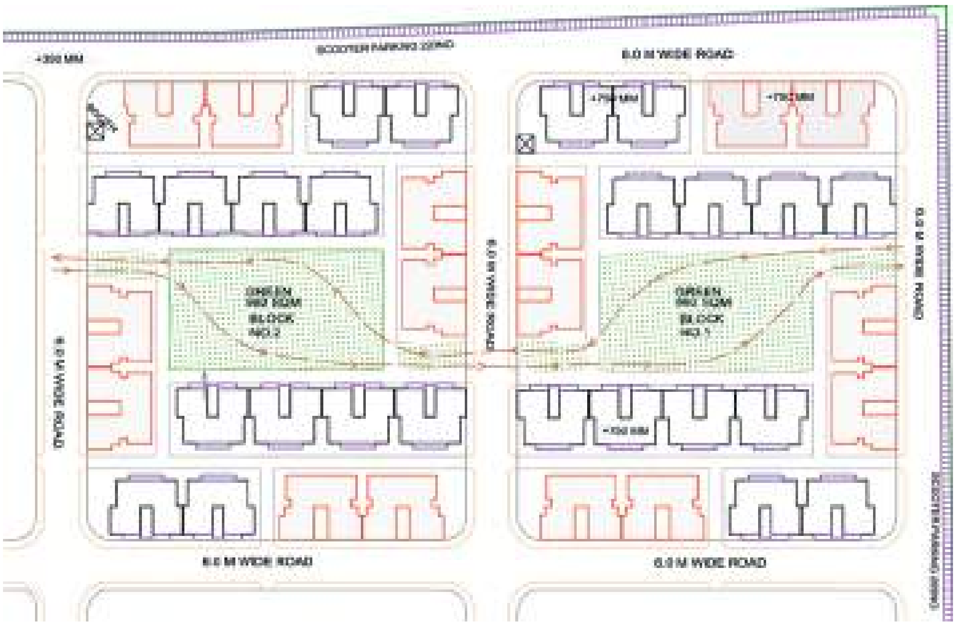


Fig. 1.30: Two clusters together

The colony belonging to Economically Weaker Sections of population shall have low vehicle ownership. The development has pedestrian pathways which is amply justified ensuring its intense use. Between the pocket A and B an eighteen metre wide "Cycle Track" has been provided extending through Industrial Estate.

The metalled road width has been reduced to 6m while keeping minimum setbacks of 9m between two blocks. The road width is sufficient to cater to the volume and type of vehicular traffic including the emergency vehicles such as Fire tenders, Ambulances, Sanitation Vehicles, etc. The parking areas shall be used by LTVs and have been paved with using precast low density paver blocks, laid on a sand cushion; thus allowing the percolation through the joints between the pavers legitimately thought as soft areas.

The paved areas that are used for movement of vehicles, pedestrians and wheel chair users in outdoor environment have been designed to facilitate easy accessibility, with well drained surface and good visual views.

The berms have been provided on all roads along the drains which adequately control drainage within the road, prevent moisture from entering the subgrade and separate the road from the pedestrian area. They also provide lateral support for the roads & pavement.

Pathways have been separated from the road by mean of using concrete segregated from black top roads, which provides both physical & visual separation. Pedestrian pathways are adequate for light vehicular use emergency.

1.15 Services Network

The linear layout of Road network the services such as sewerage, drainage, water supply, pathways provide economical solution.

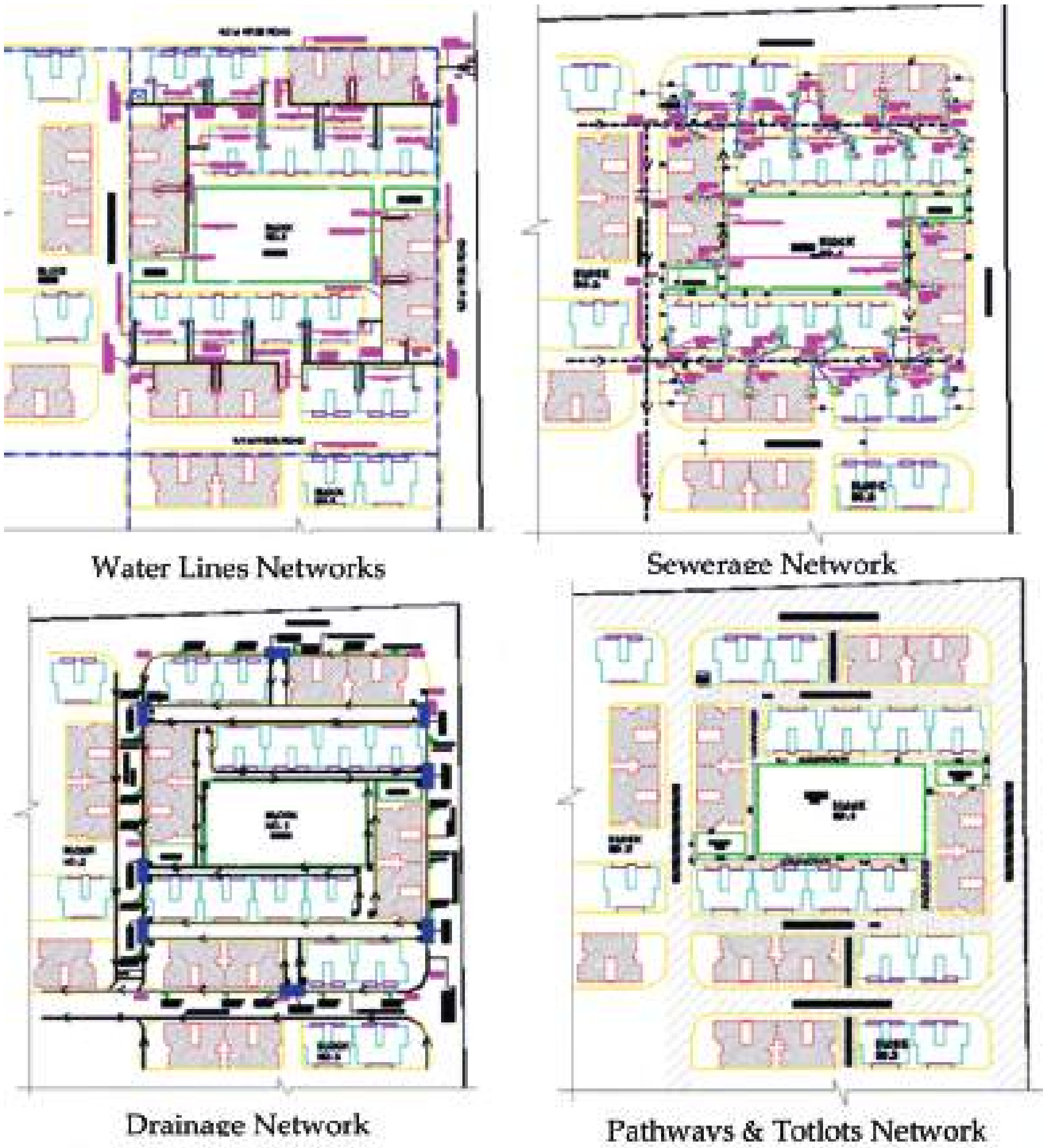


Fig. 1.31: Services Network

1.16 External Lighting


Photo 3: Electrical Poles & High Mast Towers

1. Landscape lighting has been provided by providing pole mounted light fixtures in a mast of 13.5m ht. within the park. Masts have been preferred as the bollards are prone to vandalism and damage. Street lights fixtures have also been provided on the main Electrical poles instead of a separate street light pole for economy and also that it takes into consideration energy saving, safety aspect, lighting pollution and illumination level required.
2. The small hanging transformers on poles rather added to the features.
3. The poles have been provided along the boundary walls or on the edges of the side walk with clear width of 1.5 m for circulation path.

1.17 Provisions for differently abled People


Photo 4: Ramps

1. All pathways provide easy access, approach and safety to the wheel chair users.
2. Entry to all parks is user friendly.
3. The kerb stones & drains along the roads provide physical barrier.
4. The junctions of roads & pathways have been rounded for safety.
5. The entry to blocks are wide enough (4.5m setbacks) that in case of emergency ambulance can be approached at entry point of each block.
6. High masts lights in parks surrounded by the blocks provide adequate illumination, for safety.
7. The top finish of manholes and inspection chambers covers are in alignment or flushed with the pavement, so that they facilitate easy and unobstructed movement for handicapped persons.
8. Different texture finishes & change in levels in different colours provide visual aid to handicapped for accessibility.
9. The change in level at entry in the stair well within the block has been provided with a ramp instead of steps.

1.18 Space Visualization and Blocking

Each block has 4 dwelling units on one floor served through one common stair case. Thus three storeyed blocks have 12 dwelling units in one block and four storeyed blocks have 16 dwelling units in one block.

Blocks have been in combination of two, three and four blocks in a row. These blocks have been articulated to form a cluster. By adjusting the block lengths in a cluster it had been possible to adjust the pedestrian permeability of the grid resulting in an openness at all ends of the clusters. Plantation along the perimeter of central open area has resulted in enclosed open space which is used as common garden and playground insulated from traffic.

The buildings clearly define the passage from the public space of street and side walk into the shared space of landscaped courtyards (parks). These courtyards are bounded by the units they serve and most of them have views into the outdoor space. This ensures that the children can play within sight and at calling distance of home. These courtyards (parks) are human scaled with a height to width ratio of about 1:1 to 1:2 and its boundaries are fenced, yet have easy access giving simultaneous effect of openness and privacy.

Photo 5: Space Visualization

The post occupancy evaluation and related studies of many such neighborhood schemes in various countries indicate how effective shared outdoor space can be as a significant component of the landscape wherein it is bounded by the dwellings it serves and is clearly not a public park.

The public park of about one hectare area has been centrally placed between Pocket A & B for older children to play their usual games of football, hockey, cricket etc.

Fig. 1.32: Park between Pocket A & B

1.19 Grouped Squares

Each cluster resembles a square. The visual impact of a group of squares may be compared with the effect of a cycle of murals. In both instances, each “sub block” the individual “square” (Cluster) and the single “block represent an entity per so, aesthetically self-sufficient and yet part of a comprehensive higher order – individuation and unity”.

Photo 6

In analogue on a more limited scale would be the relationship of successive rooms inside a “palace” the first room preparing for the second, the second for the third, and so on so forth; each room meaningful as a link in a chain beyond its own architectural significance. Similarly, individual ‘squares’ (Cluster) have been fused organically and aesthetically into one comprehensive whole.

The mental aesthetic effect of whole has been further enhanced due to successive images of changing heights (3 storeyed & 4 storeyed blocks)

Photo 7: Three & Four Storeyed blocks successive image

1.20 Dwelling Units

Design Requirement for Dwelling Units

In general the low cost housing as a standard dwelling unit comprise of a multipurpose room with a cooking corner and a toilet. Such dwelling units are very small due to economic reasons and do not take into account the socio-economics characteristics of the occupants.

The stereo type housing along a common corridor (such as chawls in Mumbai) have been common in sight, but such housing lacks in individual identity, privacy and vitality and are abandoned by the users after occupation.

In this project, as the dwelling units envisaged were of smaller area, there was a need for sharing of spaces for different activities at the dwelling unit level. To cater to the various work activities, outdoor space in the form of verandah had to be provided. The main design criteria of the dwelling units were to ensure maximum utilization of the space and to minimize circulation areas, with as much light and natural ventilation. The planned dwelling units give an owner pride of owning it. There are two type of houses Type I *(Fig. 1.34)* and Type II *(Fig. 1.36)*. Type I comprise of a living room, a multipurpose room, W.C., Bath, Balcony.

The Type II houses comprise of a living room with verandah, Bed room, Kitchen, Toilet.

The initial concept for Type II houses had a combined toilet (Bath + WC) *(Fig. 1.33)*. However, in the final stages, the toilet was converted into separate Bath and W.C. *(Fig. 1.36)*

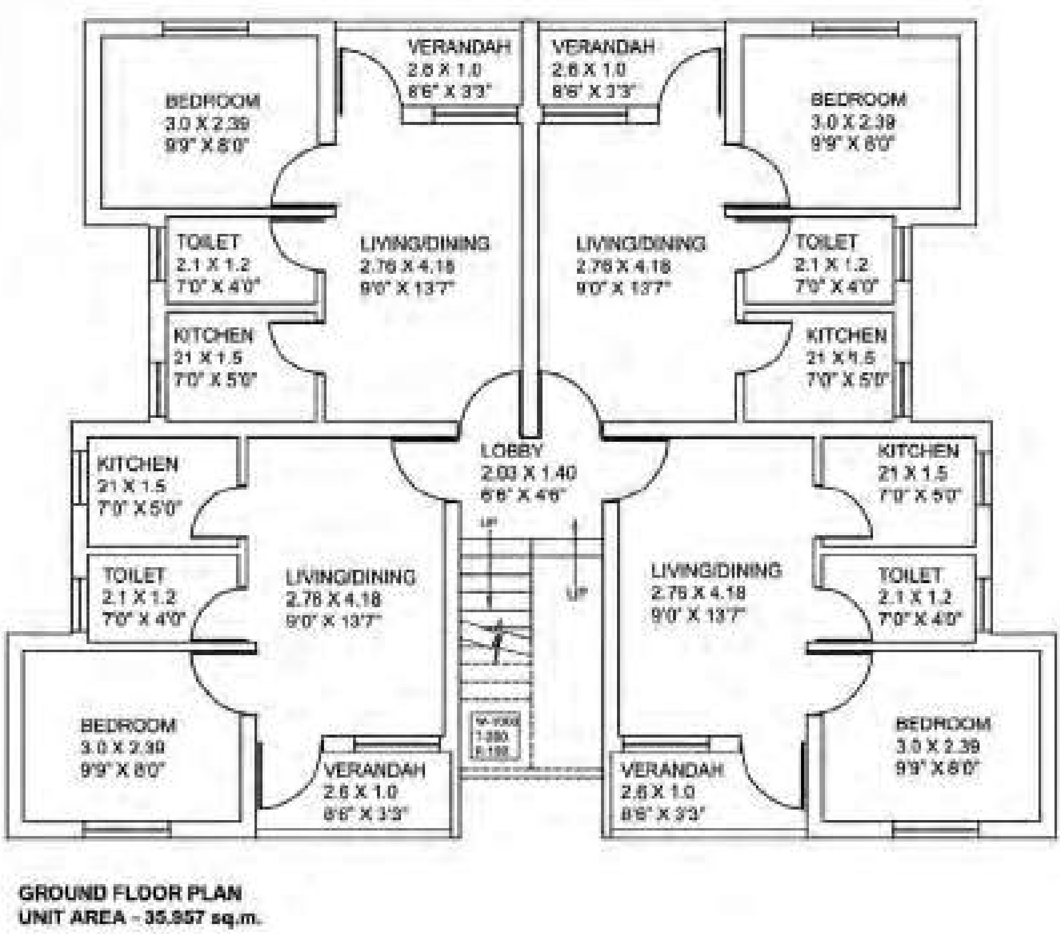


Fig. 1.33: Initial concept of Dwelling Unit plan in G+3 (35.96 sqm) – Type II with combined Toilet

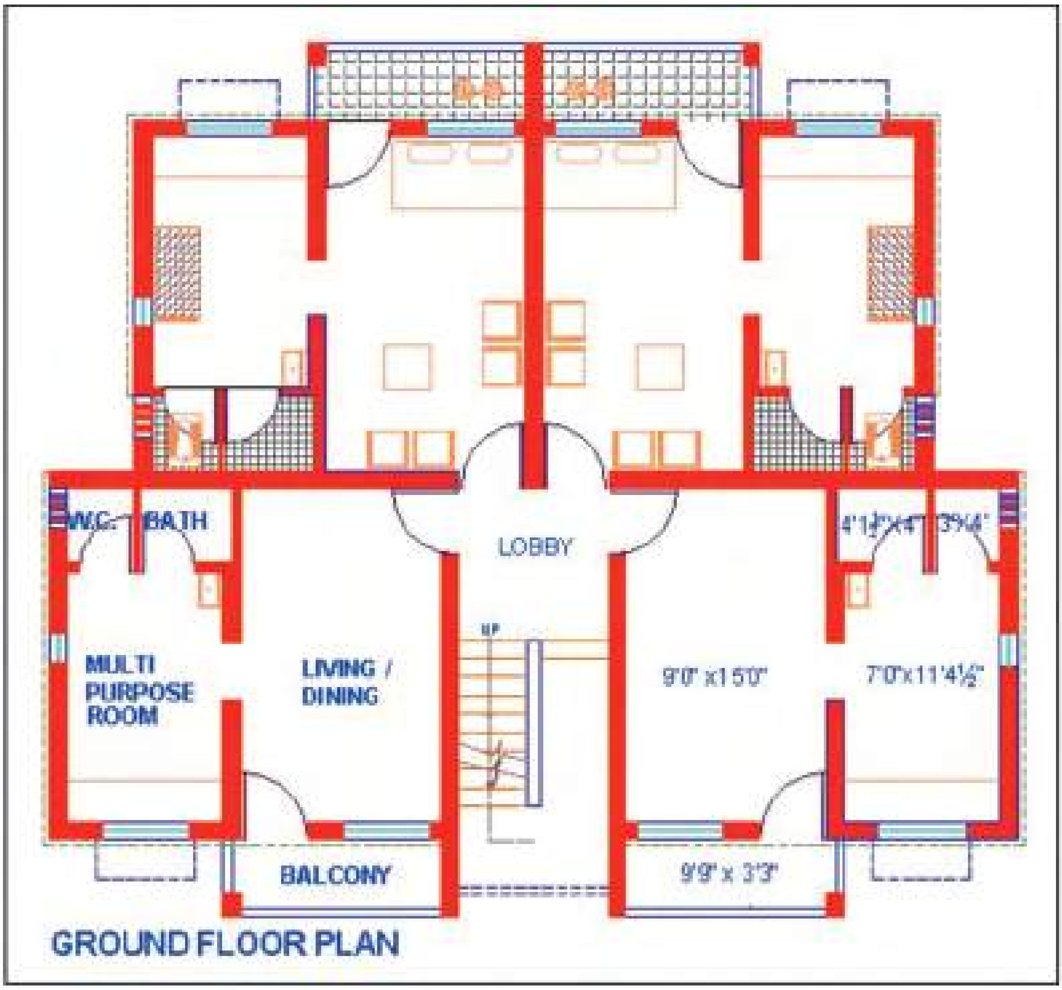


Fig. 1.34: Shows the Dwelling Unit plan in G+2 (31.73 Sqm) – Type I

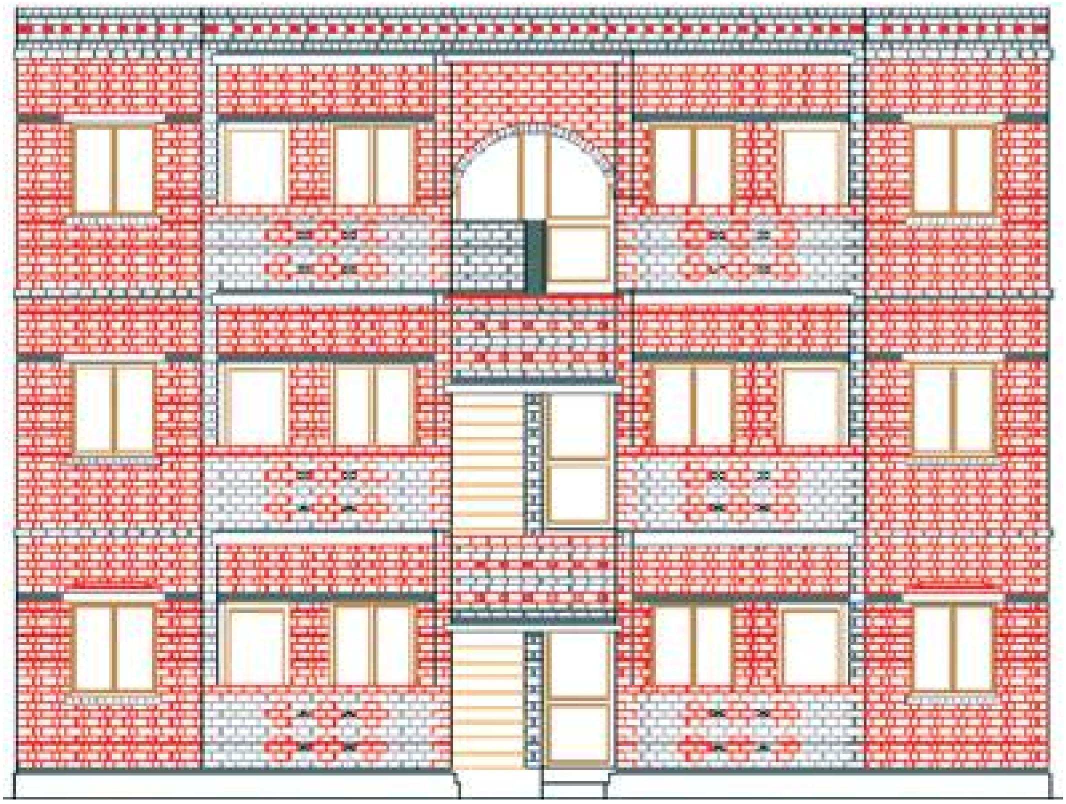


Fig.1.35: Front Elevation-Type I

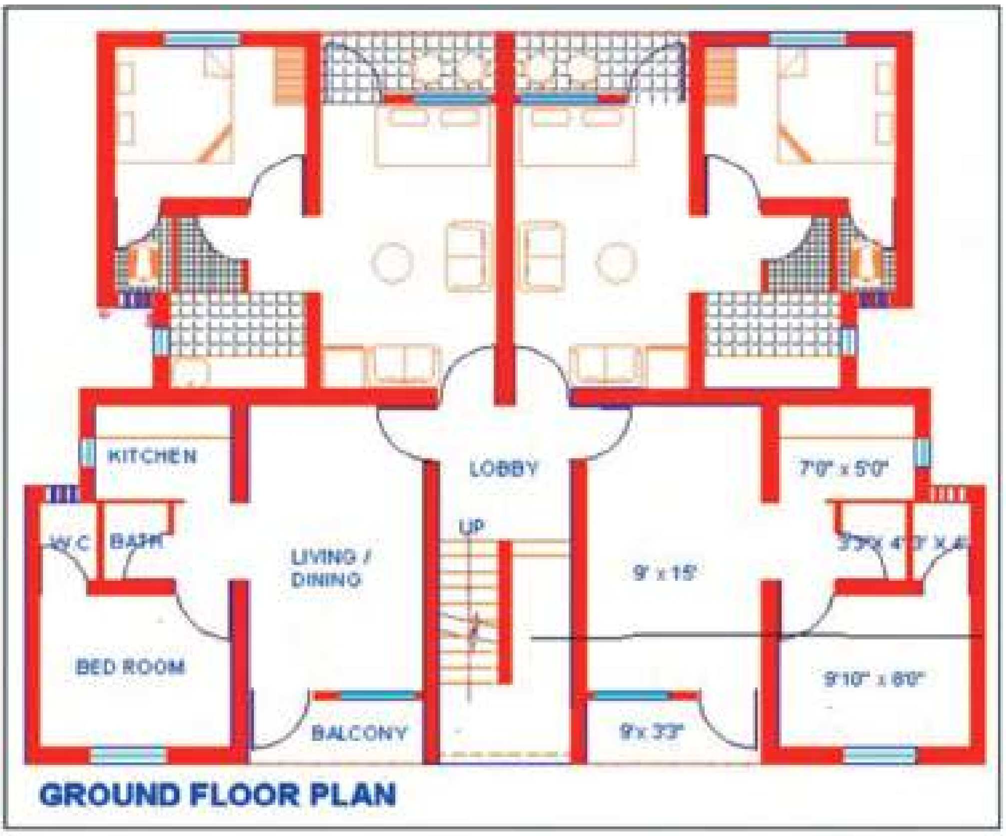


Fig. 1.36: Shows the Dwelling Unit plan in G+3 (Type-II)

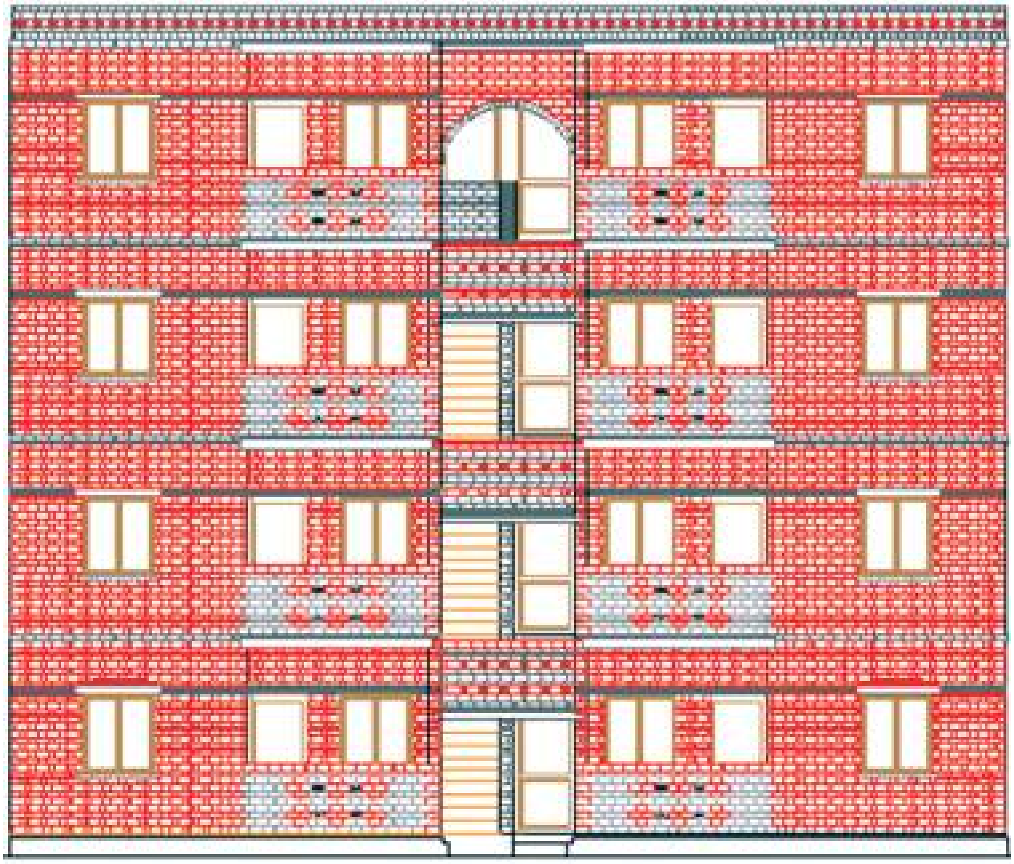


Fig.1.37: Front Elevation-Type II

The Scheme was further extended to Pocket ‘C’ wherein a new unit comprising of 39.96 sqm area in G+3 blocks are developed.

Fig. 1.38: Shows the Typical Floor Plan (Type III)

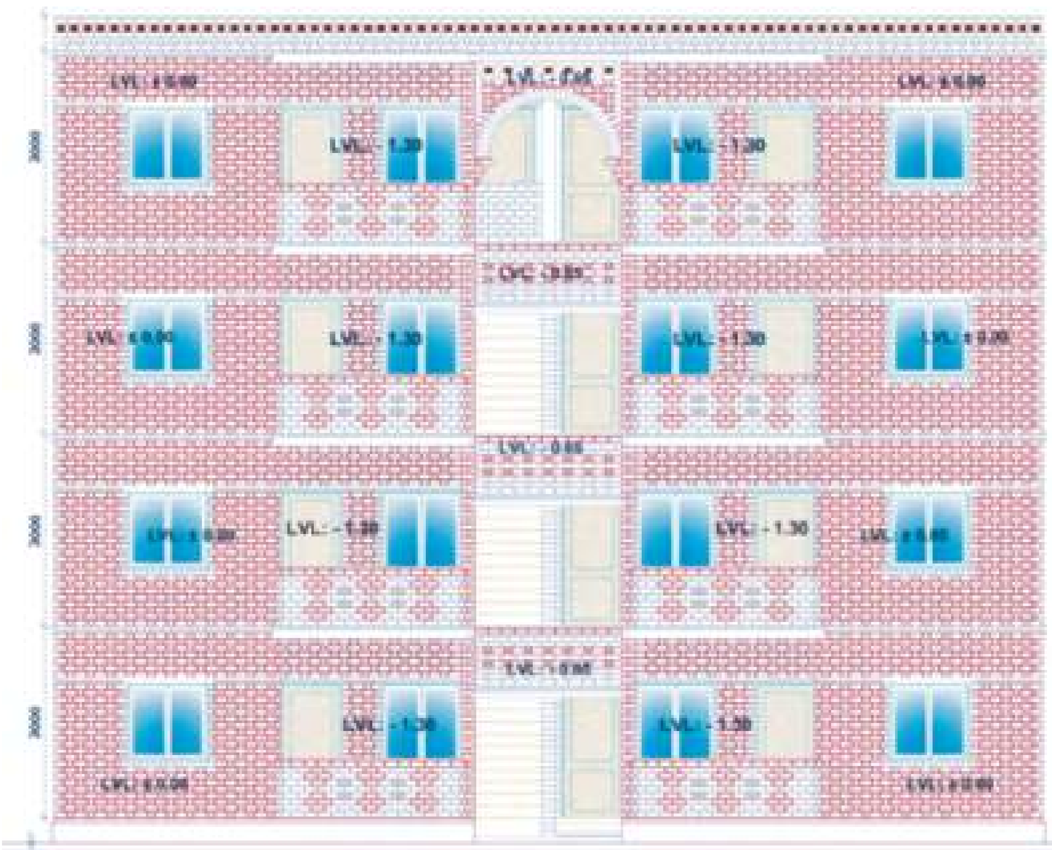


Fig. 1.39: Front Elevation – Type III

1.21 Aesthetics (Bricks as Natural Material)

Building according to artistic principle is reflected in a more or less ornate portal like an entrance stairs hall found to be in ancient architectural traditional buildings.

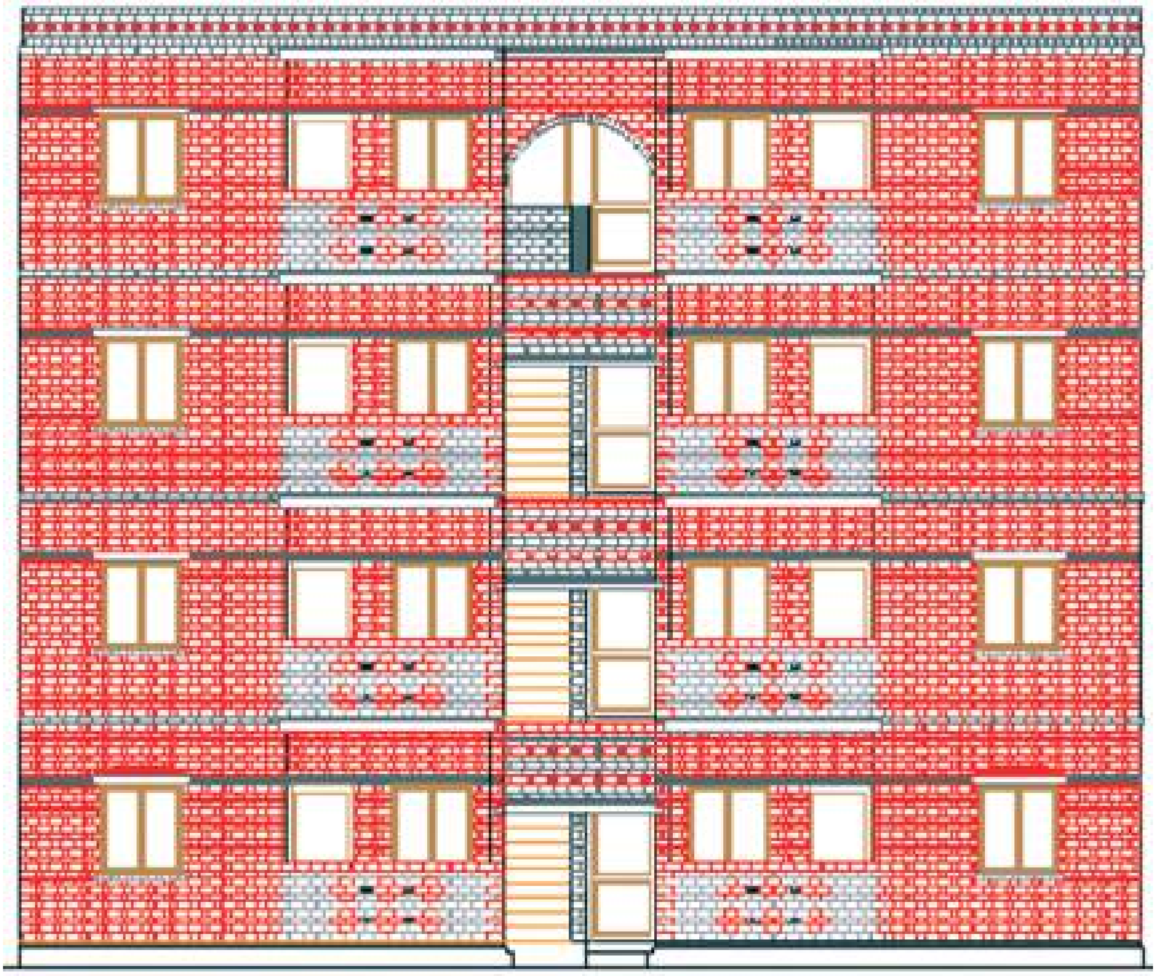


Fig. 1.40

The importance of bricks as natural building material is in use of bricks as *"State of Art and technology".*

The Architectural character is reflected in laying of courses of 'natural Red Clay Bricks' combined with 'Fly-ash bricks' as voids. Brick as the dominant material has been used in a disciplined manner to achieve the desired effect.

1.22 Building Blocks

The design of the building blocks cover following parameters for efficient performance:
- Orientation aspect
- Space Efficiency
- Grouping
- Privacy – usual & acoustical
- Circulation
- Sanitation
- Economy
- Elegancy

1.23 Other Features

Certain aesthetic considerations have been incorporated into the design of the dwelling unit, these includes:

- Treatment of interior floor spaces.
- Colour for walls, ceilings.
- Natural lighting and ventilation.
- Exterior & interior finish for walls – different materials, colour, texture and visual effect.

1.24 Efficient Structural System

The building is designed on the principles of 'box' consisting of wall panel and floor diaphragms. While individual characteristics of the panels are duly considered during casting, transportation and erection, the properties of the box made out of these individual panels are considered for transferring bending moments and shear forces due to earthquake and wind.

The "Ductility provisions" have been provided in the form of :

1. Vertical reinforcement at corner and tee junctions of walls, at jambs around openings, wherever required
1. Grade beam at piles cut off level
1. Plinth band at plinth level
1. Lintel band at Door/window lintel level (i.e. 2.1 m ht.)
1. Roof band at all load bearing and peripheral walls.

Besides economical these structures have higher lateral stiffness than framed structure.

Design Concept
(Through the lens)


Aesthetics


Aesthetics


Openness & the Parks with railings


Openness & the totlots


Road


Street lights & transformers on poles


Sit outs along boundary


Inter Locking Pavers pathways

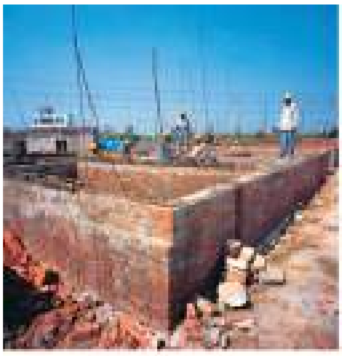

High mast towers in Parks


Saucer drains


Drains along Roads


Parking Spaces

Design Concept
(Through the lens)
(Earthquake Resistance Measures)


Plinth Band & Vertical reinforcement


Lintel band
(for earthquake resistance)


Vertical reinforcement from Grade beam


Plinth Band and Vertical reinforcement at L Junction


Plinth Band and Vertical reinforcement at T Junction


Roof Band on load bearing walls (also shows precast planks and reinforcement in haunches)

Design Concept

(Through the lens)

(Use of Cost Effective Innovative Technologies)

Mechanised Modular Bricks / Walls

Mechanised Modular Flyash Bricks

Modular Flyash bricks

Lintel-cum-Sunshade

Erection of Lintel-cum-precast Sunshade placed over window openings

Precast Planks casting

Ferrocement cooking platform

Casting of Staircase Steps (riser & tread units)

Erection of precast step

Ferrocement Water Tanks

1.25 Use of Cost Effective Innovative Technologies

- 200 mm thick load bearing wall in Super Structure
- Modular bricks with Cement + Flyash blended mortar
- Precast Reinforced Concrete planks and joist for roofing and flooring
- Ferrocement staircase treader – riser units
- Precast ferrocement sunshades, kitchen platform
- Precast ferrocement water tanks

1.26 Structural Design

1.26.1 Typical Structural Design of Plank

(1) Plank (1500 x 300 x 60)
For Intermediate Floors
Load on Plank :

(a) Dead Load :	Self : 1.500x.300x.06x25000	=	675N
	Floor : 1.50x0.30x.04x24000	=	432N
	Total	=	1107N
	Factor Load 1.50x1107	=	1660.5N
(b) Live Load :	1.50x0.30x1500	=	675N
Factor load	1.5x675	=	1012.5N

(2) Planks For Terrace Slab :
Load on plank

(a) Dead Load (self)	1.5x0.30x0.06x25000 = 675N	
Brick coba		
(b) (Average 100mm Thick)	1.5x0.30x0.10x20000 = 900N	
Total	=	1575N
Factor load 1.5 x 1575	=	2365.50N
(c) Live Load 1.5x0.30x750	=	337.50N
Factor Load 1.5x337.50	=	506.25N
BM. Due to D/L 2365.50 x 1.50 / 8	=	443.5NM
BM Due to L/L 506.25 x 1.50 / 10	=	75.95NM
Total BM = (443.50 + 75.95)	=	519.45NM
Hence d = 519.45x103 /0.138 x 20 x300	=	25.05mm
Add cover		+ 15.00mm
Total		40.05mm

Provide 60mm overall depth
Calculation for transvers reinforcement in plank
As required in IS 456 the minimum transverse reinforcement should not be less than 0.15% of Cross sectional Area
: 0.15x 1/100 x 1500x60 = 135mm2
Number of bars
Assuming 6 mm dia = 135/28.26 = 4.78 nos., Say 5 nos.
Hence spacing = 1500/5 =300mm
Provide 6 mm dia bars @ 200 mm c/c
Main Reinforcement in Plank
Ratio : m/bd2 = 519.45x103/300x452 =0.855
Ref : SP 16 Table 2 (for fe 250)
Percentage of Reinforcement = 0.412%
Total reinforcement
Required – 300x60x0.412/100 = 74.16 mm^2
Provide 6 mm dia mild steel bars
: No of bars = 74.16 / 28.26 = 2.62 nos.
Hence provide 3 nos. of 6 mm dia bars (main bars)
Distribution bars.
Ref: IS:13990:1994 (Clause 5.2.2)
Provide 6 mm dia M.S. bars @ 200 mm c/c
As transverses reinforcement which is more than 0.15% of the sectional area of

the concrete as recommended in Code IS:456.
Check for deflection as per IS456
Ref: IS 456 Fig 3 P/57 for mild steel
Modification factor against Percentage of steel ie:
=100x28.26x3/300x60 = 0.471%
M. factor = 1.9
Hence allowable L/D =1500/45 = 33.33<38
Hence safe:
Check of Shear
Percentage of tension steel = 0.471%
Shear strength of Concrete against percentage of Steel
(Ref: IS 456 Table 17-P/128)
= 0.30N/mm2
(Ref: IS456 Clause 47.2.1.1)
K= 1.3 For section less than 10mm
Tc = KxTc = 1.3x0.3 = 0.39N/mm2
SHEAR FORCE (Actual)
Tv= Vu/bd =(51.90/2)10/300x60 = 0.02N/mm2
Which less than 0.39N/mm2
Hence Safe :

Note: In above design plank for maximum size has been taken for calculation purpose. Therefore it is recommended to use any size of Plank less than the length 1.50m with similar reinforcement and depth.

1.26.2 Design of Typical Joist

Joist (2.90x0.15x0.21)
(Assuming that the partially precast joist with plan partially launched and filled inside with flange reinforcement shall be acting monolithically and will form a T-beam effect in transferring the Loads)
To calculate effective width of flange Ref: IS456 clause 22.1.2
Bf = Lo/6+bw+6Df
= (0.7x2.9)/6+0.15+6x0.06 =0.84
[considering as a balance section with tension reinforcement only]
If Df/d >0.20
= 60/185 = 0.32>0.2
Xm = 0.48 x180 = 86.40
Therefore MR = .36 6ckbw xm (d-0.42xm)+0.446 6ck (bf-bw) yf (d-05yf)
Where = (0.15x m +0.65Df)> Df
=0.36x20x150x86.4 (180-0.42x86.4)+0.446x20(840-150)60(180-0.50x60)
=(0.36x20x150x86.4x143.71)+0.446x3800x60x150
=(13409867.52) + (55393200) = 68803067.52Nmm
Or 68803.067Nm
(2) (i) Joist (2.90X0.15X0.21) (For Intermediate Floors)
(Assuming Rectangular Section)
Clearspan = 2.70m
+Bearing = 0.20m
Effective Span = 2.90m

Load on Joist

(a) Dead load

Self 2.90x0.15x0.21x25000x1.50 = 2283.75N

DL from floor and flooring (Ref) = 166/30x290 = 16047.00N

Factored Total DL = 18330.75N

(b) Live Load (Ref ib)

Factored 1012.5/30 x290 = 9787.50N

BM Due to DL = 18330.75/8 x2.90 = 6644.90Nm

BM Due to LL = 9787.50/10 x2.90 = 2838.40Nm

Total BM = 9483.30Nm

Joist for Terrace Floor

(2.90x0.15x0.21)

Effective span: 2.90m

Load on Joist

(i) Dead load

Self-factored 1.5x2.90x0.15x0.21x25000 = 2283.75N

Roof + Terracing

2365.50/30x30 = 22866.50N

Total = 25150.25N

(ii) Live Load 506.3/30x2.90 = 4894.20N

Factored

BM due to D/L 25150.25x2.90/8 = 9116.96 Nm

BM due to L/L 4894.20x2.90/10 = 1419.31 Nm

Total = 10536.27 Nm

Hence effective depth d = 10536.27 x103/0.138 x20 x150 = 159.44

Add cover = 25.00

Total = 184.44 mm

Provide 210 mm overall depth

Reinforcement

Ratio $m/bd^2 = 10536.27 \times 10^3/150 \times 185^2 = 2.05$

(Ref. SP16 Table 2 for fe 415)

Percentage of Reinforcement = 0.658

: Area of Steel = 0.658x150x210/100 = 207.27mm^2

Provide 2 No. 10 mm dia bars + 1 No. 8 mm dia bars = 207.30 mm^2

Check for Deflection

Modification factor against

Percentage of Steel from fig 3 of IS456 P/57 (for Tor steel) = 1.08

Hence allowable L/d = 20x1.08 = 21.6

Actual Provide L/d = 2900/180 = 16.11<21.6 Hence Safe

Check for Shear

Percentage of tension Steel = 0.658%

Shear strength of concrete against percentage of steel

(Ref IS 456 Table 17-P/128)

Te = 0.33 N/mm^2

Ref. IS 456 Clause 47.2.1.1 for k

K = 1.17

Tc = k x Tc = 0.33x1.17 = 0.386 N/mm^2
Actual Tv = Vu/bd = 15005.85/150x210 = 0.47mm^2
Which is > than 0.386 N/ mm^2
The balance shear will be taken by the stirrups
Although the Design Calculation is done for the complete rectangular Section of Joist, considering Simply supported rectangular Section.
Obviously the designed Section will be over safe when behaving as flanged Section.

1.27 Design of Typical Wall

To calculate actual stresses at Bottom most course of the masonry. A critically Loaded central wall of maximum length has been considered for calculation purpose (Ref drg)

(i) Load from terrace per m^2 including live load = 2515.025+489.42/1.5x2.90 =689.87 kg/m^2
(ii) Load from intermediate floors including live load = 1833.075+978.75/1.5x2.90=646.31 kg/m^2

Area of Slab (Trapezium) = 4.50 + 1.80 ÷ 2 x 1.35 x 2 = 6.30 ÷ 2 x 2.70 = 8.50m^2

Total Load 'A' From Terrace	=	689.87 x 8.50	= 5863.90 kg
Total Load 'B' From Intermediate floors	=	2 x 646.31 x 8.50	= 10987.30 kg
Self Load of Masonry 'C'	=	3 x 3 x 4.5 x 2000 x 0.2	= <u>16200.00</u> kg
Gross Load = A+B+C =		5863.90 + 10987.30 + 16200.00	= <u>33051.20</u> kg

Actual fb = 33051.20 ÷ 4.5 x 200 x 1000 = 0.367 N/mm^2

Permissible Shear Stress

(i) SR Due to Ht
Actual Ht = 2.94 + 0.40 = 3.34m
Effective Ht (Ref IS 1905 Table 4 P/11) = 0.75 x Ht = 0.75 x 3.34 = 2.505m
S.R. = 2.505 ÷ 0.20 = 12.525

(ii) S.R Due to Length of wall
Actual length of biggest panel on plan = 4.70m
Effective length (Ref IS 1905 Table 5 P/12)
= 0.80 x4.70 = 3.76m
S.R. = 3.76/0.20 = 18.80
Adopting minimum S.R.
Permissible stress =
Fb = (basic compressible stress in masonry from Table 8-1905-P/16) = 0.94
Ks = (Stress reduction factor) = 0.84
1905 Table 9 P/16
Ka = (Area reduction factor)
= (0.70 + 1.5 A)
= (0.70 + 1.50 x 0.2) = 1
Kp = (Shape modification factor 1905 Table 10 P/17) = 1
Permissible Stress
= 0.94 x 0.84 x 1x 1
= 0.79 N/mm^2 > 0.367 N/mm^2
Hence Safe.

1.28 Provisions for Earthquake Resistance

As per National Building Code Part 6 (Structural Design – Section IV Masonry)

Clause 4.2.22 specifies requirements for stability of 4 storied load bearing buildings.

i. The height to width ratio of the block is 1:1 < 2 hence safe.

ii. All load bearing walls are 200mm thick. All these walls act as stiffening walls and are continuous.
iii. The floor and roof slab are anchored to the walls with roof band.
iv. As per table 2, none of the stiffening wall has length of more than 6m
v. Crosswalls are jointed by toothing.

- Code recommends that load bearing masonry walls should not be more than 15m total height. The prescribed height for this project is 12m.
- Code recommends that the load bearing walls must be straight and symmetrical in plan, so that torsional shears are minimized. The Architectural plan satisfy the recommendation.
- Code recommends (SP:22 clause 3.4.1) symmetrical structure with respect to mass and rigidity, so that centre of mass and C.G. of the building coincide with each other, to avoid eccentricity.
- The plan is almost symmetrical. The structure has more or less equal stiffness in both directions; therefore satisfies the codal recommendation.
- Building category :- The building is in seismic zone IV and has importance factor of 1.0.
- Mortar strength required is 1:6 C.M. hence sufficient.
- The wall panels are of 200mm and the storey height is less than 3.5m (the bending check as a plate or as vertical strip is not required).
- Openings in bearing walls :- Max. openings required is 37%.
- All load bearing walls satisfy this requirement except the following :
  - Wall between living room and balcony
  - Wall between bedroom and bath/WC. Therefore Vertical reinforcement shall be required in these two walls. (As per drawing VR2 of 12mm dia provided)
- Plinth band provided with 2-8mm dia bars
- Lintel band provided with 2-8mm dia bars
- Roof band provided with 2-8mm dia bars

Note :-
- The span of walls is less than 6m; therefore 2-8mm dia bars are sufficient.
- Stirrups 6mm dia @150c/c
- Vertical reinforcement :- The vertical reinforcement required at L&T junctions and in two walls as mentioned above.

  The vertical reinforcement required is as below:-

Ground floor	12mm dia
First floor	12mm dia
Second floor	10mm dia
Third floor	10mm dia

1.29 Energy Efficiency, Eco-friendly & Green Building Concepts

Appropriate use of building materials and techniques, rationalized Architectural design, standardized precast on site production, simplicity in execution, speed of construction, efficient layout, efficient structural system optimizing the performance of building system, eco-friendliness and minimum maintenance are the key to “Affordable sustainable Housing” created by DSIIDC.

Various new technologies are being imported from European Countries in the garb of quality fast track housing. Incidentally, all these technologies are highly mechanized and are suitable only in developed countries where the man power is very costly. It requires a heavy capital investment to establish such production unit (like a full-fledged industry) in terms of land, plant & machinery, infrastructure. The cost of establishment, training, depreciation, technology transfer put together, increases the cost of construction by 20%.

DSIIDC has adopted indigenously developed and field tried technologies which are highly economical and sustainable.

Aim of sustainable Housing

- Identification of Technologies to reduce cost of construction so as to make housing affordable
- Fast-track construction technology to reduce time period of construction
- Use of local materials & technologies
- Use of waste products & technologies reducing the embodied energy
- Conservation of resource materials
- Durability
- Minimum maintenance

The basic principles of sustainable design or 'green design' as it is popularly known are been aimed at :-

- Maximum resource conservation
- Efficient utilization of non-renewable resources adopting efficient system
- Use of eco-friendly building materials & intermediate modes of construction
- Maximize use of local manpower, and renewed resources
- Waste water management

1.29.1 Low Energy Materials & Technologies

The aim for sustainability lies in adopting materials & technologies that reduce the cost and time of construction, and that cover environmental protection and energy conservation.

• No heavy equipment or sophisticated T&P required	:	Saves energy & fuel
• Less consumption of cement, Steel & aggregate	:	Saves energy
• No shuttering	:	Saves forest
• Flyash mixed in C.M	:	Saves cement & energy
• Flyash Bricks	:	Utilisation of waste product
• Perforated bricks	:	Provides better insulation & saves fuel
• Ceiling & walls, finish in white	:	Improve day light
• No external paint or plaster	:	Less maintenance
• Controlled quality concrete due to precasting	:	Less maintenance
• Ferrocement elements	:	Requires less maintenance
• Less weight of structure	:	Safer in EQ

1.29.2 Savings in Embodied Energy

• No shuttering used	-	Saves wood & steel
• 30% reduction in consumption of cement	-	Saves embodied energy
• 60% reduction in steel reinforcement (less than 1 kg/sqft. in comparison to 3.5 kg/sqft)	-	Saves embodied energy
• Perforated Bricks	-	Saves fuel

1.29.3 Seismic Resistance

The houses have been designed as per IS : 4326 with

- Load bearing walls concept with box behavior which has lateral stiffness much higher than framed structure.
- Vertical reinforcement at T & L junctions.
- Vertical reinforcement around openings.
- Plinth band, lintel band & roof band.
- Grade beam over under reamed piles foundations provided for Bawana site which behaves better under liquefaction effect.
- Building Form – Rectangular, therefore more stable.
- Building configuration is symmetrical w.r.t. mass and rigidity.
- Structure is light due to 15% less thickness of walls, 30% reduction in concrete slab and use of ferrocement thin elements.

1.29.4 Water Conservation (Saving in Water Consumption)

1. During construction:- due to lesser volume of masonry, less volume of concrete, due to no ceiling plaster, due to no external plaster.
2. The precast slab panels, stairs, sunshades, shelves etc. are cured with spray of water. There is no free flow of water, thus conservation of water during construction.
3. The precast elements are covered with thick cloth / gunny bags and then water sprayed on them. This avoids water rebound and ensures sustained and complete curing conserving water. The surface area exposed during curing of stacked planks is 1/5th, thus less evaporation conserving the water for curing.
4. Water ponding is done in sunken portion of WC/ Bath and then ponding used for curing. This conserve water (to avoid water flowing away)
5. The mechanised bricks have high compressive strength and low water absorption –thus saves water.
6. Ferrocement elements also being thin elements – consume less water.
7. Hardy plants species used which require less water Acacia Arabica, Ficus Bengalenois (Baryan) Ficus Religiosa (Pelpal) poly athia Litigifolia (Ashok) cedar in Horticulture Development.
8. Soft permeable pathways to reduce run off rain water
9. Ground water recharging through Rain Water Harvesting wells.

Chapter 2 : ECONOMICS

2.1 Approach to Economics

The cost effectiveness has been worked out in all aspects of built environment without sacrificing aesthetics, maintenance, safety and durability.

2.1.1 Economics of Resource Management

Resource efficiency features adopted in this project include :-

- Community parks, cluster parks, courtyard tot lots
- Cluster courts as well-lit source of light and ventilation
- Energy optimization
- Water conservation : for gardening untreated low bore well water
- Perforated – high – strength bricks (machine made)
- Flyash Bricks – (Utilisation of Industrialised Waste)
- Blended cement – flyash mortar
- Precast thin elements
- Minimum use of steel
- Practically no shuttering
- No external finish required – natural finish

Climatic and atmospheric actions such as rain, temperature variations, humidity, abrasion from dust and wind, chemical reactions, pollution, the drying & fading effects of sunrays, account for the deterioration of the facades. Instead of the expensive paints and cladding in elevation crystalisation with a colour less water soluble silicon paint on exposed surfaces and use of quality natural materials has made it possible to achieve the desired results.

2.1.2 Use of Appropriate Technologies

2.1.2.1 Conventional

Conventional construction is the type of construction which is done by adopting traditional specifications using traditional plant and machinery commonly used and popularly known as cast-in-situ RCC framed construction.

Conventional construction has some drawbacks like; high cost of construction inferior quality and longer construction schedule. Workers attitude of carelessness and negligence sometimes due to over confidence results into poor workmanship resulting in high maintenance cost. Conventional construction consumes more cement and steel. These materials consume high energy for their production. Higher use of high energy materials is not eco-friendly.

2.1.2.2 Hi-tech construction

The Hi-tech construction such as slip form construction, large panel industrialised prefabrication construction is high cost construction and is more suitable for metro and mega cities with large volume projects and requires.

- High Skilled workers

- High Investment in plant, Machinery and land
- Assembly Line of works to offset idle period of heavy plant & equipment
- High cost of erection and transportation

2.1.2.3 Intermediate Technology

This construction technology is a combination of partial prefabrication at site of work requiring only small equipments, which are portable and available at very small investment and partial conventional practices. This has many positive features such as :

- Partially Precast
- Use of skilled & non-skilled workers
- Generates employment
- Cost effective
- Time saving
- Low life cycle cost

This can be termed as Best practices adopted and has been successfully adopted on this project. Various features of the Technologies adopted are detailed in the subsequent paras.

2.1.3 Architectural Economics

- The unit plan the block house form / typology is almost square thus the unit has minimum perimeter of wall length.
- There are minimum offsets, thus reducing length of walls.
- The two faces of each dwelling unit has common walls without affecting the light and ventilation.
- The plan is functional and efficient. The total circulation area including the staircase is only 2.50 sqm per dwelling unit.
- Four dwelling units have been planned on one floor around one staircase.
- The wet areas have been placed around one core to achieve economy in plumbing and vertical stacks.
- The door/window openings have been minimal and rightly located to achieve load bearing behavior of the structure.
- With the use of 200mm thick walls instead of 230mm thick there is a reduction of plinth area by about 5% thereby saving in cost.
- Adoption of modular coordination has resulted in reduction in wastages.

2.1.4 Structural Economics

- Load bearing concept has been adopted instead of RCC framed structure with bricks as filler walls. A load bearing structure up to 4 Storeys is highly economical.
- With the high strength bricks, 200mm thick wall satisfy the structural requirements for G+3, structure. The mechanized bricks also reduce the thickness of plaster required. The brick wall on external facades are kept exposed without plaster, thus further saving in cost.
- The overall slab thickness using precast RC planks is only 60mm. A normal cast-in-situ slab for this type of structure requires 100mm thickness thus the dead load of slab is reduced by about 30% to 40%. Reduction in dead load means reduction in overall quantities of steel and concrete (in conventional design the dead load is more than 3 times the live load).
- For the four storeyed blocks, virtually the dead load of the structure is equivalent of a three storeyed structure. The cumulative reduced dead load of the slab and walling both, account for saving in foundations to an extent of 20%.

- The intermediate floor slabs and the roof slab are in precast RC planks and joist system. The system saves shuttering, steel and cement concrete.
- The staircase landings are also in precast RC plank & joists system. The staircase flight comprises of precast ferrocement steps (tread and riser unit) supported on walls at both ends. The precast elements save not only shuttering, concrete and steel but also eliminate the plaster, flooring and the balusters railing too.
- The other precast elements used in the structure are precast sunshade-cum lintels and precast ferrocement shelves. They are 30% to 40% economical then conventional RCC.

2.1.5 Sanitation & Plumbing Economics

- The water supply system is based on single stack system with common water tanks for 6 to 8 flats. There is an overall savings in pipe length and various connections.
- The single stack system of Plumbing for soil and waste water disposal has been adopted.
- The PTMT taps have been used instead of brass or CP fixtures.
- The wet areas have been concentrated together in and around for keeping the length of internal pipes to the minimum.
- The ferrocement water tanks have been provided which are economical as well as durable.

2.1.6 Layout & Infrastructure Economics

- The blocking has been done to achieve common walls resulting in common internal chambers connection etc.
- The layout is linear resulting in economy in services.
- For the drainage of internal area no drains are provided. The Saucer drains carry the runoff water to the main drain along the roads. The runoff is also minimized due to soft surfaces and porosity of interlocking paver pathways.

2.2 Cost Comparisons

Traditional Construction Vs Cost Effective Construction

The site is flat with no major physical features. The land was about 1.5 to 2.5 m below the road level thus requiring land filling to carry out desired infrastructure and housing works. The cost was worked out for Type-III buildings (4 storeyed) with traditional RCC framed structure as well as with load bearing construction with alternative technologies which were finally adopted for the construction of 4348 Dwelling Units.

For the purpose of evaluation of economic foundation alongwith its suitability the cost was also worked out with load bearing walls with traditional stepped footings. It was observed that traditional type of footings will not be suitable as these will be unfeasible due to large depth of earth filling required and the wider footing sections to retain the earth fill. Therefore, stepped footings / strip footings were ruled out.

The solution was, therefore, found with under reamed piles below the load bearing walls and the grade beams at an intermediate level of -550mm. First, the entire land area upto-550 mm level was filled and compacted. The piles were provided with grade beam at - 550mm level. Brick wall was then raised over the grade beam as load bearing wall. The vertical reinforcement (VR-1) provided from the grade beam. The plinth band was provided at plinth level.

The savings worked out as a result of use of alternative technologies are summarized in *Table 2*.

Cost comparison for individual heads such as walling per sqm, roofing / slab per sqm, shelves and sunshades has also been summarized in *Table 3*.

The cost comparison of the dwelling units are tabled in subsequent pages of the chapter.

The cost comparison of such elements such as foundations, superstructure, slab etc. were also worked out and are tabled for Construction of 1184 Type III houses (39.74 sqm) at Bawana.

- Rates adopted for the estimates are from DSR – 2002.
- Cost Index of 34.34% on both estimates as prevalent at the time has been added.
- Rates of Non-schedule items analysed on the basis of DSR – 2002.

Table 2
Cost Comparison Civil Work

Conventional		**Cost Effective Technologies**	
Building cost with conventional specification		Building cost (for 1 block of 16 DU)	
For 1 block of 16 units	24,85,384.00	Civil work	19,29,023.00
Add 34.34% Cost Index	8,53,481.00	Add 34.34% Cost Index	6,62,427.00
Total	33,38,865.00	Total	25,91,450.00
Cost per DU (33,38,865.00 ÷16)	2,08,679.00	Cost per DU (25,91,450.00 ÷16)	1,61,966.00
		P.A.	39.74 sqm
Cost per sqm	5,251.10	Cost per sqm	4,075.63

Saving in cost = 2,08,679.00 – 1,61,966.00 = 46,713.00 = 22.38%

Table 3
Cost Comparison of different items Conventional Vs Alternative
Comparison of various Alternate Technologies vs Conventional Technologies

S.No.	Item of Work	Conventional	Alternative	Savings
1.	Slab	Cast-in-situ 100mm thick solid slab Rs. 580.27 per sqm	Precast RC Planks & Joists Rs. 419.82 per sqm	27.65%
2.	Walling System	230 mm thick FPC bricks with 15mm plaster stone grit plaster Rs. 594.63 per sqm	200 mm thick perforated modular bricks Rs. 489.82 per sqm	17.62%
3.	Door / window / chaukhats	Second class teak wood chaukhat (75x60 mm) Rs. 213.50 per m	T–iron/angle iron 40x4x6mm Rs. 96.43 per m	54.83%
4.	Door / Shutters opening size 900x2100mm	Teak wood (2nd Class) frame + 35 mm thick Flush door shutter Rs. 2443.35 per shutter	T-iron frame + 35 mm thick flush door shutter Rs. 2052.71 per Shutter	15.98%
5.	Kitchen Shelf	Cast in-situ R.C. shelf 75mm thick CC 1:1½:3 Rs. 425.00 per sqm	Precast ferrocement shelf in CM 1:½ - 25 mm thick per sqm Rs.213.00 per sqm	49.88%
6.	Sun Shades	Cast in-situ R.C. Sun Shades 1:1½:3 Rs. 444.15 per sqm	Precast RCC sunshade 60 mm thick Rs. 354.50 per sqm	20%
7.	Stairs	Cast in situ slab in RCC 1:1½:3 in waist slab and brick masonry steps Rs. 2394.32 each (single flight with 10 steps)	Precast ferrocement steps 25 mm thick in cm 1:1½ Rs. 1558.00 each (Single flight with 10 steps)	34.95%
8.	Flooring	40mm thick CC 1:2:4 flooring finished with a floating coat of neat cement over a base course of 100mm thick in CC 1:5:10 (1 cement : 5 fine sand : 10 graded stone aggregate) Rs. 234.25 per sqm	25mm thick CC 1:2:4 flooring finished with a floating coat of neat cement over a base course of 75mm thick in CC 1:5:10 (1 cement: 5 fine sand: 10 graded brick aggregate) Rs. 164.08 Per sqm	29.95%

A single essential element "the staircase" plays important role in small size of dwelling units, as its proportionate cost per dwelling units is predominant.

A unique method of precast Ferrocement stair case has brought in saving of more than 34% in cost of stair case as given in *Table 4*.

Table 4

Cast in situ waist slab in RCC 1:1½:3 and masonry steps for stairs (Single, flight with 10 step) Rs. 2394.32	Precast ferrocement steps using cm 1:1½ (1 cement : 1½ fine sand) (Single flight 10 steps) Rs. 1557.50

Percentage Savings = 34.95%

The plumbing services constitute about 10 to 15% of cost of civil work. Considerable saving has been achieved by adopting single stack system as observed in *Table 5*.

Table 5
Cost Comparison
Conventional Vs Cost Effective of Plumbing / Sanitation

Conventional (Dual Stack System)		Cost Effective (Single Stack System)	
SW Pipes (soil waste pipes)		Soil waste pipe	
100 mm = 125.60 m @ 271.15	34056.00	100 mm = 70 m @ 271.15	18981.00
75 mm = 48 m @ 230.05 m	11042.00	75 mm = 23 m @ 230.05	5291.00
M.S. Holder Bat Clamp		M.S. Holder Bat Clamps	
100 mm = 48 nos. @ 44.35 each	2129.00	100 mm = 20 @ 44.35 each	887.00
75 mm = 20 nos. @ 43.25 each	865.00	75 mm = 8 @ 43.25 each	346.00
Bend (with access door)		Bend (with access door)	
100 mm = 8 nos. @ 157.35	1259.00	100 mm = 4 @ 157.35	629.00
75 mm = 4 nos. @ 121.00	484.00	75 mm = 4 @ 121.00	484.00
Plain Band		Plain Band	
100 mm = 8 nos. @ 120.70	966.00	100 mm = 4 @ 120.70	483.00
75 mm = 4 nos. @ 101.00	404.00	75 mm = 4 @ 101.00	404.00
Plain Junction		Plain Junction	
100x100x100 mm = 4 @ 195.15	781.00	100x100x100 mm = 12 @ 195.15	2342.00
		75x75x75 mm = 3 @ 137.65	413.00
Junction with access door		Unequal Junction	
100x100x100mm = 16 no @ 225.15	3602.00	100x100x75 = 12 @ 195.15	2342.00
75x75x75 mm = 8 no @ 164.30	1314.00		
Terminal guard		Terminal guard	
100 mm = 4 no @ 108.45 each	434.00	100 mm = 4 nos. @ 108.45 each	434.00
		100 mm collar = 8 @ 96.25 each	770.00
Lead caulked joints		Lead caulked joints	
100 mm = 130 nos. @ 78.45 each	10198.00	100 mm = 96 nos. @ 78.45 each	10042.00
75 mm = 43 nos. @ 66.55 each	2862.00	75 mm = 44 @ 66.55 each	2928.00
Stay Clamps		Stay Clamps	
4 nos. @ 30.70 each	123.00	4 nos. @ 30.70	123.00
Floor Traps		Floor Traps	
100x100 mm = 32 @ 285.40 each	9133.00	100x100 mm = 16 @ 285.40	4566.00
Painting of SCI pipe		Painting of SCI pipe	
100 mm = 125.60 @ 12.65 m	1589.00	100 mm = 70 m @ 12.65 m	886.00
75 mm = 48 @ 9.65 m	463.00	75 mm = 23 m @ 9.65 m	222.00
Total	81704.00	Total	52573.00

Saving due to Single Stack System = Rs. 81704 – 52573 = Rs. 29131 = 35.65%

It is a universal fact that cost of construction goes on increasing with time and delays in construction adds on to the already tight budget. The Alternative technologies adopted also save time period of construction. The major component of time period is consumed in intermediate and roof slab. Casting of slab requires about 20 days schedule of centering / shuttering, reinforcement, casting, de-shuttering and the ceiling plaster. The table 5 gives the Economics of time period of construction which is almost 60% of the conventional period.

Table 6
Affordability in Technology
Comparison Chart – Time Saving

S. No.	Description	Conventional	Cost effective Proposal
1.	Foundation	6 days	6 days
2.	Superstructure: Casting of column, beams, slabs including shuttering, placing reinforcement, casting and removal of form work (each Floor)	16 days	6 days (precast slab)
3.	Raising Brick wall (each floor)	3 days	3 days
4.	Internal plastering (each floor)	2 days	1 day (no ceiling plaster)
5.	External plastering (each floor)	3 days	No Ext. plaster
6.	Flooring (each floor)	1 day	1 day
7.	Plumbing & Elec.(each Floor)	4 days	4 days
	One Block	122 days	71 days

Economics of man power

During the rainy days, the labour force is made idle. The precast technology adopted reduces such idle periods and allows the workers to carry out the routine work.

Economics of capital investment / plant & machinery

Largely said, the precast technology in India is costly due to high degree of mechanisation. The Indigenously developed and time tested technology "The RC plank and joist system" and various other precast elements such as stair case steps, sunshades, lintels, water tanks do not involve any high capital investment. No manufacturing industry required. Since, all the precasting is done at the site itself, no capital investment required for Land, Building and Machinery. There is no component of foreign elements like patent fee / technology transfer fee. Also that these are not monopolised technologies. Everyone is free to use.

The table below *(Table 7)* gives the cost element of the precast plant & machinery required for RC Planks and joists stair case sunshades, shelves. The lifting and transporting equipments such as cranes, loaders are not mentioned, as these are common equipments adopted on all large construction sites.

Table 7
Affordability in Technology
Capital Investment of Mechanization
(For 20 Lacs Sqft built-up area for roofing) (Time period: 27 months)

RC planks Casting machines 7 Nos. @ 85000	= 5.60 lacs
Twin moulds 14 Nos. @ 20000	= 2.80 lacs
Pellets 700 Nos. @ 1000	= 8.00 lacs
MS Channels for Joists 70 Nos. @ 2500	= 1.75 lacs
MS Angles for Steps, Sunshades, Shelves	= 0.50 lacs
	= 18.65 lacs
Cost per Sqft = Rs. 0.93 say Rs. 1.0 per Sqft	
Open platform (20000 sqft) & Temporary Shed (10000 sqft)	= 10.00 lacs
Total	= 28.65 lacs
Total cost per Sqft = Rs. 1.43 per Sqft (say Rs. 1.50 per Sqft)	

Economics of Overheads and Maintenance

The technology for cost reduction can succeed only, if it saves cost, improves quality, saves time, saves overheads both during construction and during operation.

The design and technology of this project also saves the overheads and the maintenance. The savings in overheads which in terms of quantification can be 2 to 3% based on the experience because of reduction in construction time.

Cost Comparison of Building Elements

Thus due to the technologies adopted a saving about 20% is achieved over conventional cost over all for the same Architectural plans.

Various cost comparative tables referred above are given as under.

Table 8
Conventional RCC Slab vs Precast RC Planks

	Cost with Conventional Specifications		**Cost Effective Specifications**
	Cast in situ 100 mm thick R.C. slab in C.C. 1 : 1 ½ : 3. Details for 1 sqm		Precast R.C. Planks and Joists System of Roofing using C.C. 1 : 1½ : 3 Details of cost for a room size 2900 x 4700 (c/c) 2.90 x 4.70 = 13.63 sqm
1.	C.C. 1:1½ :3 = 0.10 Cum@ 2324.20 (DSR 02, Item 5.3) C.C. (1:2:4) = 2120.65 add difference for using C.C.;: 1½ : 3 = 203.55 2351.35 – 2174.80 = 203.55 2324.20	232.42	C.C 1 : 1½ : 3 for joists 2 x 2.90 x 0.15 x 0.15 = 0.1305 cum @ 3208.00 per cum = 418.64 (A) (DSR 02, Item 5.22) In CC 1:2:4) = 3004.45 Add for using CC 1:1½:3 = 203.55 3208.00 CC 1:1½:3 in planks i/c cast in situ conc.
2.	Steel reinforcement = 9 kg @ 21.85/kg (Taking average steel Reinforcement for slab @ 90kg/cum of R.C.C. (DSR 02, Item 5.29.7)	196.65	2.90 x 4.70 x 0.06 = 0.82 cum @ 4192.45 per cum = 3437.81 (B) (DSR 02: item 5.23) In CC 1:2:4 = 3988.90 add for using
3.	Centering shuttering for slab = 1 sqm @ 111.20 per sqm (DSR 02, Item 5.14.3)	111.20	1:1 ½: 3 = 203.55 4192.45 Steel reinforcement In joists 12mm dia = 2 x 3 x 2.85
4.	Ceiling plaster 1 sqm @ 40.00 per sqm (DSR 02, Item 13.24.1)	40.00 Rs.580.27 Per sqm	= 17.10m @ 0.89 kg/m = 15.22 kg 6 mm dia 150 mm c/c = 2 x 20 x 0.45 (175 + 175 + 100) = 18.0m @ 0.22 kg/m = 3.96 kg Steel in planks (6mm dia) 3 x 1.50 = 4.50 m 9 x 0.25 = 2.25 m 6.75 m @ 0.22 kg/m = 1.49 kg 1.49 kg x 30 = 44.70 kg Negative reinforcement 6mm dia 2x2x2.85 = 11.40 30x4x0.72 = 86.40 97.80 m @ 0.22 kg/m =21.51kg 85.39 kg @ 21.85 kg = 1865.77 (C) For 13.63 sqm (A+B+C) = 5722.22 For 1 sqm = 419.82

Table 9
Walling Comparison of 230 mm thick wall using FPS bricks,
15 mm thick plaster 1:6 inside, stone grit plaster on external surface
Vs
200 mm thick brick wall using perforated modular brick,
12 mm thick plaster 1:6 inside and exposed brick work outside

Detail for 1 sqm of Wall Area

	Cost with Conventional Specifications			**Cost Effective Specifications**	
	230 mm thick FPS bricks			200 mm thick modular perforated bricks (exposed)	
1	Brick work 0.23 cum @ 1545.15 per cum (DSR Item 6.1.10+6.3)	355.38	1	Brick work 0.20 cum @ 1851.15 (DSR Item 6.43C) upto Plinth level	370.23
2	15 mm plaster 1 sqm @ 51.00 /sqm in Cm 1:6 (DSR Item 13.9.4)	51.00	2	Extra for super structure 0.20 cum @ 262.45 (DSR Item 6.45)	52.49
3	Stone grit plaster 1 sqm @169.25 per sqm (DSR Item 13.112)	169.25	3	12 mm plaster 1 sqm @ 44.00 per sqm (DSR Item 13.8.4)	44.00
4	Forming of groove 2 m @ 9.50/m (Av) (DSR Item 13.116)	19.00	4	Silicon Treatment on exposed surface for water proofing	23.10
	Total	594.63		Total	489.82

Percentage saving = 594.63 – 489.82 = 104.81 ÷ 594.63 x 100 = 17.62%

Other benefits apart from cost.

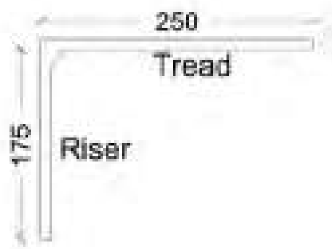
- Plinth area gets reduced.
- Saving in foundation as dead load of walls for foundations get reduced.
- Better insulation due to perforations
- Green building concept
- Less maintenance
- Indian heritage character

Table 10
Cost Comparison
RCC Shelves vs Precast Ferrocement Shelves

Cost with Conventional Specifications	**Cost Effective Specifications**
RCC Shelves (Cast-in-situ) – 75mm thick Details of cost for 1 shelf Size 1.50 x 0.70 = 1.05 sqm Concrete 1 : 1.5 : 3 = 0.08 cum @ 2324.20 cum = 185.94 1.05 x 0.075 = 0.08 cum Shuttering 1.40 x 0.60 = 0.84 sqm @ 111.20 sqm = 93.41 Finishing = 0.94 sqm @ 13.30 sqm = 12.50 1.40 x 0.60 = 0.84 1.40 x 0.075 = <u>0.10</u> 0.94 sqm Steel reinforcement 0.80 cum x 90 = 7.20 kg @ 21.45 kg = <u>154.44</u> For 1.05 sqm = 446.29 **Rate per sqm = 425.00**	Precast Ferrocement shelves – 25mm thick using cement mortar (1:1.5) (1 cement 1.5 fine sand) i/c 2 layers of chicken mesh 24gauge 12.5mm and 1 layer of WWF 12gauge – 25x75mm spacing sandwiched in chicken mesh. Detail for 1 sqm Cement mortar 1:1 ½ 0.027 cum @ 2701.60 per cum = 72.94 Rate of cement mortar 1:2 = 2103.60 (DSR 02 2106, P -74) Add for using 1:1 ½ mix Cement 0.23 tonne @ 2600.01 (0.91 – 0.68) = <u>598.00</u> tonne 2701.60 /cum 2 layers of chicken mesh = 66.00 2.20 sqm @ 30.00 per sqm (i/c wastage) (code 1220 p326) Welded fabric 1.50 kg @ 24.70 per kg = 37.05 A (5.29.5 DSR 02)

Cost with Conventional Specifications	Cost Effective Specifications
	Labour for laying: Mason 0.006 @ 130.00 each= 0.78 Beldar 0.054 @ 93.00 each= 5.02 = 7.98 (2.75 – 0.75 = 2.0 per cum x 0.027 = 0.054) Bhishti 0.022 @ 99.40 each = 2.18 7.98 (0.9 – 0.07 = 0.83 per cum x 0.027 = 0.022) Cement mortar 1.70 units @ 1.66 each = 2.82 Sundries in carriage etc, hoisting, fixing etc. 5.20 units @ 1.66 each = 8.63 195.42 Add 1% water charges on all excepts 'A' i.e. on 158.37 = 1.58 197.00 Add 10% C.P and OH on all except 'A' on 159.95 = 16.00 **213.00** **Per sqm** (0475 cum) 0.68 tonne cement is in 1 cum of cement mortar 1:2 (0.63 cum) 0.91 tonne cement is in 1 cum of cement mortar 1:1½

Table 11
Cost Analysis Precast Staircase vs RCC Stairs

Cost with Conventional Specifications	Cost Effective Specifications
 	
Waist slab = √6.25 + 3.70 = √9.95 = 3.15 = 3.15x1.10x0.10= 0.346cum R.C.C. 1 : 1 ½ : 3 = 0.346 cum @ 2324.20/cum = 804.17 Shuttering =3.15sqm@106.40/sqm = 335.16 Reinforcement 90 x 0.346 = 31.14 kg @ 21.85 = 680.41 (5.29.7) Brick work in steps 10 x ½ x 0.25 x 0.175 x 1.0 = 0.22 cum @ 1545.15 per cum = 339.93	Precast ferrocement staircase steps: (25 mm) (Cost of one flight) Detail for 1m x 0.45 = 0.45 sqm 0.45 sqm @ 213.00 per sqm = 95.85 Extra labour for L-shape etc. Mason – I, 0.011 no @ 130.00 each = 1.43 Mason – II, 0.011 no @ 110.00 each = 1.21 Beldar 0.045 no @ 93.00 each = 4.18 Mortar for fixing etc. 2 units @ 1.66 = 3.32 Extra = 10.14 = 10.14

Cost with Conventional Specifications			Cost Effective Specifications		
Plastering on step 10x1.0x0.45 sqm			Steel reinforcement		
= 4.50 sqm (It 6.1.10 + 6.3)			2 x 0.95 = 1.90 @ 0.22 kg/m	=	9.18
10 x ½ x 0.25 x 0.20 = 0.25 sqm			= 0.42 kg @ 21.85 (DSR – 5.22)		
4.75 sqm			Angle iron nozing		
@ 49.40 per sqm			25 x 25 x 5mm		
(15 mm in cm 1:4)	=	234.65	1.00m @ 1.80 kg/m		
DSR 02, Item 13.8.2			= 1.80kg @ 21.95/kg	=	39.51
(for 1 flight having 10 steps)		----------	(10.1 DSR 02)		-----------
		2394.32			154.68
			Add W.C. on 10.14 @ 1%	=	0.10
			Add CP+OH on 10.24 @ 10%	=	1.02
			For 0.45	=	155.80
			Per sqm	=	346.22
			For 1 flight		
			10 steps x 0.45 sqm		
			= 4.50 sqm @ 346.22 per sqm	=	1558.00

Table 12

RCC (Cast in situ) Sun Shades Vs Precast RC Sun Shades

Cost with Conventional Specifications			Cost Effective Specifications		
R.C.C. Sunshades (Cast-in-situ)			Precast RCC Sun Shades		
Details of cost for 1 Sunshade			Size 1 m x 0.60 x 0.06		
Size = 1m x 0.60 x 0.075 = 0.045 cum			= 0.036 cum @ Rs. 4192.45 per cum	=	150.93
Concrete 1 : 1.5 : 3			Steel Reinforcement		
= 0.045 cum @ 2324.20 cum	=	104.59	= 2.88 kg @ Rs.21.45 per Kg	=	61.77
Shuttering			For 0.60 sqm	=	212.70
0.53 sqm @ 111.20 per sqm	=	58.94	Rate per sqm	=	354.50
Finishing					
1.21 sqm @ 13.30 per sqm	=	16.09			
0.53 x 2 = 1.06					
2 x 0.075 = 0.15					
1.21 sqm					
Steel Reinforcement					
= 4.05 kg @ 21.45 per kg	=	86.87			
0.045 x 90 = 4.05 kg		----------			
For 0.60 sqm	=	266.49			
Rate per sqm	=	444.15			

Savings = 444.15 – 354.50 = 89.65 (20%)

Table 13
Foundations & Plinth

Using Conventional Technologies			**Using Cost Effective - Technologies**		
1 (1.1) (1.2) (1.3)	Earth work cutting / filling including supply of good earth	24779.00	1 (1.1) (1.2) (1.3)	Earth work cutting / filling	18514.00
2 (1.4)	Sand filling under floors	1945.00	2 (1.4)	Sand filling under floors	2125.00
3 (2.1) (2.2) (2.5)	PCC in foundations and under floors	36519.00	3 (2.1a) (2.2a) (2.4)	PCC in foundations and under floors	19480.00
4 (3.1) (3.4a) (3.4b) (3.4c) (3.5)	RCC in foundation & Plinth RCC upto P.L. 92457.00 Centering shuttering for Col. footing 7604.00 Plinth Beam Shuttering 7533.00 Col. Shuttering 4248.00 Steel reinforcement (Partially) 95463.00 207305.00	207305.00	4 (3.1a) (3.1b) (3.3) (3.4a) (3.5) (3.6) (3.9)	RCC in foundation & Plinth RCC (1:1.5:3) 4254.00 RCC (M25) 20531.00 PB centering shuttering 12418.00 PB Shuttering 4633.00 Steel 17502.00 Piles - Steel 47527.00 Pile 161912.00 268777.00	268777.00
5 (4.1)	Brick work in foundation and plinth	144071.00	5 (4.1)	Brick work in foundation and plinth	54012.00
		414619.00			362908.00

Saving = 414619.00 – 362908.00 = Rs. 51711.00 = 12.47%

Table 14
Superstructure
Cost of One Block (16 DU)

Using Conventional Technologies			**Using Cost Effective - Technologies**		
1	RCC in Superstructure (110.74 – 58.43 – 2.18) = 50.13		1	RCC in Superstructure	
(3.2)	RCC frame	116512.00	(3.2a)	RCC (VR)	26359.00
(3.3)	Structure	47781.00	(3.3)	RCC bands	33979.00
(3.4)	Columns	41625.00	(3.4a)	Shuttering	18530.00
(3.5)	Beams	181705.00	(3.5)	Steel reinforcement	24500.00
2 (4.2 to (4.5)	Brick work in Superstructure	447457.00	2 (4.2 to (4.9)	Brick work in Superstructure	563658.00
		835080.00			667026.00

Saving = 835080.00 – 667026.00 = 168054.00 (20.12%)

Table 15
Overall Savings

With Conventional Specification		With Cost Effective Technologies	
Civil Work	2485384.00	Civil Work	1929027.00
Internal Services		Internal Services	
• Sanitary Water Supply (Dual Stack System)	171425.00	• Sanitary Water Supply (Single Stack System)	132468.00
• Internal Electrical	224116.00	• Internal Electrical	224116.00
Total	2880925.00	Total	2285611.00
Add 34.34% Cost Index on Civil & Sanitary items on Rs.2656809.00	912348.00	Add 34.34% Cost Index on Civil & Sanitary items on Rs.2061495.00	707918.00
Total	3793273.00	Total	2993529.00
Cost per dwelling unit	237080.00	Cost per dwelling unit	187096.00
		Savings Achieved per block =	799745.00
			21.08%

Savings for 1 block = Rs. 7,99,745.00

Savings for 1184 D.U. (74 blocks) = 74 x 7,99,745.00 = 5,91,81,130.00 Say = Rs. 591.81 Lakh

Table 16
Foundation
Cost of One Block for Civil Works (4 Storeyed) 16 Flats

With Conventional Specification			With Cost Effective Technologies		
1.1	Earth work in excavation in foundation trenches or drains	16979.00	1.1	Earth work in excavation in foundation trenches or drains	1522.00
1.2	Filling available excavated earth	5986.00	1.2	Filling available excavated earth	4496.00
2.1 (a)	Providing and laying in position cement concrete (1:4:8)	21401.00	2.1 (a)	Providing and laying in position cement concrete (1:6:10) using Flyash	5435.00
2.5	Extra for providing and mixing water proofing compound in plinth beam	1511.00	2.4	Extra for providing and mixing water proofing material in Plinth band	310.00
3.1	Providing and laying in position specified grade of reinforced cement concrete excluding the cost of centering shuttering and reinforcement in RCC 1:1½:3	92457.00	3.1 (a)	Providing and laying in position specified grade of reinforced cement concrete excluding the cost of centering shuttering and reinforcement in RCC 1:1½:3	4254.00
			(b)	Providing and laying in position machine batched M25 concrete	20531.00
3.4 (a)	Centering shuttering in Lintels, beams, plinth beams, girders, bressumers and cantilevers. (Partial 35.29 sqm @ 87.95)	7501.00	3.4 (a)	Centering and shuttering including strutting, propping etc. (Partial 21.32 @ 87.95) for plinth band etc.	1875.00
(b)	Column footings	7604.00			
3.5 (a)	Thermo Mechanically treated bars (Partial 3921.15 kg @ 21.85 per kg)	85677.00	3.5 (b)	Reinforcement for R.C.C work (Partial 161 kg + 6.93 @ 21.85)	18655.00
			3.6	Structural steel work in single section for piles	47527.00

With Conventional Specification			With Cost Effective Technologies		
			3.9 (a)	Boring, providing and installing cast in situ under ream piles with single bulb.	161912.00
4.1	Brick work with FPS bricks in Foundation & plinth cement mortar 1:6	144071.00	4.1	Brick work with FPS bricks of class designation	54012.00
	Total	383187.00		Total	320529.00
	Add Cost Index @ 34.34%	131586.00		Add Cost Index @ 34.34%	110070.00
	Total	514773.00		Total	430599.00
	Foundation Cost per DU	32173.00		Foundation Cost per DU	26912.00

Savings for 1 block = 84174.00 (16.35%)

Saving for 1184 D.U. (74 blocks) = 74 x 84174.00 = Rs. 6228876.00 Say= Rs. 62.29 Lakh

4.3 Specifications

Table 17

With Conventional Specification	With Cost Effective Technologies
• RCC framed structure in R.C.C 1:1.5:3	• Load bearing structure with machine made modular bricks • RC bands at P.L/L.L/R.L in CC 1:1.5:3 • Vertical reinforcements at corners and junctions
• Independent column footings	• Under reamed Piles footings
• Filler walls using FPS CD - 75 bricks	• Non load bearing walls using Fal-G bricks
• Cast in situ R.C Slab in RC 1:1.5:3 for roofing	• Precast R.C planks and joists using C.C 1:1.5:3 for intermediate floors / roofs
• Cast in situ R.C stairs in CC 1:1.5:3	• Precast ferrocement steps for stairs
• T- iron frames for doors / windows	• T- iron frames for doors / windows
• Flush door shutters	• Flush door shutters
• 40 mm thick P.C.C 1:2:4 flooring	• 25 mm thick P.C.C. 1:2:4 Flooring
• Kota stone on R.C.C Cooking shelf	• Kota stone on Ferrocement cooking shelf
• 12 mm cement plaster in cm 1:6 on inner walls	• 12 mm cement plaster in cement plaster in cm 1:6 on inner walls
• 6 mm thick ceiling plaster in cm 1:3	• No ceiling plaster
• Washed stone grit plaster on exterior face of walls.	• Exposed brick work with a coat of silicon treatment
• Brick coba for terracing	• Brick coba for terracing

Chapter 3 : THE CONSTRUCTION

3.1 Phasing of Development

The site is broadly divided into 11 Sectors so that the construction sequence is well managed and phased out with the required infrastructure. Each cluster works as an independent Block of units. The water supply and sewerage system have been designed in a manner that the residents can be allotted the dwelling units in 'phases' and that they can move into a cluster even while construction is going on for other clusters. This has helped in easy and efficient implementation of the project.

3.2 Analysis of Alternative Technologies

All technique were put to value analysis in group discussions consisting of officers from clients, consultants, BMTPC and CBRI. Value analysis of every technique was undertaken.

It is a general practice to adopt cast-in-situ slabs for floors and roofs. By adopting this construction an average of 25% of the cost of building is spent on floor/roof item only. Research and development works in the country have shown that partial precast systems of floor/roofs are best suited for the country. These systems are convenient to adopt in the field, speedier and economical in construction.

A number of such partially precast systems for roofing currently available were explored. These include the precast R.C. channel units, R.C. cored units, R.C. waffle shells, R.C. Planks and joists system, brick panel system etc. After a careful consideration of the different types of partially precast systems, it was decided to adopt precast planks and joists system for roof/floor.

Value analysis was also carried out for items like RC stair case, RC shelves and RCC sunshades, ferrocement steps, shelves and ferrocement water tanks.

Based on this exercise, it was finally decided to adopt following innovative techniques in the project :-

i. Foundation
   - Under reamed piles for foundations

ii. Super structure
   - Single brick thick load bearing wall using combination of modular Fal G & mechanised modular perforated bricks
   - Precast ferrocement steps for stairs
   - Precast ferrocement shelves for kitchen
   - Precast R.C. sunshades
   - Use of Flyash with cement mortars

iii. Roofing
   - Precast RC Planks and Joists

3.3 New Technologies Adopted in the Project

Innovative & cost effective Technologies

- Load bearing EQ resistant structure
- Modular walls (200 mm instead of 230 mm)
- High strength mechanized perforated bricks
- High strength Flyash (Fal-G) Modular bricks (manufactured at site)
- Precast R.C. Planks and Joists System for intermediate Floors and Roofs
- Precast ferrocement stairs steps

- Precast ferrocement shelves & platform
- Precast lintels
- Precast sunshades
- Flyash for Land filling
- Single stack system of plumbing
- PTMT eco friendly taps & fittings
- Saucer drainage system
- Use of waste brick bats
- Centralised High mast towers instead of lights on poles

3.4 Under-Reamed Pile Foundation

In areas with soil having low bearing capacity and filled up soil areas, it is a conventional practice to provide spread footing foundations. Research and development work has shown that a unique solution for providing foundations in such areas is by way of Under-reamed piles.

Under-reamed piles are bored, in situ concrete piles with one or more bulbs formed by enlarging the bases of the bore-holes by means of an under-reaming tool. By increasing the numbering under reams or bulb load carrying capacities of the pile can be considerably increased.

Photo 8: Pile Casting through a Tremie

The principle involved is to anchor the building by means of these piles at a depth where the soil has a nearby stable moisture content during the various seasons round the year and as such does not suffer any appreciable seasonal movement. In order to avoid inconvenience in construction as well for easy handling of construction equipment the dimensions of the piles have been standardized. The diameter of the pile ranges between 200 mm to 450 mm and depth of the pile preferably kept upto 8.50 m. the diameter of the under-reamed bulb is generally 2.50 times the diameter of the pile.

Arising from the additional bearing capacity and anchorage derived from the bulbs, these piles provide safe and economical foundations in soils of poor capacity overlying firm strata.

In this project single under-reamed piles of 8.5 m length have been provided having a diameter of 250 mm. The reinforcement has been decided on the basis of the load coming on each pile. Typically the reinforcement consists of 3 bars of 10 mm dia. These piles are located at each corner and T – junctions in the block and throughout the length of the load bearing wall.

Alternatively, in this project the reinforcement bars were replaced by single-angle iron section equivalent to the steel reinforcement.

The construction process involved the identification of the corners and T-junctions, layout on ground, boring for the pile including the under-ream, inserting the reinforcement cage in the bore hole and concreting through tremie. The concreting is done to the top level of grade beam. The top 200 mm is dismantled because of impurities & sludge mixed up, before laying the grade beam.

Augur Boring in Progress

Photo 9: Reinforcement Cage in Under-ream Borehole

Photo 10

Photo 11

Casting of Under-reamed Piles in Progress

In the project a total of 13000 under-reamed piles have been provided and it has been possible to achieve an economy of 10% in foundations as compared with the isolated and step footings. By adopting these piles it has also been possible to achieve speed in construction.

3.5 Walling

In one of the simplest subdivisions one can consider walls to be

- Load bearing, and
- Non load bearing

Walls built of masonry or in-situ cast walls can either be load bearing or non-load bearing. In load bearing construction, the weight of floors and walls of upper storeys are carried by the walls and transferred evenly to the foundation. The non-load bearing walls are part of RC framed construction where in loads are transferred through beams and columns.

Masonry walls are done by use of bricks or blocks (may be called as the masonry unit) which are usually held together with the help of mortar. Use of clay bricks and stone for masonry walls have been known since ancient times. In recent years, new materials like hollow or solid concrete blocks, hollow clay blocks, light weight blocks have emerged as the other alternatives for masonry walls.

3.5.1 Masonry Bonding

Bonding of bricks / blocks for masonry walls using conventional bricks in, English bond and Flemish bond are well known. English bond, however, is the most commonly used for construction in India.

3.5.2 Load Carrying capacity of the Masonry

Based on the masonry strength required to resist gravity loads masonry unit strength and mortar strength combination gives the basic compressive stress required. For example IS 1905 code gives a table to choose basic compressive strength of masonry based on a combination of mortar strength and brick strength.

Table 18
Basic Compressive Stresses for Masonry (After 28 Days)

S. No.	Mortar Type	Basic Compressive Stresses in N/mm^2 Corresponding to Masonry Units of which Height to Width Ratio does not exceed 0.75 and Crushing Strength in N/mm^2 is not less than											
		3.5	5.0	7.5	10	12.5	15	17.5	20	25	30	35	40
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	H1	0.35	0.50	0.75	1.00	1.16	1.31	1.45	1.59	1.91	2.21	2.50	3.05
2	H2	0.35	0.50	0.74	0.96	1.09	1.19	1.30	1.41	1.62	1.85	2.10	2.50
3	M1	0.35	0.50	0.74	0.96	1.06	1.13	1.20	1.27	1.47	1.69	1.90	2.20
4	M2	0.35	0.44	0.59	0.81	0.94	1.03	1.10	1.17	1.34	1.51	1.65	1.90
5	M3	0.25	0.41	0.56	0.75	0.87	0.95	1.02	1.10	1.25	1.41	1.55	1.78
6	L1	0.25	0.36	0.53	0.67	0.76	0.83	0.90	0.97	1.11	1.26	1.40	1.06
7	L2	0.25	0.31	0.42	0.53	0.58	0.61	0.65	0.69	0.73	0.78	0.85	0.95

3.5.3 Single Brick thick load bearing walls in multi storeyed buildings

3.5.3.1 Earlier the design of load bearing brick wall was made on empirical methods based on long established experience of Architects/Engineers, for example, wall thickness for a four storeyed building as per empirical method is to be 18”, 13.5”, 9” and 9” for ground, first, second and third storeyes respectively. While through rationalized design method by using better quality bricks, improved methods of construction, single thickness brick wall can be adopted for all the four storeys resulting in economy in cost and consumption of materials. The thickness of masonry walls depends on

- The strength of bricks and mortars used.
- Unsupported height or length of the walls
- Eccentricity in vertical loading
- Location and dimension of the opening
- Location of longitudinal and cross walls. To achieve best efficiency the imposed load is distributed uniformly and eccentricity of loading is kept to a minimum.

3.5.3.2 The IS code of practice for structural safety of buildings : Masonry walls (IS : 1905-1969) is referred in the design of masonry walls. The basic stress in the brick work depends upon the crushing strength of the bricks used and the mortar adopted in the construction of the wall. The basic stresses for brick work are given in Table II of the code. The permissible compressive stresses which can be allowed on the brick walls are to be reduced by a stress factor depending on the slenderness ratio and the equivalent eccentricity of loading given in table III of the code.

3.5.3.3 The slenderness ratio of a wall is an important factor governing the permissible stress. For a wall the slenderness ratio is obtained by dividing the effective height by the effective thickness or the effective length by the effective thickness, whichever is less. For a column the slenderness ratio is the effective height divided by the corresponding lateral dimension. The effective thickness is the actual dimension of the brick plus the specified thickness of the masonry. The effective heights and lengths of masonry walls and columns for various conditions of support are given in IS : 1905.

3.5.3.4 While designing single brick thick load bearing walls the criteria for seismic design of structures as have been given in IS:1893-1975 (criteria for earthquake resistant design of structure) and IS:4326-1993 (code of practice for earthquake resistant design and construction of buildings).

3.5.4 Load Bearing Mechanised Perforated Modular Brick Walls

Most of the conventional bricks manufactured in the country have dimensions of 230x115x75mm except in the State of West Bengal where the bricks have a dimension of 250x125x75mm. If quality control is not exercised in the moulding and burning of the bricks they end up having non-uniform shape, size and strength.

Trends across the world have shown that it is quite convenient to incorporate modular size in constructions which have nominal dimensions of 200x100x100mm and actual size 190x90x90 mm. The main advantages in using modular bricks include the following :-

i. Give more floor area.
ii. A saving of about 10% in the quantity of bricks and about 22% saving in the consumption of mortar.
iii. Reduction in consumption of clay and coal (for burning).

Modular bricks can also be manufactured with perforations which make them lighter in weight and are easy to handle. Being perforated, it creates air cavities in masonry which is a bad conductor of heat, thereby controlling inner room temperatures resulting in better thermal comforts. Further if these bricks are machine made, they offer smooth outside face, which does not require further plastering. With all these properties, mechanized modular perforated bricks construction offers all the inherent advantages, besides being economical in construction. They have high compressive strength and low water absorption, lesser size variation, lesser distortion and chippage and are thus more-durable. Modular perforated bricks come under the category of REB (Resource Efficient Bricks). These bricks use less energy and resource for their production as such these are known as REB. These cores or holes help in the manufacturing process. These cores (circular) create uniforms drying and burning of the bricks. It is easier to lay perforated bricks and give better bondage in the wall. These perforated bricks provide better thermal comforts resulting in saving in energy bill.

Use of mechanised modular perforated bricks also give benefit of saving in plaster thickness. Minimum compressive strength of bricks for use as exposed brick work is 12.5 N/mm^2. Machine made bricks with the extrusion and wire cut process meet the requirement. Modular bricks are used in masonry in Flemish Bond which provides a view appealing to eyes and provide temptation to have the exposed surface of the wall with colourless water proofing treatment.

Photo 12

3.5.5 Flyash (Fal G) Bricks Masonry

Photo 12

Photo 13

Flyash is a finely grounded residue resulting from the combustion of pulverized bituminous coal or sub bituminous coal (Lignite) in thermal power plants. It is generally grey, abrasive, acidic, refractory in nature and posses pozzolanic properties as fuel. Fal-G is a cementitious material which has a composition of flyash 70%, lime 15% and calcinated gypsum 15%. With this technology mechanised bricks are being manufactured using 60% sand, 28% flyash, 6% lime & 6% calculated gypsum. The lime content can be varied to achieve higher strength of bricks.

3.5.5.1 A compressive strength of 50 to 60 kg. per sqcm. is expected to be achieved from these bricks. For higher strengths composition of 50% flyash, 10 to 12% lime, 30% coarse sand, 5% gypsum and 2 to 5% cement is adopted. Cement not only provides early strength but also reduces breakage of corners / edges during handing.

3.5.5.2 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 pan mixture to form a stiff paste. The paste is poured into the steel moulds with hydraulic press. The bricks are then cured in air for about a fortnight. The bricks gain the final strength in longer period due to slow reaction of lime and active flyash. Random samples are tested for compressive strength before being used for construction.

3.5.5.3 These bricks can be manufactured in modular size which would enable saving in the quantity of bricks and mortar. These bricks do not require to be burnt in a kiln.

3.6 Roofing / Intermediate Slabs

By the use of precast roofing/flooring elements, the expenditure involved on this item can be reduced and a considerable amount of speed in construction is achieved. The planning of the building is done in a manner that spans are maintained to a particular module (100 mm). By doing so precast units of only one size will be required in construction which would result in preparing one size of mould only. Buildings planned on cross wall system are well suited for adoption of precast units.

The moulds for precasting are manufactured with steel. Steel moulds can be used for a large number of castings and are economical in the longer run. The precast units are designed by common methods of a structural design, adopting elastic theory or ultimate load theory. Ordinary mild steel are used as reinforcement. The M.S. provide better ductility.

Casting of the units is to be done with great care. Honeycombing etc. should be completely eliminated by using vibration. The units are to be properly cured before they are used in the building. Handling methods require particular attention during transportation & placement to avoid breakage and damage to the finished surface.

All openings are pre-planned and provided for in the moulds so that chipping or breaking of the precast units is completely avoided. Fan hooks, electrical conduits etc. are embedded in the in-situ concrete.

The water proofing of roof requires great care as there are a number of joints in the precast roof assembly. Therefore for terracing brick coba treatment has been provided which provides insulation and water proofing both. The coba also bonds well with the precast system.

3.6.1 Precast R.C. Planks and Joists system for Roofing & Intermediate Slab

This system consists of precast R.C. planks 60 mm thick supported over partially precast RC joists of 150 mm width and 150 to 200 mm depth with stirrup projecting out on the top. To provide for Tee-beam effect with the joist, the plank is made partly 30 mm thick. A 100 mm wide tapered concrete fillet is provided for strengthening the haunch portion during handling and erection.

The RC Planks typically have 3 Nos. 6mm dia bars as main reinforcement and 3mm dia mild steel wire @ 150mm c/c or 6 mm dia bars up to 200mm c/c as transverse reinforcement. The in-situ concrete at every joint with 2 no. 6mm dia as negative reinforcement form the flange of the tee beam along with the joists and provide monolithic effect. The scheme is suitable for intermediate floors and roofs or lightly loaded buildings and upto a span of 4.5 m. For larger spans main beams can be provided at suitable spacing to support the partially precast joists. For large spans the precast joist become heavy and erection cost increases.

During the construction, the joists are first erected and propped at mid span. Prop has to be of minimum size of 350x150x30 mm with the support of balli. The Planks are placed over the joists side by side. After placing reinforcement across the joist, concrete is filled over the joist and the haunches of planks and finished level. After the in-situ concrete has attained strength, the props are removed. No structural deck concrete is provided over the planks.

Photo 14: Precast components – Casting Yard

The maximum weight of a typical plank of 1500 mm length is 60 kg. which can be easily handled manually. The roof is designed for composite action. The partially precast joists are designed as Tee beams. The reinforcement in joists is provided as per design depending upon the span, spacing, load and end conditions.

Photo 15

This system has been found very economical. It saves about 14% steel, 27% concrete and 20% in overall cost of roofing besides saving in time. BIS has also issued IS codes for use of his roofing / flooring system and its design – in the form of specifications and code of Practice.

Some of the precautions are as under which must be observed while erecting the system.

- Proper curing of cast-in-situ concrete for minimum 10 days.
- Props are not to be removed till cast-in-situ concrete has attained the desired strength.
- Floor finish to be provided directly over the planks.
- 'V' groove pointing in Cement sand mortar in the ceiling along the joints at the planks.

Photo 16

3.6.2 Performance of RC Planks & Joists (Source : CBRI)

Fire Resistance

Fire resistance of RC plank slab with 3 cm concrete floor finish in respect of fire rating criteria is 1 hour and 45 minutes (while for 10 cm RC slab it is 2 hours).

Rain Penetration

Ponding tests over RC plank scheme were carried out and it was found that there was no seepage of water through the joints when all the suggested precautions, specially of filling of joints and laying a mortar layer over them before concreting in the haunches was followed.

Impact Load Test

The plank assembly without any floor finish over it have been tested under impact load by dropping a well tied gunny bag load of 40 kg. from a height of 1.2m. No sign of distress in the roof assembly has been observed.

Thermal Performance

The thermal transmittance (U) value of 6cm thick RC plank with 7.5 cm average thick mud phaska and 6 cm tiles above is 2.189 K.Cal/Hr/M^2/C

3.6.3 Validation of Technology – Precast RC Planks and Joist System

Time Tested Technology	Important Codes
IS : 13990 : 1994	Precast reinforced planks & joist & flooring specifications.
IS : 13994 : 1994	Specifications
CBRI Building Research Note (4) 1982 & 1987	Precast RC planks flooring/Roofing scheme
IS : 4326 : 1993	Code of practice for EQ resistance design & Construction of buildings improvised
NBC : 2005 (part 6) clause 6.3.1, 7.3.1.1 Part 6 section 7B	Prefabrication system accepted standards

Approved Technology by CBRI, BIS (IS:13994, IS:13990), IIT Delhi and as per NBC-2005

3.6.4 Economy

The quantities of cement, steel, labour and overall cost for a room of 3.5m x 3.5m have been calculated and compared with conventional RCC slab. The savings are as under :

Reinforcement	:	14%
Cement	:	27%
Coarse Aggregate	:	27%
Fine Aggregate	:	25%
Overall Cost	:	21%

Since the scheme uses precast components, shuttering is eliminated and propping is required only for pre-cast joists. Because of precast components quality can be controlled and the components being of moderate size and weight, no heavy mechanical handling and erection is required. Because of prefabrication, the construction time of roof can be reduced by about 40% as compared to the conventional insitu RCC slab.

3.7 Thin Precast R.C.C. Lintel cum Sunshade

The lintels are designed on the basis of the assumption that the load from a triangular portion of the masonry above, acts on the lintel. Bending moment of WL/8 where W is the load coming on the lintel and L is the span of the lintel assumed for the design purpose. A thickness of 15 cm is required by this method.

Thin precast R.C.C. lintels are designed taking into account the composite action of the lintel with brick work. It is applicable only when the load on the composite lintel is uniformly distributed. The thickness of the lintel is kept equal to the thickness of brick itself having a bearing of 200 mm on either supports. The sunshade is casted along with the lintel. The projected reinforcement of lintel beam is lapped with cast – in – situ lintel band reinforcement for continuity.

Use of precast lintels speeds up the construction of walls besides eliminating shuttering and centering. Adoption of thin precast lintels and sunshades results in upto 50 percent saving in material and cost.

Sequence of Casting Erection, Placement of Precast Elements (RC Planks, Joists, Sunshade cum Lintels)

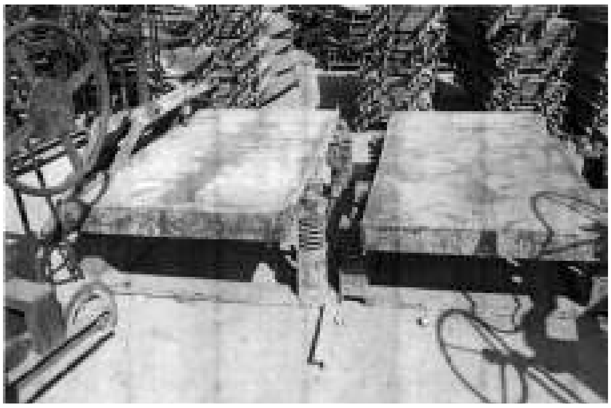


Photo 17: Vibrating Table for twin mould

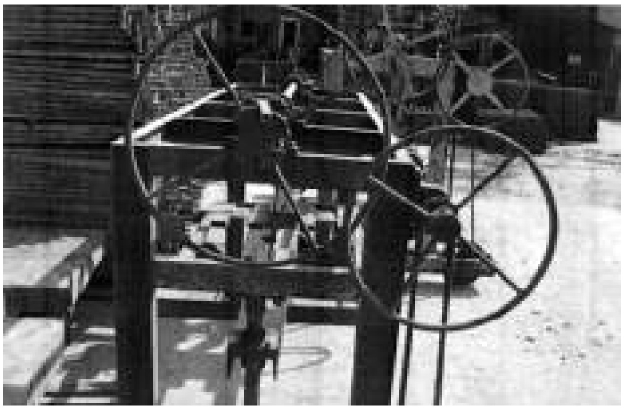


Photo 18: Wheels of the machine

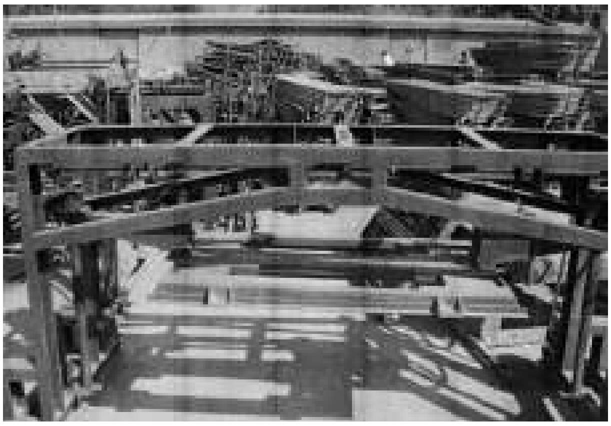


Photo 19: The Machine with mould

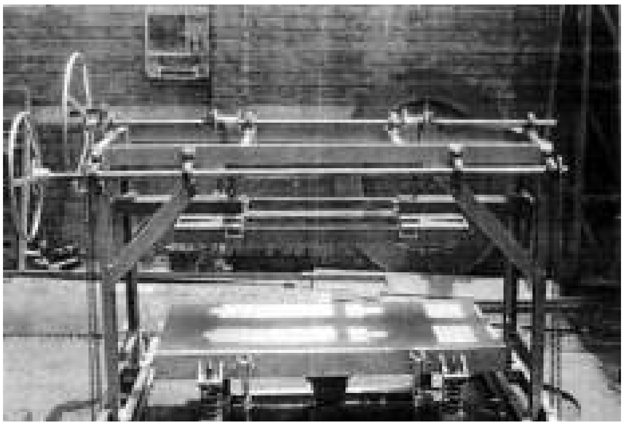


Photo 20: Machine placed over casting Table

Photo 21: Pellets stack ready for precasting

Photo 22: Binding Planks Reinforcement

Photo 23: Stack of reinforcement cage for different size of planks

Photo 24: Placing twin plank reinforcement

Photo 25: Placing mould over reinforcement cage

Photo 26: Tightening the mould clamps

Photo 27: Pouring of concrete in mould

Photo 28: Finishing the planks

Photo 29: Demoulding (loosening the clamps)

Photo 30: Lifting mould after casting

Photo 31: Ready casted twin planks over pellets

Photo 32: Lifting casted plank with pellet

Photo 33: Casted planks on pellets stacked for initial strength

Photo 34: Planks in curing tank

Photo 35: Stacking of Precast planks

Photo 36: Curing of stack of planks


Photo 37: RC joists being precasted


Photo 38: Precasted joists under covered shed


Photo 39: Precasted joists stacked


Photo 40: Precasting of joists with eges laying machine


Photo 41: Manual lifting joists


Photo 42: Precast joists loading on trolley


Photo 43: Precast joist loaded on trolley


Photo 44: Transporting planks through Tractor – trolley from casting yard

Photo 45: Lifting of planks mechanically

Photo 46: Lifting & placing of planks mechanically

Photo 47: Planks placed over joists & walls

Photo 48: The rows of planks with havneh reinforcement

Photo 49: Portable concrete plant

Photo 50: Filling cast-in-situ concrete in haunches perforated brick walls with vertical reinforcement visible

Photo 51: The slab after cast-in-situ concrete filled up haunches. The flyash brick serves as shuttering and cornice band

Photo 52: The sunk slabs and vertical reinforcement projecting out

Photo 53: Ceiling view after placement of joists

Photo 54: Form work and reinforcement of precast sunshade cum lintel

Photo 55: Precasted sunshade cum lintel

Photo 56: Curing of Sunshades

Photo 57: Precast sunshades stacked for curing & lifting

Photo 58: Loading of precast sunshades on trolley

Photo 59: Precast sunshades placed over window opening

Photo 60: Precast Sunshade Reinforcement lap with lintel band

3.8 Ferrocement

3.8.1 Ferrocement is a special form of reinforced concrete. It is a composite material consisting of cement sand mortar (matrix) reinforced with layers of small diameter wire meshes. It differs from conventional reinforced concrete primarily by the manner in which the reinforcement is arranged within the brittle matrix. Since its behavior is quite different from that of conventional reinforced concrete in performance, strength and potential applications, it is classed as a separate material. Usually steel bars are also used in addition to wire mesh, to form a steel skeleton, which helps in retaining the required shape of the ferrocement components once the cement mortar hardens. The wire mesh reinforcement is uniformly distributed across the thickness of the element. This helps in achieving improved mechanical properties viz. fracture, tensile and flexural strength, fatigue and impact resistance. In addition, it also eliminates the use of formwork particularly for complicated shapes. Ferrocement is used as thin structural components where strength and rigidity are developed through form. Cement is ideally suited for prefabricated construction and in particular for housing applications. The success of ferrocement in various terrestrial applications can be attributed to:

i. Ready availability of material locally
ii. Need of low level technology for its production
iii. Better utilization of available human resources and
iv. Architectural flexibility

3.8.2 Ferrocement can be considered as a material with many paradoxes. This is because it possesses a degree of toughness, ductility, strength, crack resistance and durability considerably greater than other forms of reinforced concrete. It has been possible to achieve these improved properties in structural components having a thickness of 25mm. Normally improvements in properties of material are associated with sophistication in manufacturing processes with increased demand for quality control. This is not so in case of ferrocement, as these improved properties, can be achieved with almost primitive techniques without any advanced technology.

3.8.3 Materials

The materials used for ferrocement are cement, sand, wire mesh and steel bars. The properties of these materials are discussed below :-

3.8.3.1 Cement

Ordinary Portland cement of grade 43 that is commercially available in the market is satisfactory for ferrocement construction.

3.8.3.2 Sand

Well-graded Natural River sand with particle size less than 4.75 mm having fineness modulus between 2.5 – 3.0 is suited for ferrocement construction. The cover to reinforcing mesh is small and cannot be exceeded. Hence to prevent corrosion of steel reinforcement grading of sand for mortar mixes become very important to get workable cement mortar with low water cement ratio. The water used for preparing cement sand mortar is potable and relatively free from organic compounds. The proportion of cement sand mix generally varies from 1:1½ to 1:3 and water cement ratio varies from 0.35 to 0.55.

3.8.3.3 Wire Mesh

One of the important constitute of ferrocement is wire mesh reinforcement. These generally consist of thin galvanized wires. Properties of ferrocement depend on the type, quantity, orientation and strength properties of the mesh reinforcement. Different types of mesh reinforcement are available in the market, which are suitable of ferrocement construction.

Hexagonal wire mesh also commonly known as chicken wire mesh is fabricated from drawn wires of diameter varying from 22-26 gauge and woven into hexagonal patterns with mesh opening varying from 10mm to 25mm. this is the cheapest, easiest to handle and most commonly used in ferrocement construction.

Woven wire mesh is fabricated by simply weaving the galvanized wires into desired grid sizes without welding them at the intersections. The grids are generally square, the mesh wires are not perfectly straight and some amount of waviness exists.

Welded wire mesh is fabricated in rectangular or square pattern by perpendicular intersecting wires (generally 2 – 3 mm diameter) made of low to medium tensile strength steel (which are much stiffer than hexagonal or woven wire mesh) and welded together at the intersections.

Expanded metal mesh, which is sometimes used in ferrocement construction, is formed by slitting thin gauge sheets and expanding them in a direction perpendicular to the slits to produce diamond shape openings. This mesh has inherent advantages like good mechanical bond and ease of placing.

3.8.4 Skeletal Steel

As the name implies this is generally used for making framework of the structural component upon which layers of wire mesh reinforcement are laid and also serve as spacer to wire mesh. The steel rods are provided in both longitudinal and transverse directions. When they are provided for non-structural purpose, they are spaced as widely as possible and when provided for carrying external loads, their spacing is governed by design considerations. In general, mild steel roads or galvanized iron wires of diameters varying from 2 mm to 6 mm are used. Sometimes for structural purpose high yield strength deformed bars are also employed.

3.8.5 Admixtures

Admixtures are additives, which are introduced in the cement sand mortar mix to modify some of the properties of the mortar in its fresh and hardened states. These materials may be chemical admixtures in which case they are added in quantities no larger than 5% by weight of cement or other materials in which case they are added in excess of 5% of weight of cement and referred as additives. Different types of admixtures are used to improve/modify properties of mortar.

3.8.6 Construction Methods

Ferrocement construction does not require skilled labour nor heavy capital investment on equipment to produce them. There are four major steps in ferrocement construction, viz. placing of reinforcement, mixing of mortar, placing mortar and curing. As the reinforcement content in ferrocement is very high (up to 8% by volume) and is uniformly distributed throughout the thickness of the element, the essential requirement is that the continuous mesh reinforcement has to be completely impregnated and covered with cement mortar. Basically to achieve this goal one may either force the cement mortar into the pre-existing skeletal steel framework or alternatively force layers of mesh reinforcement into a bed of mortar. A number of techniques are being used for placing the mortar into the framework of mesh. Among these are hand plastering of mortar from one side against a mould or from both sides.

3.8.7 Mechanical Properties

Ferrocement derives its unique properties due to the subdivision and distribution of the reinforcement which can be described with the two parameters namely volume fraction of reinforcement defined as volume of reinforcement per unit volume of ferrocement and specific surface of reinforcement defined as surface area of reinforcement per unit volume of ferrocement. Within the elastic range ferrocement can be considered as a homogeneous material and its elastic properties can be obtained from the elastic properties and volume fractions of its constituents.

The advantages of Ferrocement elements include :-

- High strength to weight ratio compared to reinforced concrete
- High crack resistance and impermeability to water
- Lightweight elements due to relatively small volume of material required
- Ease in maintenance and repair
- Easy provision of accessories, conduit holes etc.

In keeping with the advantages of ferrocement it was decided to use ferrocement elements in construction in place of the conventional RCC construction. These included ferrocement shelves, ferrocement steps in stairs and ferrocement water tanks.

3.8.8 Ferrocement Shelves

Conventionally, cooking platforms are provided in 50 mm thick cast-in-situ RCC slabs. In this project, precast ferrocement cooking shelves have been used which are easier to cast, easier to handle and light weight besides being economical. The cooking platform provided has 25mm thickness having one layer of welded mesh 25x75mm of 2 mm dia and two layers of chicken mesh 24 gauge, embedded in cement mortar. Besides reduction of dead load it has resulted in an economy of about 35%.

Photo 61: Casting of precast ferrocement shelves

3.8.9 Ferrocement Staircase Steps

Stair case is an essential part of any building as it provides access to different floors in the structure. Conventionally, staircases are constructed in Reinforced Cement Concrete, having a waist slab, treads and risers, hand rails etc. The per square metre load on account of the staircase is higher than the residential portion of the building. Similarly, the cost of stair case is always more than the built up area of rest of the building, due to treads and risers railing, baluster etc.

An economical method of providing a staircase is to eliminate the waist slab and use precast steps (tread & riser unit). In the Bawana project, precast ferrocement elements, combining the tread and riser have been used which have been supported on walls. These elements which are 25 mm thick do not require any plastering, or flooring and railing. The use of these elements has led to a saving of 40% to 50%.

Photo 62: Preparing Mesh

Photo 63: Mould ready for casting

Photo 64: Laying first layer of mortar

Photo 65: Mesh placed on mould

Photo 66: Mesh placed on battery of moulds

Photo 67: Laying mortar and finishing

Photo 68: Giving finishing touch to precast steps

Photo 69: Stacking of precast steps

Photo 70: Precast steps placed in first flight

Photo 71: Precast steps placed in first & second flight

Photo 72: Precast landing

Photo 73: View showing precast sunshade, landing

3.8.10 Ferrocement Water Tanks

In the present day scarcity of water and limited water supply during the day, it has become essential to have a provision to store water for use. There are a number of options available to store water viz. brick masonry tanks, RCC water tanks, PVC tanks etc.

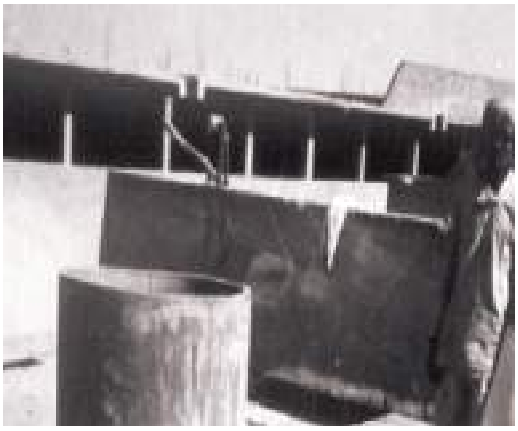


Photo 74: Ferrocement Water Tank

Photo 75: Ferrocement Water Tanks

In this project ferrocement tanks of 1200 litres & 1600 litres have been provided which have a dia of 1.5m. For these tanks, the base and the cylindrical container have been casted separately. The wall thickness is 25mm. Two layers of chicken mesh along with GI wire in helical shape have been provided in the walls.

3.9 Earthquake Resistance Features

- Grade Beam
- Vertical Corner Reinforcement
- Plinth band
- Lintel band
- Roof band

Photo 76: Grade Beam & Vertical Reinforcement (for Earthquake Resistance)

Photo 77: Plinth band & Vertical Reinforcement (for Earthquake Resistance)

Photo 78: Photograph of lintel band

Photo 79: Photograph of roof band

Photo 80: Vertical Reinforcement L - Junction

Photo 81: Vertical Reinforcement T - Junction

3.10 Partial Replacement of Cement by Flyash

Flyash is a fine residue obtained from thermal power stations using ground or powdered coal as boiler fuel. It can be utilized in various forms as building material. The thermal power stations in the country throw large quantities of flyash which goes as waste but which can be effectively used as partial replacement of cement.

Investigations carried out in research laboratories have shown that replacement of cement (OPC) by flyash up to 20% by weight in concrete and mortars does not adversely affect the strength of the resultant mix. The flyash should however conform to the following chemical and physical requirements (IS : 3812 – Part II – 1966)

It should however be seen that the mixing should be done thoroughly and the proportions of the materials should be carefully controlled to obtain the requisite strength. Moreover as the density of flyash ranges from 750 to 850 kg/m^3 it is preferable to check the weight / volume ratio at intervals on site to ensure proper mix control when batching is done by volume.

The use of flyash partially replacing cement improves plasticity making the mix more easily workable. Denser concrete/mortar is obtained thereby making it more impermeable. Besides this the surface finish of concrete is also improved and the segregation and bleeding in lean concrete is also reduced. Instead prescribed M_2 mix of 1 cement : 6 coarse sand, mortar mix of 1:1:6 (1 Cement : 1 Flyash : 6 coarse sand) has been used, resulting in saving of cement without affecting the required strength.

3.11 Services

Single Stack System of Plumbing

In the conventional system of drainage for buildings two separate pipes are provided. One for the soil which takes discharge from the water closet, urinals etc. and the other for the discharge from the baths, sinks and wash basins etc. Besides, a vent pipe is also fitted with both the pipes to prevent breakage of seal of the traps of different appliances. The single stack system of plumbing which replaces the above system is essentially a one pipe system in which the wastes from kitchen, bath etc. and soil from toilets is carried out of the building in a single stack. The ventilation is also completely omitted and the service stack itself serves the purpose of a ventilation pipe. It embodies the merits of both the conventional two pipe system and the modern one pipe system.

In the single stack system of plumbing the loss of seal due to self siphonage, induced siphonage and back pressure should be avoided. The shape of appliances, slope, diameter and length of the branch pipes requires careful designing. Deep seal traps have been used to keep intact the water seal.

The use of the above system effects saving in quantity of pipes and fittings and also gives a cost saving of up to 30% in plumbing work.

Single stack water supply system
For water supply system also, the single stack plumbing has been adopted.

3.12 Tendering System

After finalizing the new innovative techniques and other specifications to be adopted in conjunction with the architectural planning and design of the dwelling unit, the detailed working drawings were prepared with all minute details like design of pile foundations, size of piles, pile – reinforcement, details of earthquake strengthening measures needed as per codal requirements, size and sections of planks and joists, requirement of steel as per designs, thickness, size of ferrocement elements to be adopted etc.

This exercise was carried out in order to avoid any future cost escalations. As a result of group discussions it was decided that lump – sum tendering system should be adopted for the scheme. Lump sum tendering system requires all detailed drawings for each item of work so as not to leave any scope for cost variations during construction stage.

In order to assess the real capabilities of the contractors and their potential to undertake this unique self-contained composite project the bids were invited in two parts separately containing technical and financial bids.

M/s Era Construction (I) Ltd. Were found technically eligible and competitive in financial bid and as such DSIIDC and consultants found them suitable for award of work.

The adoption of theory of Modular – Coordination weighed in favour of Lump-sum tendering and it has resulted in saving in construction time, less wastages of materials & labour, easy supervision, uniform and simplified measurement practices. This also helped in close coordination at all stages of building process like designing, component production and monitoring of construction.

Prebid meetings, where representatives of various contracting firms were present, were also represented by officers of BMTPC and CBRI.

CBRI and BMTPC Scientists were there to answer any technical queries or doubts regarding proposed technologies in-order to quash any fears in the minds of bidders. Technical presentation and interactive discussions between consultants, Bidders, Promoters and Executors resulted in confidence-building.

Chapter 4 : CONSTRUCTION MANAGEMENT AND QUALITY CONTROL

4.1 Supervision and Control

Proper supervision and management control was ensured through the Engineering Staff of DSIIDC and project management team of the consultants. Periodical visit by the officials from CBRI and BMTPC, helped in proper planning and implementation of project in the field. Design and detailing of the precast elements with the help of BMTPC and CBRI officers have played a vital role in execution of the project.

4.2 Quality Assurance

Quality assurance functions involved.

- Drawing up contract clauses / specifications, laying down the detailed requirement of materials, processes, standards including tests to be conducted and laying down acceptance criteria.
- Exercising checks and tests during the construction phase in order to ascertain that the work done conforms to the standards and specifications laid down.

In this project in order to achieve proper quality assurances, the tender documents were prepared in clear terms, proper specifications formulated, construction practices and processes to be followed were laid down properly. Various standards to be followed were clearly indicated as per CPWD Specifications.

A well-defined coordination between Clients, Consultants and Contractors was needed and in this project all concerned thrived to achieve it.

In order to achieve timely targets and better quality control it was decided to set-up a casting yard at the site of work for the production of precast RC and ferrocement elements and productions unit for manufacturing of Fal G bricks. This resulted in better quality control on the produce, timely delivery of the elements as per scheduled requirement for which proper delivery / demand schedule was maintained.

For proper quality analysis and quality control, a laboratory with field testing facilities was setup. Periodical tests were conducted at the construction site as well as through approved Laboratories.

4.3 Various tests to be conducted for materials during construction are given in *Table 19*.

Table 19 (Format)

S. No.	Item	Test Required	Test Conducted	
			In house	External Lab
1.	Stone Agg. 10.20 & 40 mm			
2.	Coarse Sand			
	a) Sieve Analysis			
	b) Silt Content / Bulkage			
3.	FPS Brick			
	a) Dimensional test			
	b) Water absorption			
	c) Compressive strength			
4.	Modular Bricks			
	a) Dimensional test			
	b) Water absorption			

S. No.	Item	Test Required	Test Conducted	
			In house	External Lab
	c) Compressive strength			
5.	Fly Ash Bricks			
	a) Dimensional test			
	b) Water absorption			
	c) Compressive strength			
6.	Reinforcement Steel			
	a) 6 mm			
	b) 8 mm			
	c) 10 mm			
	d) 12 mm			
7.	Structural Steel			
	a) MS Angle 40 x 40 x 5			
	b) MS Angle 40 x 40 x 6			
8.	Cement			
9.	Tiles			
10.	Door Shutter			
11.	Water Proofing Compound			
12.	Lead			
13.	Enamel Paint			
14.	Wooden Primer			
15.	Steel Primer			
16.	Water			
17.	Rebound Hammer Test			
18.	Cube Test			
19.	Slump Test			

4.4 Some of the Mandatory Tests to be Conducted for Important Materials are given in *Table 20***.**

Table 20

Material	Test	Relevant IS Code
Cement	Fine ness	IS:4031, IS:269, IS:1489 & IS:455
	Soundness	IS:4031, IS:269, IS:1489 & IS:455
	Setting time (initial & final)	IS:4031, IS:269, IS:1489 & IS:455
	Compressive strength	IS:4031, IS:269, IS:1489 & IS:455
	Consistency	IS:4031, IS:269, IS:1489 & IS:455
Sand	Organic impurities	IS:2386, IS:383, IS:456
	Silt content	IS:2386, IS:383, IS:456
	Particle size distribution	IS:2386, IS:383, IS:456
	Bulking of sand	IS:2386, IS:383, IS:456
Coarse aggregate	% of soft or deleterious material	IS:2386, IS:456, IS:383
	Particle size distribution	IS:2386, IS:456, IS:383
	Estimation of organic impunities	IS:2386, IS:456, IS:383
	Surface moisture	IS:2386, IS:456, IS:383
	Determination of 10% fine	IS:2386, IS:456, IS:383
	Specific gravity	IS:2386, IS:456, IS:383
	Bulk density	IS:2386, IS:456, IS:383
	Agg. Crushing strength	IS:2386, IS:456, IS:383
	Agg. Impact value	IS:2386, IS:456, IS:383
Fly Ash	Chemical properties	IS:3812
	Physical properties	IS:3812

Material	Test	Relevant IS Code
Water	pH Value	IS:3025, IS:456
	Limit of acidity	IS:3025, IS:456
	Limit of alkalinity	IS:3025, IS:456
	% of solids	IS:3025, IS:456
	Chlorides	IS:3025, IS:456
	Suspended matters	IS:3025, IS:456
	Sulphates	IS:3025, IS:456
	Inorganic solids	IS:3025, IS:456
	Organic solids	IS:3025, IS:456
Concrete	Compacting factor	IS:1199
	Weight, cement and air content	
	Cube test	IS:516, IS:1199, IS:456
Steel for RCC	Tensile strength	IS:1608
	Retest	IS:1786
	Rebound test	IS:1786
	Nominal mass	IS:1786
	Bend test	IS:1599
	Elongation test	IS:1786
	Proof stress	IS:1786
Brick work	Dimension	IS:3495, IS:1077
	Compressive strength	IS:3495, IS:1077
	Water absorption	IS:3495, IS:1077
	Efflorescence	IS:3495, IS:1077
White glazed tiles	Water absorption	IS:777
	Crazing test	IS:777
	Impact test	IS:777
	Chemical resistant test	IS:777
Wood Flush door	Timber : Moisture content	
	End Immersion test	IS:2202
	Knife test	IS:2202
	Adhesion test	IS:2202

4.5 The tables 21 to 30 show the methodology as sample test.

Table 21
Format for Water Test Report (Sample)
(Without Admixture / With Required Admixture)

Sample : Water collected

S. No.	Tests	Results	IS Limit	Protocol
a)	Volume of 0.02 N H_2SO_4 required to neutralize 100 ml sample using mixed indicator (ml)		25.0 ml Max	IS : 456
b)	Volume of 0.02 N, NaOH required to neutralize 100 ml sample using phenolphthalein (ml)		5 ml Max	IS:456
c)	PH value		Not less than 6	IS:3025 Pt-11-1983, Reaff-1996

Test conducted on __________ (date) at site laboratory of ______________________ in presence of the following persons :-

(Representative of agency) (Representative of Contractors)

Table 22
Format for Sample Test of Cubes for Compressive Strength

Project :
Agency : _ _ _ _ _ _ _ _ _ _ _ _ _ (Contractor)
Client : ____________________

S. No	Date of Sample	Item of work and location	Mix	Date of testing	No. of days	Compressive strength obtained for individual cubes Kg/ Cm^2	Average strength Kg/Cm^2 (B)	Differences (Max. – Min.) (A)	% of (A) over (B)	Acceptability	Remarks

Signature of Contractor's Authorised Representative

Signature of Client

Table 23
Format for Sample Test of Bricks for Water Absorption

Name of Project:
Name of Agency : _ _ _ _ _ _ _ _ _ _ _ _ _ (Contractor)
Name of Client : ________________
Class of Designation : 125
Brand of Brick : Mechanised Modular perforated Brick

S. No.	Date of taking Sample	Identification mark	Wt. of dry brick (gms) 19-04-2005	Wt. of brick after immersing 24 hrs. water (gms)	Date of testing	Percentage water absorbed in individual brick	Average percentage water absorbed	Acceptability	Remarks
1		I							
2		II							
3		III					6.63%	Max 20%	Satisfactory
4		IV							
5		V							

Signature of Contractor's Authorised Representative

Signature of Client

Table 24
Format for Sample Test of Bricks for Water Absorption

Name of Project:
Name of Agency : _ _ _ _ _ _ _ _ _ _ _ _ _ (Contractor)
Name of Client : ___________________
Class of Designation : 75
Brand of Brick : Non-Modular Brick (FPS)

(Example)

S. No.	Date of taking Sample	Identi-fication mark	Wt. of dry brick (gms) 19-04-2005	Wt. of brick after im-mersing 24 hrs. water (gms)	Date of test-ing	Percentage water absorbed in individual brick	Aver-age per-cent-age waterab-sorbed	Accept-ability	Remarks
1		I							
2		II							
3		III						Max 20%	Satisfac-tory
4		IV							
5		V							

Signature of Contractor's Authorised Representative

Signature of Client

Table 25
Format for Test of Bricks for Water Absorption

Name of Project:
Name of Agency : _ _ _ _ _ _ _ _ _ _ _ _ _ (Contractor)
Name of Client : ___________________
Class of Designation : 100
Brand of Brick : Fly Ash Brick

(Example)

S. No.	Date of taking Sample	Identi-fication mark	Wt. of dry brick (gms)	Wt. of brick after immers-ing 24 hrs. water (gms)	Date of testing	% water absorbed in individual brick	Average % water absorbed	Accept-ability	Remarks
1		A.T.							
2		A.T.							
3		A.T.						Max 20%	Satisfac-tory
4		A.T.							
5		A.T.							

Signature of Contractor's Authorised Representative

Signature of Client

Table 26
Test of Bricks for Dimensions (Format)

Name of Project:
Name of Agency : _ _ _ _ _ _ _ _ _ _ _ _ _ (Contractor)
Name of Client : ____________________
Designation of Brick : 125 (Mechanised Modular perforated Brick)

S.No.	Brick Brand	Date of Testing	Dimension obtained for 20 Bricks (cm)	Acceptability (cm)	Remarks
1.			L = 380	372 – 388	Satisfactory
			W = 180	176 – 184	Satisfactory
			H = 180	176 – 184	Satisfactory

Signature of Contractor's Authorised Representative

Signature of Client

Table 27
Format for Test of Bricks for Compressive Strength

Name of Project:
Name of Agency :
Name of Client :
Class of Designation : 125 (Mechanised Modular perforated Bricks)

(Example)

S. No.	Date of taking sample	Identification mark	Date of testing	Dial Gauge Reading (KN)	Compressive strength obtained for individual bricks Kg/Cm^2	Size of bricks	Average strength Kg/cm^2 (B)	Remarks
1		I				19 x 9		Required 125 kg/cm^2
2		II				19 x 9		
3		III				19 x 9		
4		IV				19 x 9		
5		V				19 x 9		

Table 28
Format for Test for Sand

Name of Project:
Name of Agency : _ _ _ _ _ _ _ _ _ _ _ _ _ (Contractor)
Name of Client :

Silt Content of Sand
Date of testing : Limit

1. Volume of saturated sand and silt = 92 ml
2. Volume of silt = 5.4 ml
3. Percentage silt content after 3 hours = 5.86% 8%

Bulking of Sand

Date of testing :

1. Volume of moist sand = 150 ml
2. Volume of saturated sand = 128 ml
3. Percentage bulking of sand = 17.18% Bulkage range 15% to 30% depending upon moisture content ranging between 2% to 5%.

Signature of Contractor's Authorised Representative

Signature of Client

Table 29
Format for Gradation Test for Sand

Name of Project:
Name of Agency : _ _ _ _ _ _ _ _ _ _ _ _ _ (Contractor)
Name of Client :
Sample : Coarse Sand
Date :

S.No.	Sieve Size (mm)	Wt. Retained Gms.	Cumulative Wt. Retained Gms.	Percentage Retained	Percentage Passing	Limit Zone–II
1	10 mm				100	100
2	4.75 mm				93.90	90-100
3	2.36 mm				80.45	75-100
4	1.18 mm				63.45	55-90
5	600 micron				43.05	35-59
6	300 micron				24.05	8-30
7	150 micron				10	0-10
8	PAN					

Sample taken 2000 gm.

Signature of Contractor's Authorised Representative

Signature of Client

Table 30
Format for Gradation Test for Aggregate

Name of Project:
Name of Agency : _ _ _ _ _ _ _ _ _ _ _ _ _ (Contractor)
Name of Client :
Sample : 20 mm Aggregate
Date :

S.No.	Sieve Size (mm)	Wt. Retained Gms.	Cumulative Wt. Retained Gms.	Percentage Retained	Percentage passing	Limit
1	40	0	0	0	100	100
2	20	660	660	13.20	86.80	86.100
3	10	3950	4610	92.20	7.80	0-20
4	4.75	279	4889	97.78	2.22	0-5
5	PAN	111	5000			

Sample taken 5000 gm.

Signature of Contractor's Authorised Representative

Signature of Client

Photo 82: Brick Compression Test

Photo 83: Sieve Analysis

4.6 Tests for Structure Elements

As Structural elements were produced at site workshop under strict controls, the quality of final product was assured.

4.6.1 Field Load Tests for alternative technologies adopted

- RC planks deflection test
- RC planks & joist assembly load test
- Ferrocement steps load test
- Rebound hammer non-destructive test
- Under reamed piles load test
- Sonic integrity test for piles.

4.6.2 Testing of precast RC Planks & Joists as per IS 13990:1994 (Precast Reinforced Concrete Planks and Joists for roofing and flooring specification)

R.C. PLANKS

General

- The planks are to be tested after 28 days of laying of in-situ concrete in haunches. The haunch concrete shall be cured for 14 days.
- The selected plank shall be simply supported with a bearing of 40mm / 50 mm over a brick wall finished level and smooth with cement mortar 1.4

Deflection Test

The maximum allowable deflection in millimeters is 40 x L^2/d, where 'L' is the effective length of the plank in metres and D is the total thickness of the plank in millimeters.

In case of DSIIDC project at Bawana the maximum length of a plank is 1.50 metres and the total thickness is 60mm. Therefore effective loaded length is 1.50-2x0.040= 1.42m

Load Calculations

Panel length = 1500mm
Dimensions of the panel = 1500x30x60mm
Loaded area of the plank = 1.42 x 0.30 = 0.426 sqm, say 0.43 sqm
Superimposed Dead Load of the floor finish & Cushion = 0.43 x 150 = 64.5 kg, say 65 kg
Superimposed Live Load (as per I.S. code for low income housing = 0.43 x 150 = 65 kg
Superimposed Test live load = (1.25 x LL) = 1.25x65 = 81.25, say 82.00
Maximum allowable deflection in this case is 40 x $(1.42)^2$/60 = 1.344, say 1.35 mm

Testing of Planks

a) Allowable Deflection and Deflection Recovery Test

The stages of testing are as under :

Explanatory Example
(Sample)

PE-1 (Plank Size)	=	1480 mm x 300 mm
Bearing	=	40 mm
Clear Span	=	1400 mm
• Imposed Dead Load (for Flooring) 40mm flooring	=	100 kg/m^2
• Imposed Live Load	=	200 kg/m^2
• Design Live Load for Testing (1.25 x 200)	=	250 kg/m^2
• Total Load for Testing	=	350 kg/m^2
• Loaded Area of Plank (1.40m x 0.30m)	=	0.42 m^2

Step - 1

Initial Dead Load to be applied as UDL	=	0.42 m^2 x 100
	=	42.0 kg
Reading on Dial Gauge to be recorded	=	$\pm$ 0 Say (X)

Step - 2

Further Load as UDL	=	0.42 m^2 x 250
	=	105.00 kg

Step - 3

Retain the Load for 24 Hours

Record Second Reading on Dial Gauge after completion of 24 hours = Say (Y)

Step - 4

Check Deflection = Y – X mm

Permissible Deflection

$$< \frac{40\,L^2}{D} \quad (L = \text{in m}) \quad (D = \text{in mm})$$

$$< \frac{40 \times 1.4 \times 1.4}{60}$$

$$< \mathbf{1.307\ mm}$$

(if the deflection observed is < 1.307 mm it is safe and no further test required)

Failure Load Test

The RC Plank which has passed the deflection recovery test shall be tested further to 'Failure Load Test'. The loading of the plank shall continue till the plank fails. If no failure occurs by crushing or breaking of the unit, the load causing a deflection of 1 in 60 of the clear span of the unit shall be considered as the failure load.

Table 31
Deflection Recovery test of Reinforced concrete Precast Planks
(As per IS : 13990-1994)
(Sample)

S. No.	Load (kg)	Dial Gauge (mm)	Date	Time
1.	62.50	1	14-09-2005	9:15 am
2.	140.62	1.1	14-09-2005	9:20 am
3.	140.62	1.23	15-09-2005	9:30 am
4.	62.50	1.01	15-09-2005	9:35 am
5.	62.50	1.01	15-09-2005	11:20 am

Size of Plank	:	1.490m x 0.30m x 0.06m
Dead Load	:	62.50 kg
Total Load applied	:	140.62 kg

Deflection was found within permissible limit.

Photo 84: Shows RC Planks Deflection Test and RC Planks Failure Load Test

Photo 85: Precast Plank Load Test for Failure

4.6.3 The entire slab comprising of precast planks, joists and in-situ haunches were also tested for deflection

Photo 86

Photo 87

Precast Slab Assembly Load Test (Deflection of entire slab)

Table 32
Location : Pocket-_____, Block-_____, Cluster-_____, Flat-_____
Sample Load Test for First Floor Slab (Bed Room)

Room Size	2.98 x 2.41	=	7.18 sqm
Live Load		=	150 Kg/sqm
Test Load	150 x 1.25	=	187.50 Kg/sqm
Total Design Load	7.18 x 187.50	=	1347 Kg
Average Wt. of Single Brick		=	2.99 Kg
No. of Bricks Required	1347 ÷ 2.99	=	450 Nos. of Bricks

Date	Time	Load in Kg	Dial Gauge Reading initial +0 (mm)	Deflection (mm)	Remarks	Max deflection as per IS:13990 Calculations
26-12-2005	01:10 PM	1346	0.16	0-16	Immediate loading	1.70 mm
27-12-2005	02:10 PM	1346	0.27	0-27	After 24 hours of loading	

Note **:** As per IS : 1994, if the deflection is less than the permissible deflection. No further recovery test is required.

Result : The deflection after 24 hours of loading comes out to much less than the permissible limit. Hence the performance of assembly is satisfactory.

4.6.4 The piles were also tested by loading the piles with sand bags and the settlement checked.

Photo 88: Loading in progress for Pile Test

Photo 89: For settlement installed below the load platform

4.6.5 For safety check, even non-destructive tests were carried out for under reamed piles. The Sonic-Integrity Test (SIT) for piles foundation included pulse velocity test.

Photo 90: Non Destructive Pile Integrated Test

Photo 91: Non Destructive Pile Integrated Test

4.7 Time and Site Management

The fundamental requirement of any good construction is to ensure quality, speed and overall economy.

4.7.1 The precast RC plank system of roofing requires remarkably short completion period compared to conventional system of cast-in-situ concrete.

The roofing elements and other structural elements such as sunshades, lintels, stairs steps are produced in a site workshop, while simultaneously the site preparation and foundations are under way. The precast elements are transported from workshop to the erection site. The construction time, with the technologies adopted is almost 30 to 40% less than conventional system, because the use of these technologies require almost no centering or shuttering etc. at job sites. These technologies make the construction free from common problems associated with cast-in-situ work that makes other activities difficult.

The precast system allows other activities such as conduiting, plumbing, Door and Window frames, simultaneously. Plastering and other wall finishes follow immediately after laying of slab. Due to precasting, ceiling plaster is not required.

The monitoring of time management at site was done in a planned manner so as to check the progress from time to time. PERT chart / Bar chart were developed to watch the progress of the work.

A long term success of a project depends upon the quality of construction and the workmanship involved during the implementation process. The construction quality is to a great extent dependent on the quality of material used and the routine and mandatory tests carried out from time to time. These become essential as materials are procured from different sources having variable engineering properties.

The formats of Tests have been dealt in earlier paras of this chapter.

For proper management, the number and types of precast elements and other materials were worked out.

4.7.2 Different sizes of Precast R.C. Elements

The sizes of planks and joists were limited to four and three respectively. In fact the use of principles of Modular – coordination for architectural design helped in restricting the sizes of precast elements like planks, joists, lintels, sunshades to two or three only which helped in saving in construction time and reducing the wastages. Adoption of modular coordination for architectural planning is a helpful tool in adoption of Precast technologies. Table 15 given below give details of the sizes of the elements used in the project whereas table 16 and 17 quantify the Precast Elements. These figures are just to indicate the size of the project.

Table 33
Sizes of Planks & Joists

Description	Sizes	
	Type – I & II	Type – III
Planks		
PE 1	1490 x 300	1492 x 300
PE 2	930 x 300	1280 x 300
PE 3	1140 x 300	1230 x 300
PE 4	830 x 300	1080 x 300
PE 5	------	870 x 314
Joists		
JE 1	2930 x 150 x 150	2900 x 150 x 150
JE 2	2610 x 150 x 150	2400 x 150 x 100
JE 3	2330 x 150 x 100	1700 x 150 x 100
JE 4	2260 x 150 x 100	------

Table 34
Quantity of Various Precast Elements

S.No.	Description of Item	Unit	Quantity (For One Block)			Total Quantity (For Whole Project)
			Type I	Type II	Type III	
P	Planks					
P1	PE1	Nos.	345	981	720	198429
P2	PE2	Nos.	14	165	160	30750
P3	PE3	Nos.	368	30	144	59776
P4	PE4	Nos.	139	26	180	33399
P5	PE5	Nos.	---	---	21	1554
J	Joists					
J1	JE1	Nos.	36	64	64	15892
J2	JE2	Nos.	0	16	16	2848
J3	JE3	Nos.	36	16	16	7348
J4	JE4	Nos.	12	16	16	4348
S	Sunshades, lintels, etc.					
S1	W1	Nos.	12	16	16	4348

S.No.	Description of Item	Unit	Quantity (For One Block)			Total Quantity (For Whole Project)
			Type I	Type II	Type III	
S2	W2	Nos.	0	16	16	2848
LB	Lintel Beams	Nos.	24	48	48	11544
PB1	Plinth beam of length 2200 & 2800 mm	Nos.	4	6	6	1568
PB2	Plinth beam of length less than 2200 mm	Nos.	4	8	8	1924
	Ferrocement					
FC1	Stair's Step	Sqm	13.43	20.15	20.15	5266
FC2	Kitchen Platform	Sqm	12.60	11.20	11.20	3569
FC3	Bed Block	Nos.	168.00	224.00	224	60872
FC	Water Tank	Lit	2400.00	3200.00	3200	869600

Note :-
Type I = 125 blocks of 12 DUs each
Type II = 104 blocks of 16 DUs each
Type III = 74 blocks of 16 DUs each

Table 35
Total Number of Precast Elements (for 3164 + 1184) houses

Precast Elements	Total Required (Nos.)
RC Planks	323908
RC Joists	30436
Lintel Beam	11544
Sunshades	7196
Plinth Beam (for partition walls)	3492
Stair Case Steps	11476
Kitchen Working Platform	4348
Water Tanks	606
Bed Block	60872
Total Precast Elements	456278

4.7.3 Estimation of Concrete & steel reinforcement for precast elements. The quantities worked out provide monitoring, quality control, management and check for wastage, pilferage, efficiency (Table 18 to 22)

Table 36
Reinforcement Steel in individual Precast Elements
(Sample Type I)

S. No.	Description	Dia.	No.	Length	Total Length	wt/m	Wt.
	Precast Planks :						
1	PE 1 (1490 x 304.3)	6	3	1.460	4.380	0.222	0.972
			11	0.274	3.014	0.222	0.669
							1.641
2	PE 2 (930 x 304.3)	6	3	0.900	2.700	0.222	0.599
			7	0.274	1.918	0.222	0.426
							1.025
3	PE 3 (1140 x 304.3)	6	3	1.110	3.330	0.222	0.739
			9	0.274	2.466	0.222	0.547
							1.287
4	PE 4 (830 x 304.3)	6	3	0.800	2.400	0.222	0.533
			7	0.274	1.918	0.222	0.426
							0.959
	Precast Joists :						
1	JE 1 (2930 x 150 x 210)	6	21	0.570	11.970	0.222	2.657
		8	1	2.890	2.890	0.395	1.142
		10	2	2.890	5.780	0.617	3.566
							7.365

S. No.	Description	Dia.	No.	Length	Total Length	wt/m	Wt.
2	JE 2 (2610 x 150 x 160)	6	18	0.475	8.550	0.222	1.898
		8	1	2.570	2.570	0.395	1.015
		10	2	2.570	5.140	0.617	3.171
		8	1	1.300	1.300	0.395	0.514
							6.598
3	JE 3 (2330 x 150 x 160)	6	17	0.475	8.075	0.222	1.793
		8	1	2.290	2.290	0.395	0.905
		10	2	2.290	4.580	0.617	2.826
							5.523
4	JE 4 (2260 x 150 x 160)	6	17	0.475	8.075	0.222	1.793
		8	1	2.220	2.220	0.395	0.877
		10	2	2.220	4.440	0.617	2.739
							5.409
	Precast Sunshade :						
1	Sunshade W1	6	14	1.14	15.96	0.222	3.54
		8	5	2.3	11.5	0.395	4.54
		6	5	1.27	6.35	0.222	1.41
							9.50
2	Sunshade W2	6	9	0.84	7.56	0.222	1.68
		8	5	1.85	9.25	0.395	3.65
		6	3	0.72	2.16	0.222	0.48
							5.81

Precast Lintel

Lintel (1150 x 100)

Length=1.150 + 2 x 40 x 0.008 = 1.79
Wt. of 8 mm bar = 1.79 x 0.395 = 0.71 kg
Wt. of 6 mm bar = 1.79 x 0.222 = 0.40 kg
Total Wt. = 1.11 kg

Lintel (1300 x 100)

Length = 1.300 + 2 x 40 x 0.008 = 1.94
Wt. of 8 mm bar = 1.94 x 0.395 = 0.77 kg
Wt. of 6 mm bar = 1.94 x 0.222 = 0.43 kg
Total Wt. = 1.20 kg

Table 37
Reinforcement Steel for Precast Element (Sample Type I)

	Unit	Qty. per	Steel per Unit (kg)			Steel per Block (kg)		
			6 mm	8 mm	10 mm	6 mm	8 mm	10 mm
Planks								
PE1	Nos.	345	1.64			566.31	0	0
PE2	Nos.	14	1.03			14.35	0	0
PE3	Nos.	368	1.29			473.51	0	0
PE4	Nos.	139	0.96			133.24	0	0
Joists								
JE1	Nos.	36	2.66	1.14	3.57	95.66	41.0958	128.38536
JE2	Nos.	0	1.90	1.53	3.17	0.00	0	0
JE3	Nos.	36	1.79	0.90	2.83	64.54	32.5638	101.73096
JE4	Nos.	12	1.79	0.88	2.74	21.51	10.5228	32.87376
Sunshades								
W1	Nos.	12	4.95	4.54		59.43	54.51	0
W2	Nos.	0	2.16	3.65		0.00	0	0
Lintel Beams	Nos.	24	0.42	0.74		9.96	17.76	0
PB >2200 & 2800 mm	Nos.	2	2.58	3.90	6.10	5.16	7.8052	12.19192
PB <2200 mm	Nos.	2	1.05	1.85		2.11	3.6972	0
Total						1445.79	167.95	275.18

Table 38
Concrete in Precast Elements (Sample Type I)

S. No.	Description	Length (m)	Breadth (m)	Height (m)	Qty. (cum)
	Precast Planks				
1	PE 1 (1490 x 304.3)	1.490	0.304	0.030	0.014
		0.890	0.234	0.030	0.006
		0.300	0.100	0.030	0.001
					0.021
2	PE 2 (930 x 304.3)	0.930	0.304	0.030	0.008
		0.330	0.234	0.030	0.002
		0.300	0.100	0.030	0.001
					0.012
3	PE 3 (1140 x 304.3)	1.140	0.304	0.030	0.010
		0.540	0.234	0.030	0.004
		0.300	0.100	0.030	0.001
					0.015
4	PE 4 (830 x 304.3)	0.830	0.304	0.030	0.008
		0.230	0.234	0.030	0.002
		0.300	0.100	0.030	0.001
					0.010
	Precast Joists				
1	JE 1 (2930 x 150 x 210)	2.930	0.150	0.150	0.066
2	JE 2 (2610 x 150 x 160)	2.610	0.150	0.100	0.039
3	JE 3 (2330 x 150 x 160)	2.330	0.150	0.100	0.035
4	JE 4 (2260 x 150 x 160)	2.260	0.150	0.100	0.034
	Precast Sunshade				
1	Sunshade W1	1.500	0.180	0.100	0.027
		1.300	0.600	0.050	0.039
		1.300	0.600	0.025	0.020
					0.086
2	Sunshade W2	1.050	0.180	0.100	0.019
		0.750	0.300	0.050	0.011
		0.750	0.300	0.025	0.006
					0.036
	Precast Lintel				
1	Lintel (1150 x 100)	1.150	0.090	0.100	0.010
2	Lintel (1300 x 100)	1.300	0.090	0.100	0.012

Table 39
Concrete in Precast Elements per block (Type I)

Description of Item	Unit	Qty. per block	Concrete per unit	Total Concrete of one block
Planks :				
PE1	Nos.	345	0.021	7.154
PE2	Nos.	14	0.012	0.164
PE3	Nos.	368	0.015	5.552
PE4	Nos.	139	0.010	1.402
Sunshades				0.000
W1	Nos.	12	0.086	1.026
W2	Nos.	0	0.036	0.000
Bed block	Nos.	168	0.002	0.403
			Total	**15.701**

Description of Item	Unit	Qty. per block	Concrete per unit	Total Concrete of one block
Joists :				
JE1	Nos.	36	0.066	2.373
JE2	Nos.	0	0.039	0.000
JE3	Nos.	36	0.035	1.258
JE4	Nos.	12	0.034	0.407
Lintel Beams	Nos.	24	0.011	0.265
PB 2200 & 2800 mm	Nos.	4	0.056	0.225
PB 2200 mm	Nos.	4	0.018	0.072
			Total	**4.600**

Table 40
Estimated Material Data for 3164 Houses (Type I & II) Pocket A & B

• Flyash Brick	30 Lacs
• Mechanised perforated modular clay brick	195 Lacs
• Conventional FPS Brick	50 Lacs
• Cement	3.20 Lacs bags
• Reinforcement steel	1135 MT
• Coarse Sand	17,200 cum
• Fine Sand	28,400 cum
• Water Proof Silicon Paint	1.26 lac sqm
• No. of under Reamed Piles	13000
• Precast Elements	
- RC Planks	2,33,300
- RC Joists	22,150
- Sunshades	4,828
- Stairs Steps	8,430
- Kitchen Platforms	3,164
- Water Tank	458
• Electric Conduit	1,79,200 metre
• Wires & Cables	6,94,700 metre
• Main Water Line	4,393 metre
• Sewer line	3,362 metre
• Drain	7,030 metre

4.8 Time management

Daily & Weekly programme schedule for precasting and other works at site had been monitored.

Table 41
Weekly Sample Work Schedule for Structure

October					November					December				
	Block	Floor	Flat	Weekly Total		Block	Floor	Flat	Weekly Total		Block	Floor	Flat	Weekly Total
1-Oct				0	1-Nov					1-Dec	12/2/I(3)	GF	12	
2-Oct					2-Nov	11/5/I	FF	8		2-Dec	11/9/II	FF	8	28
3-Oct	10/6/I(4)	2F	16		3-Nov				32	3-Dec	9/1/II	2F	8	
4-Oct					4-Nov	11/7/I(4)	FF	16		4-Dec				
5-Oct	10/8/I	2F	8	32	5-Nov	11/8/II	GF	8		5-Dec	11/2/II	2F	8	
6-Oct					6-Nov					6-Dec				
7-Oct	10/1/II	2F	8		7-Nov	12/1/I(3)	FF	12		7-Dec	11/3/II	2F	8	24
8-Oct					8-Nov					8-Dec				
9-Oct					9-Nov	11/2/II	GF	8	36	9-Dec	11/6/II	2F	8	
10-Oct	10/4/II	2F	8		10-Nov	11/3/II	GF	8		10-Dec				
11-Oct					11-Nov					11-Dec				
12-Oct	11/1/I(4)	FF	16	32	12-Nov	11/6/II	GF	8		12-Dec	11/8/II	2F	8	
13-Oct					13-Nov					13-Dec	12/2/II	FF	12	
14-Oct	11/4/I	GF	8		14-Nov	11/4/I	2F	8		14-Dec				28
15-Oct					15-Nov					15-Dec	11/9/II	2F	8	
16-Oct					16-Nov	11/5/I	2F	8	40	16-Dec				
17-Oct	11/5/I	GF	8		17-Nov	11/9/II	GF	8		17-Dec				
18-Oct					18-Nov					18-Dec				
19-Oct	11/7/I(4)	GF	16	36	19-Nov	11/7/I(4)	2F	16		19-Dec	11/2/II	3F	8	
20-Oct					20-Nov					20-Dec				
21-Oct	12/1/I(3)	GF	12		21-Nov	12/1/I(3)	2F	12		21-Dec	11/3/II	3F	8	32
22-Oct					22-Nov					22-Dec				
23-Oct					23-Nov	11/8/II	FF	8	36	23-Dec	11/6/II	3F	8	
24-Oct	10/1/II	3F	8		24-Nov	11/2/II	FF	8		24-Dec	9/1/II	3F	8	
25-Oct					25-Nov					25-Dec				
26-Oct	10/4/II	3F	8	32	26-Nov	11/3/II	FF	8		26-Dec				
27-Oct					27-Nov					27-Dec	12/2/I(3)	2F	12	
28-Oct	11/1/I(4)	2F	16		28-Nov	11/6/II	FF	8		28-Dec				28
29-Oct					29-Nov				8	29-Dec	11/8/II	3F	8	
30-Oct					30-Nov					30-Dec	11/9/II	3F	8	
31-Oct	11/4/I	FF	8	8						31-Dec				
				140					**152**					**140**
				696					**848**					**988**

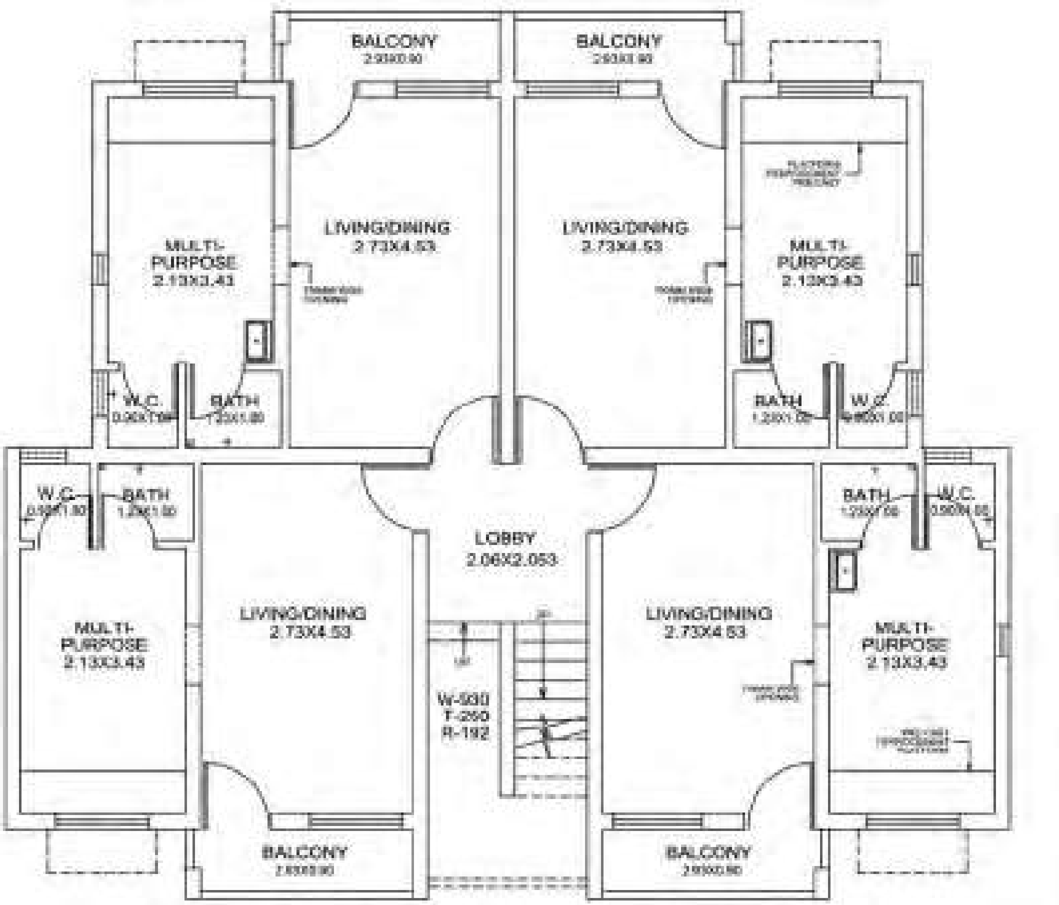
Chapter 5 : DRAWINGS

List of Drawings :

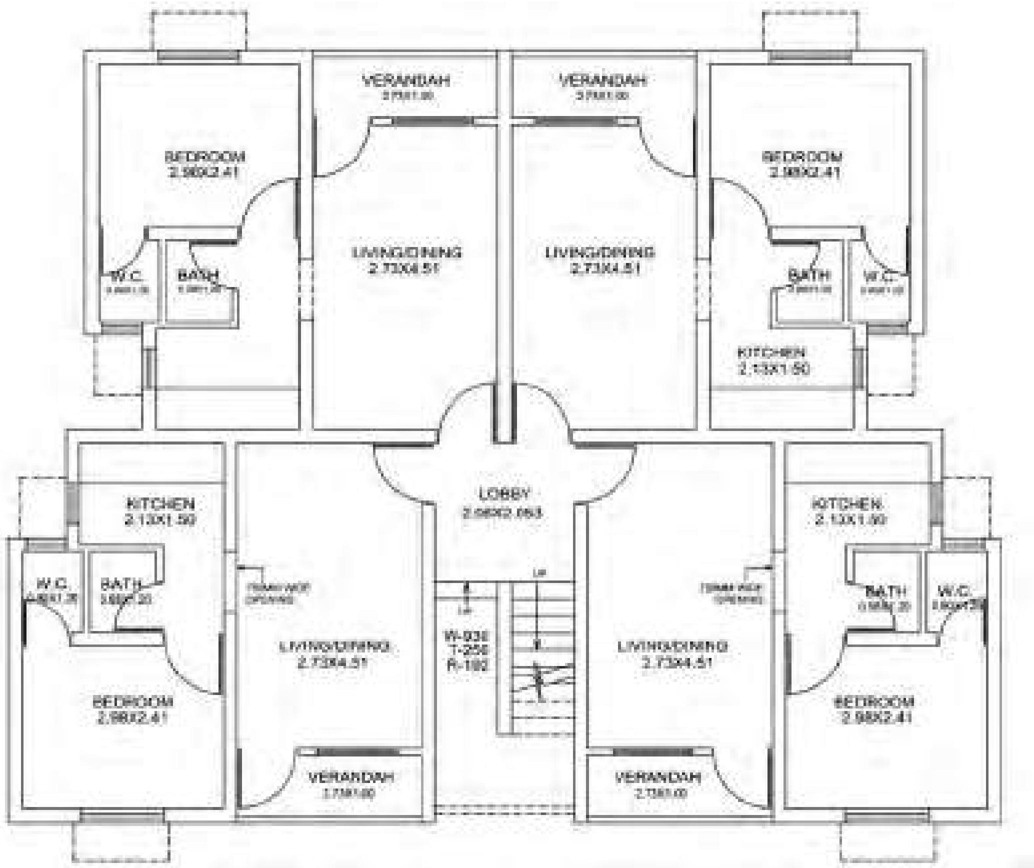
5.1 Master Layout (3164+1184) = 4348 houses

5.2 Layout Pocket A & B (3164 DU)

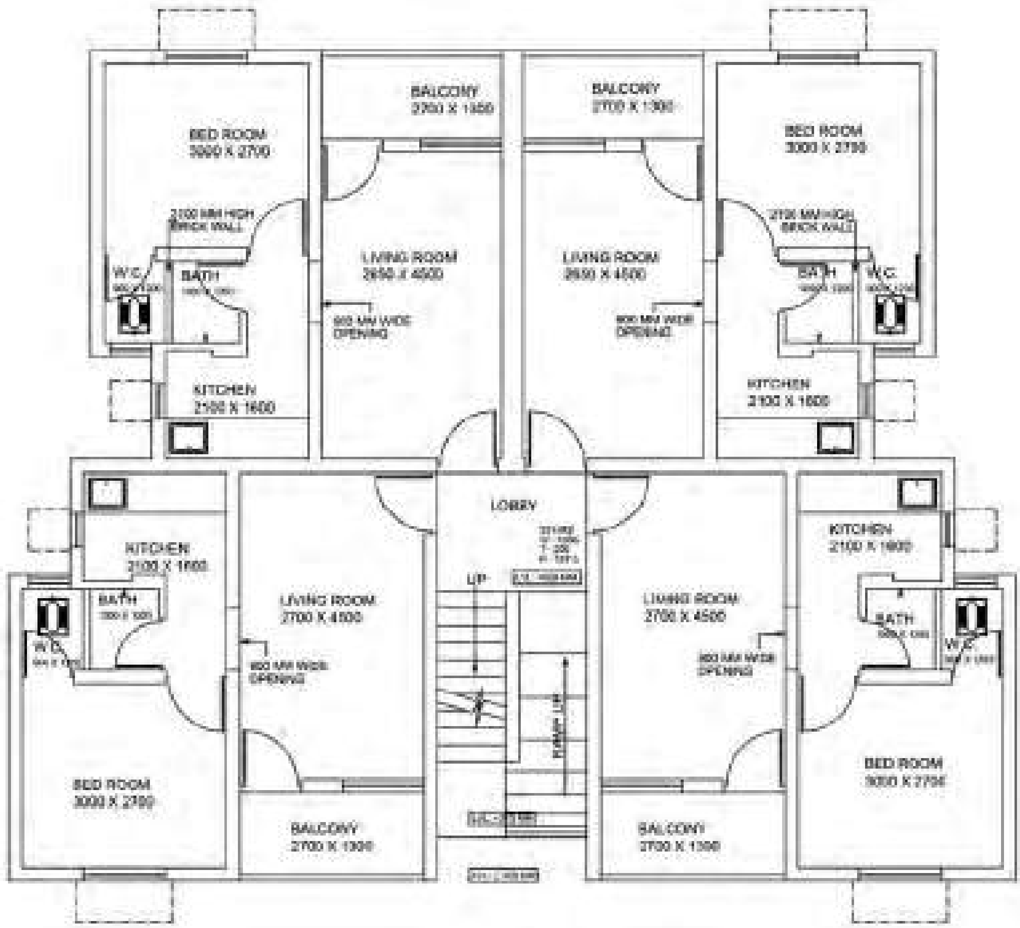
5.3 Ground Floor Cluster Plan Type I



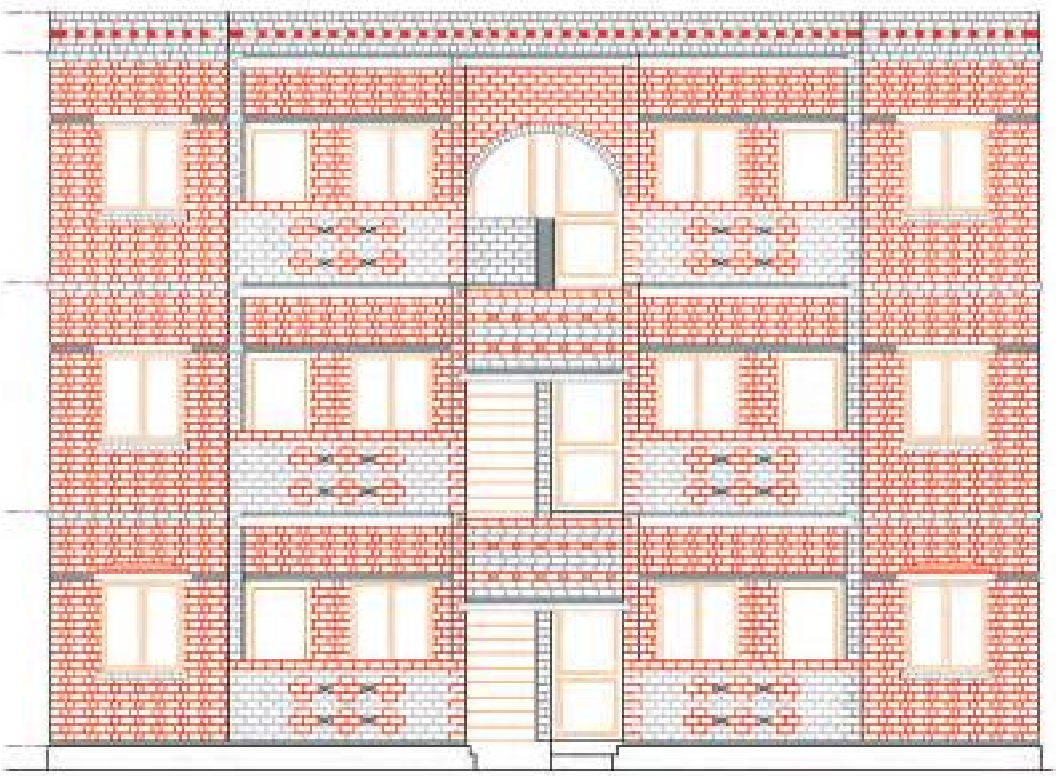
8.4 Ground Floor Cluster Plan Type II



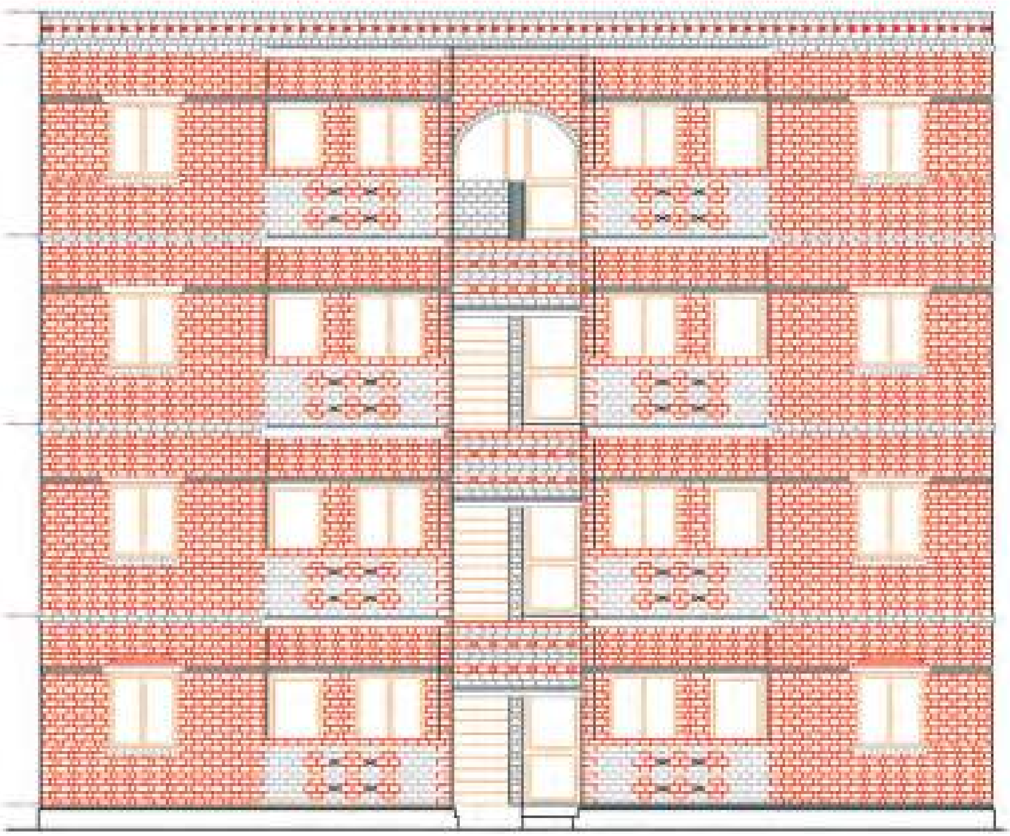
5.5 Ground Floor Cluster Plan Type III



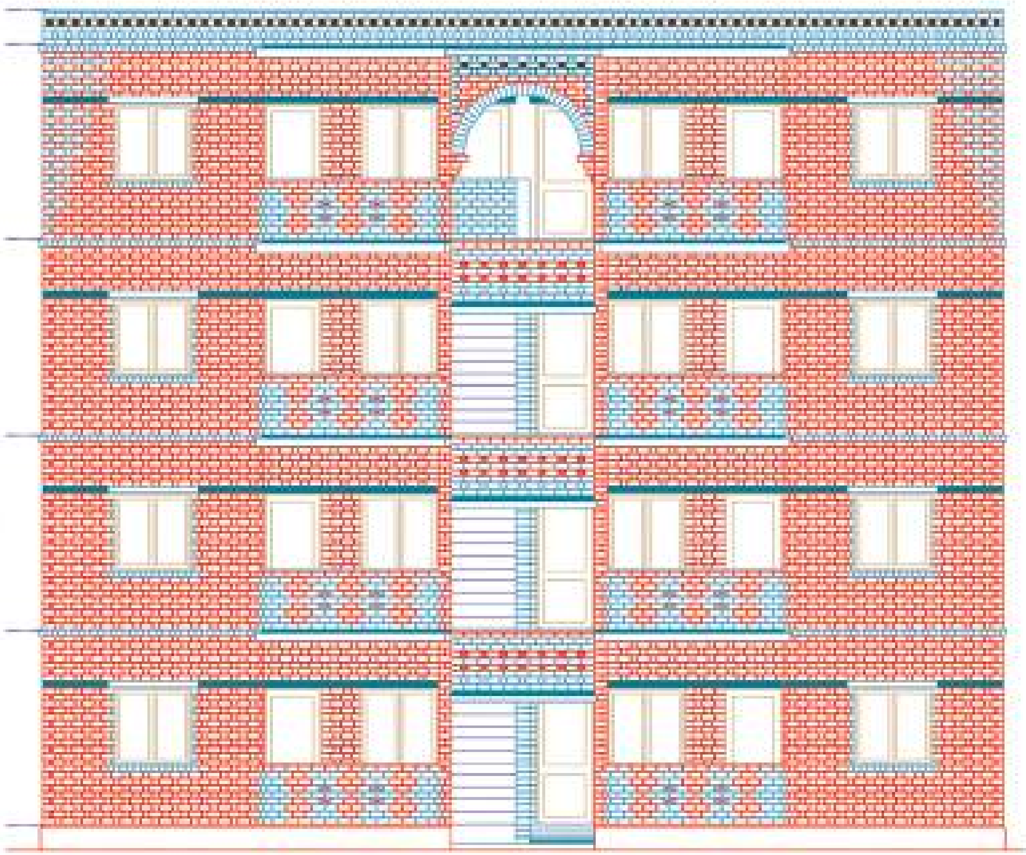
5.6 Front Elevation Cluster Type I



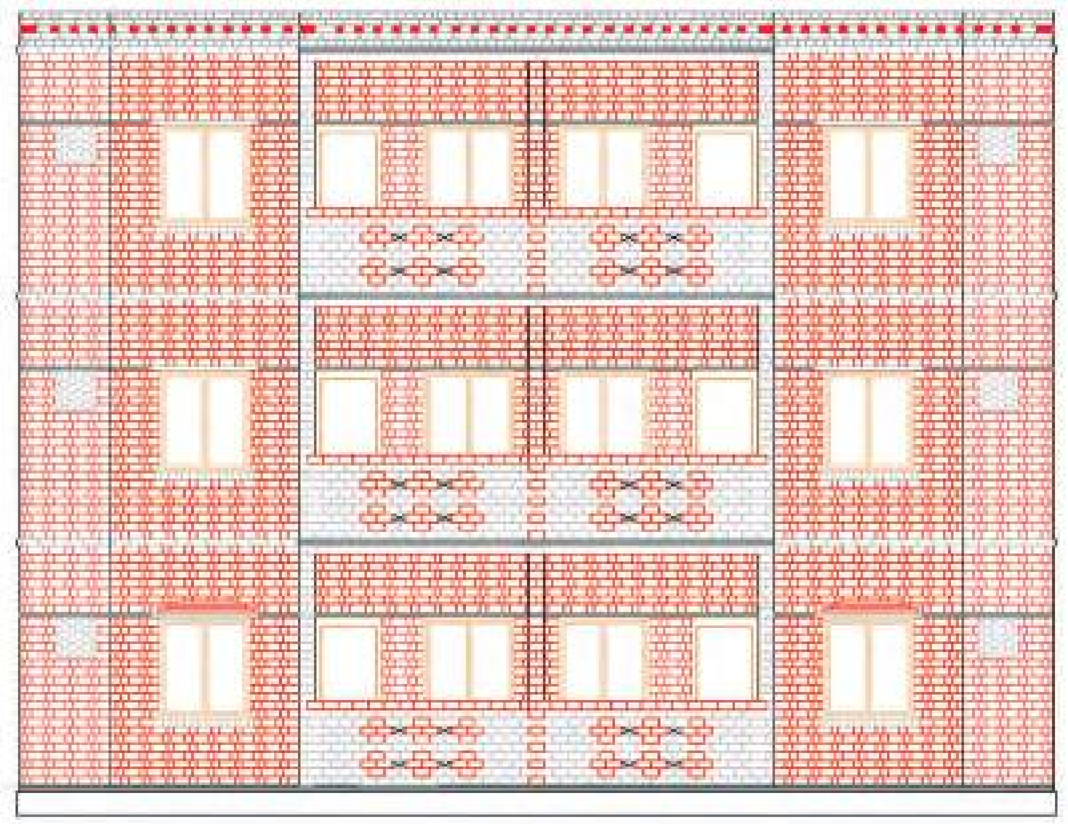
5.7 Front Elevation Cluster Type II



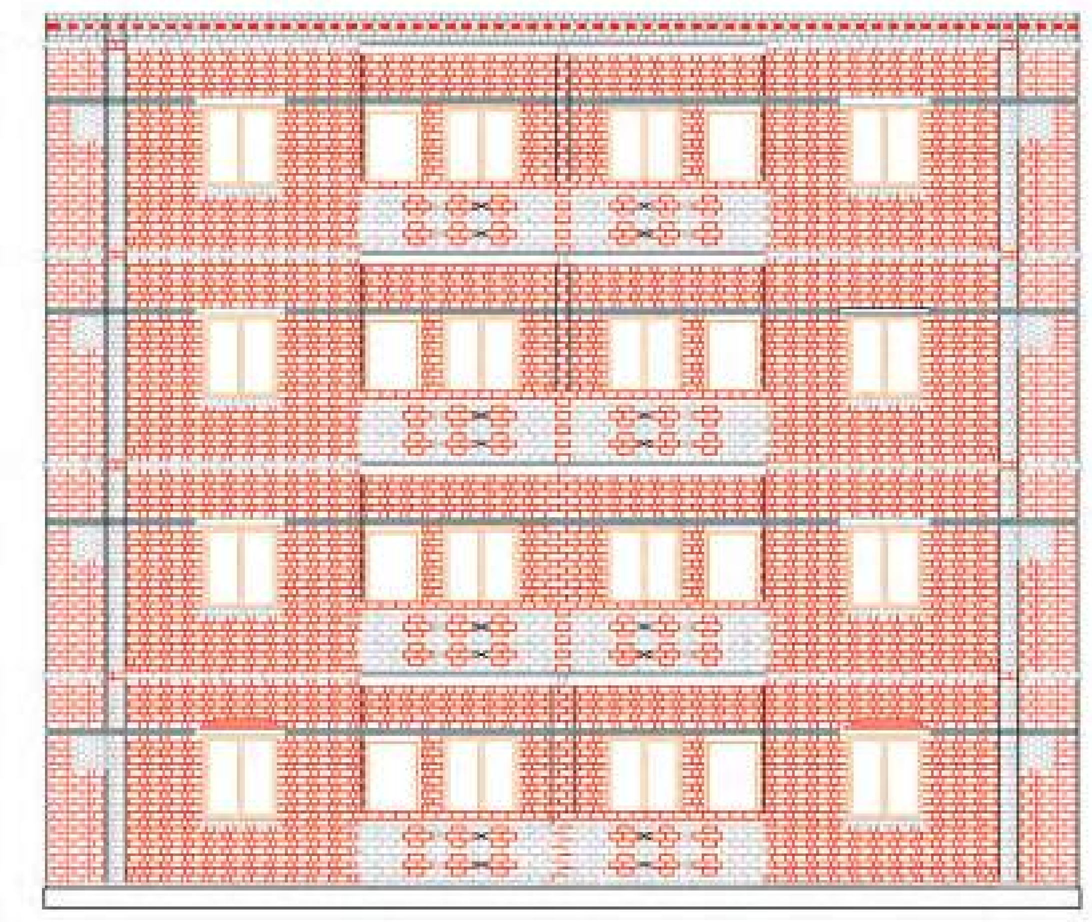
5.8 Front Elevation Cluster Type III



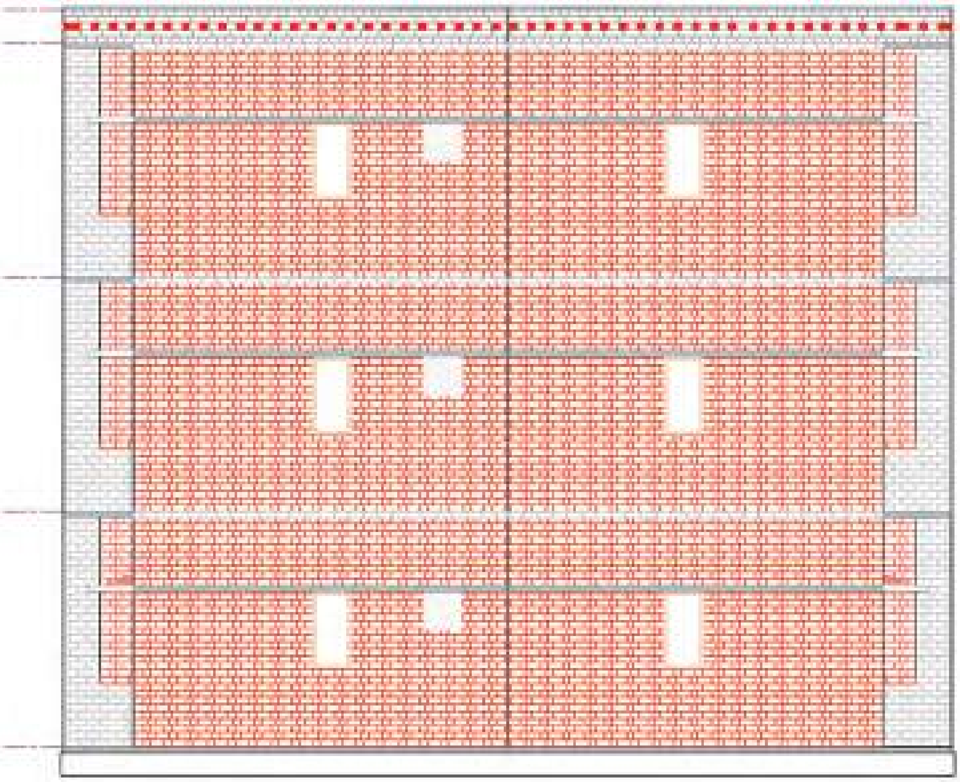
5.9 Rear Elevation Cluster Type I



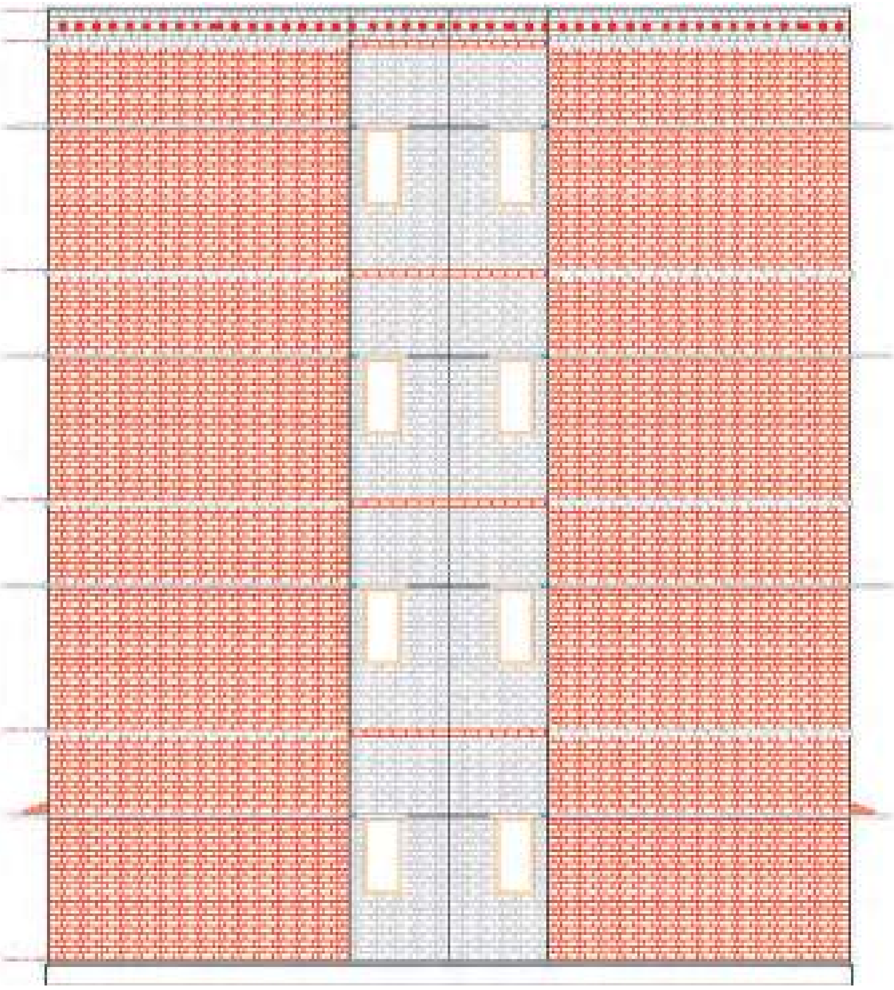
5.10 Rear Elevation Cluster Type II



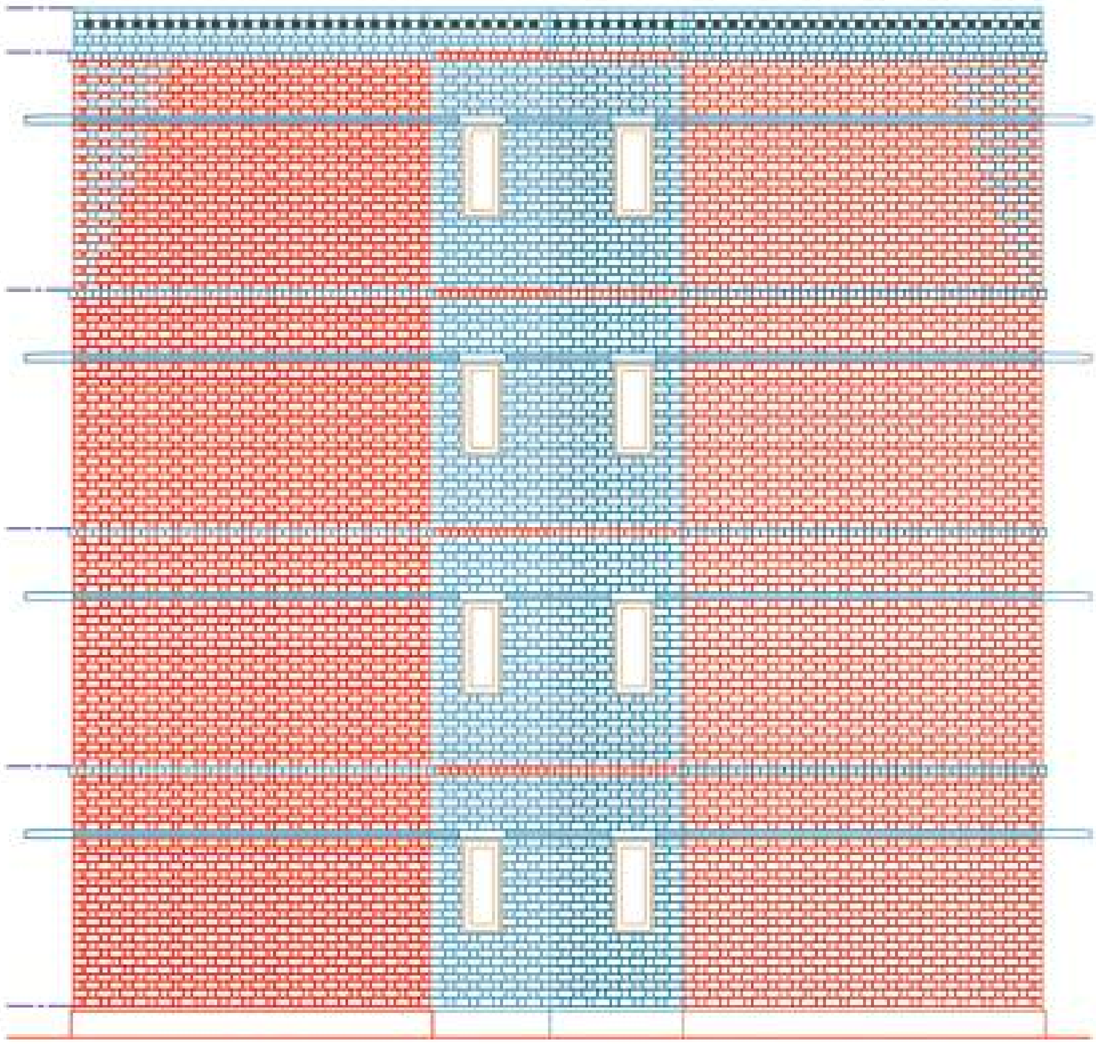
5.11 Side Elevation Cluster Type I



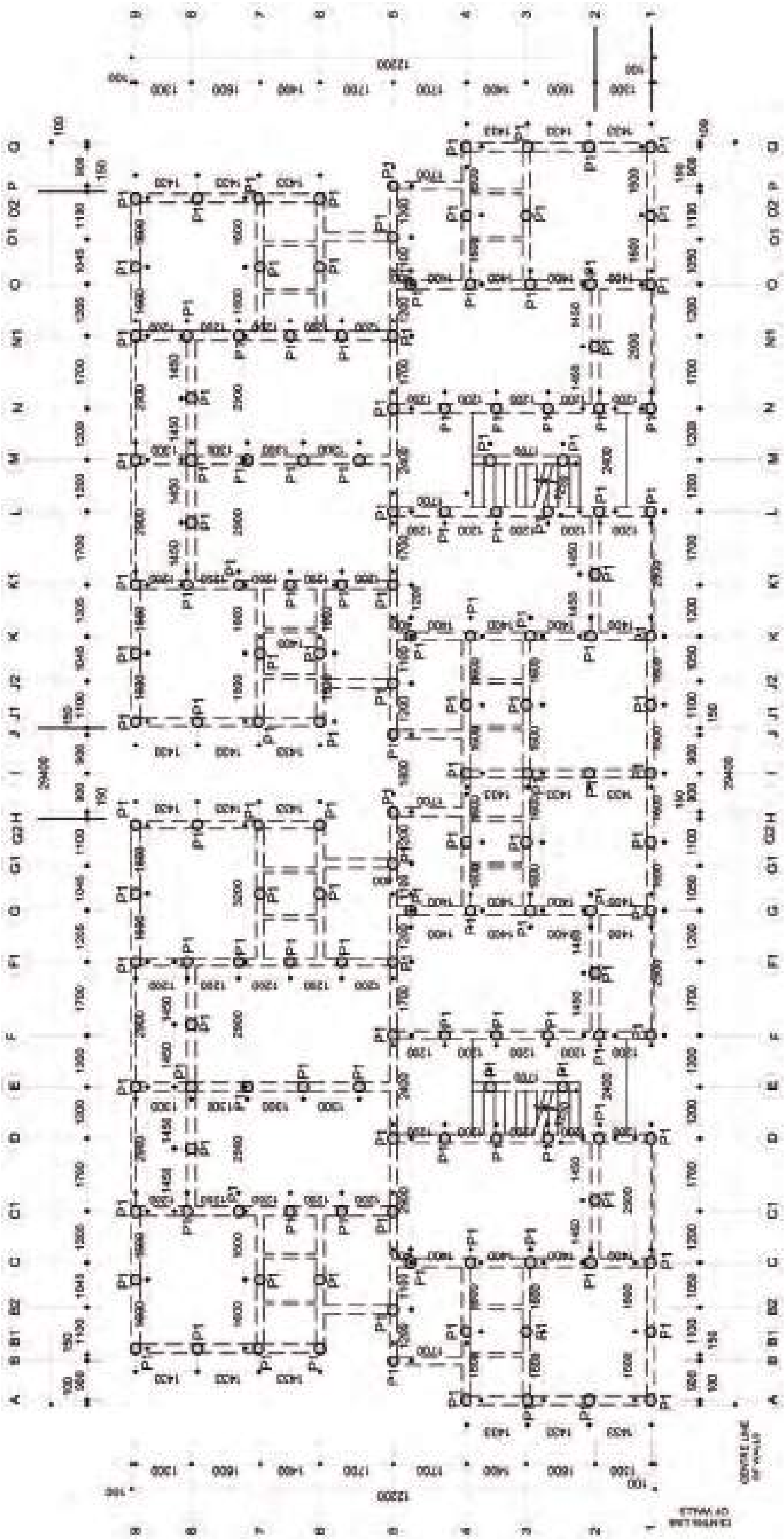
5.12 Side Elevation Cluster Type II



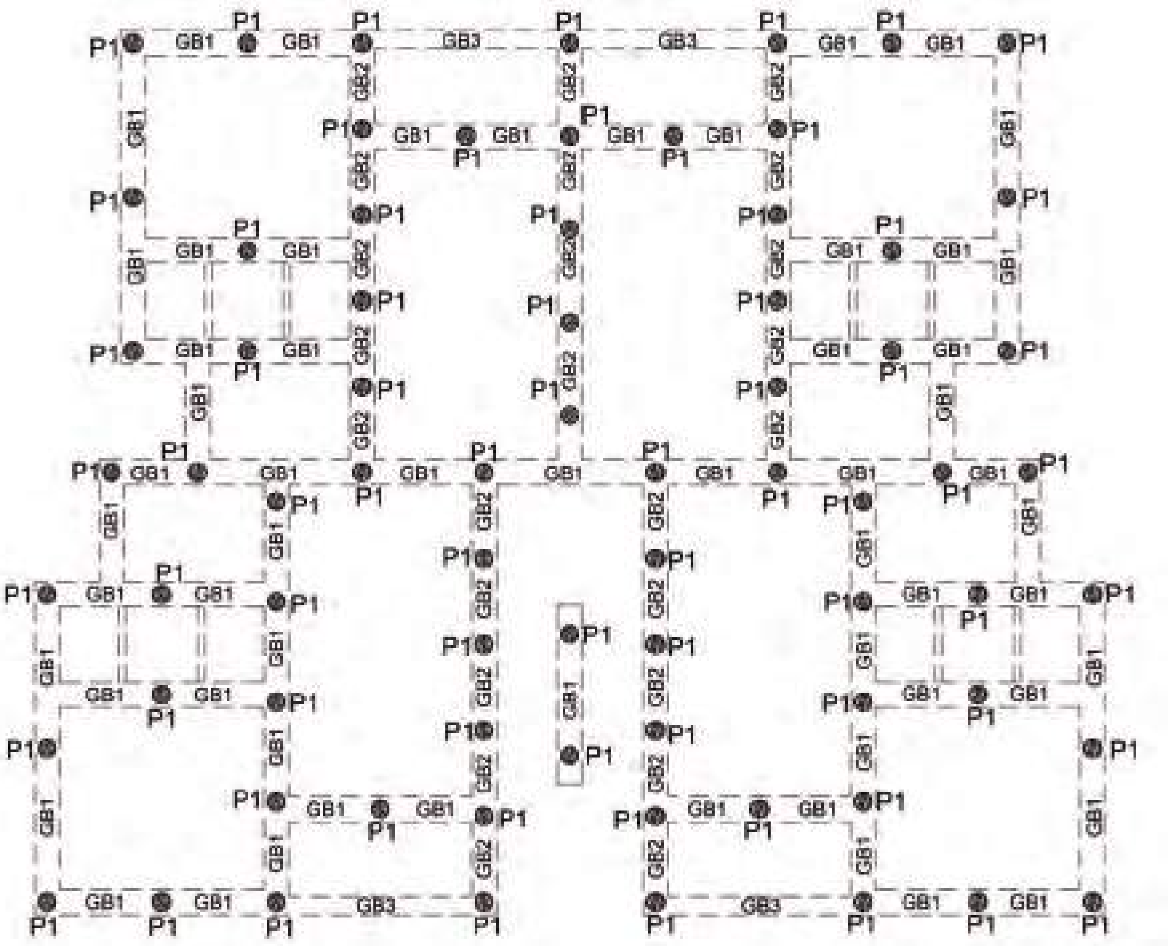
5.13 Side Elevation Cluster Type III



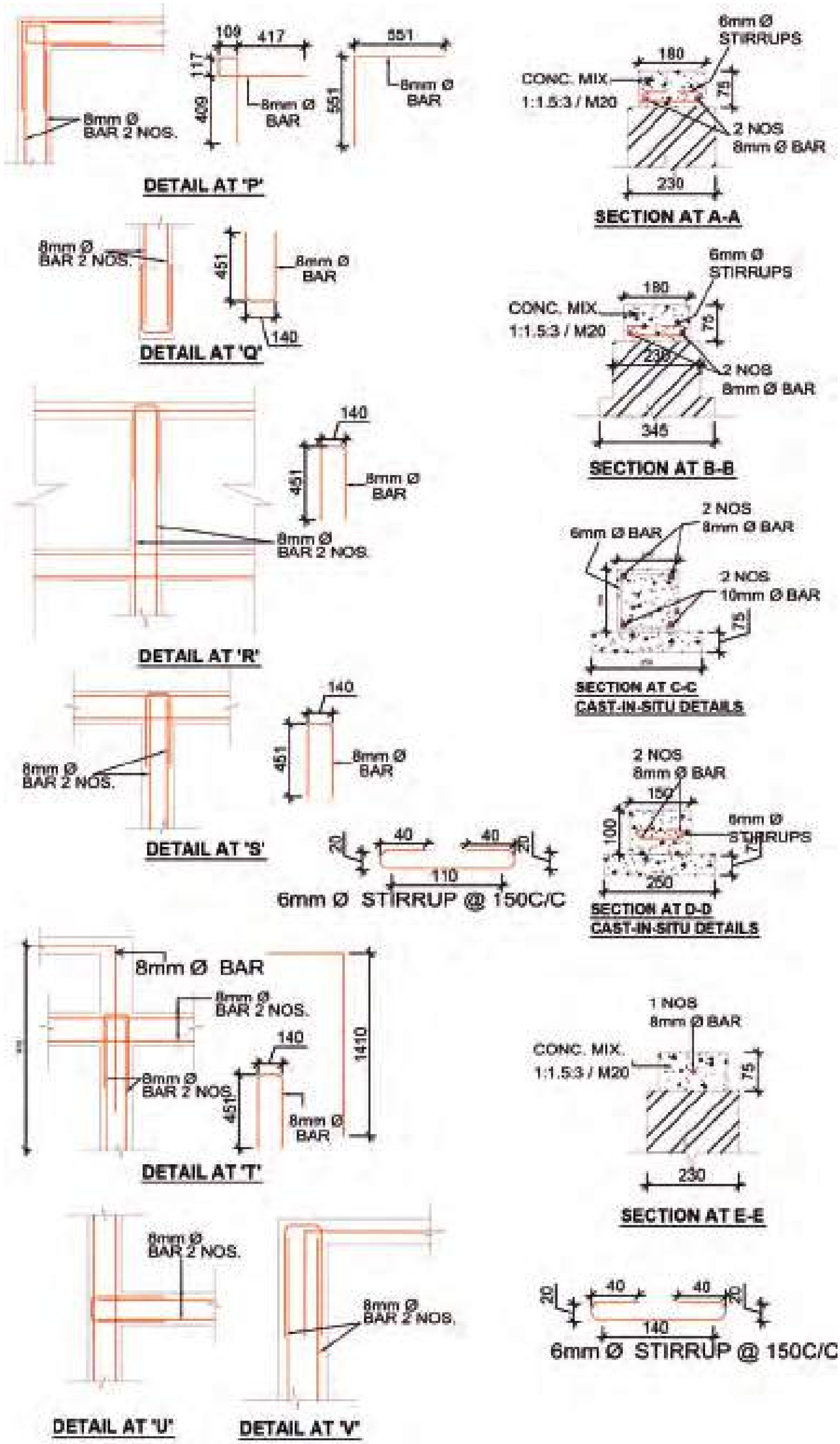
5.14 Pile Foundation Plan Type II



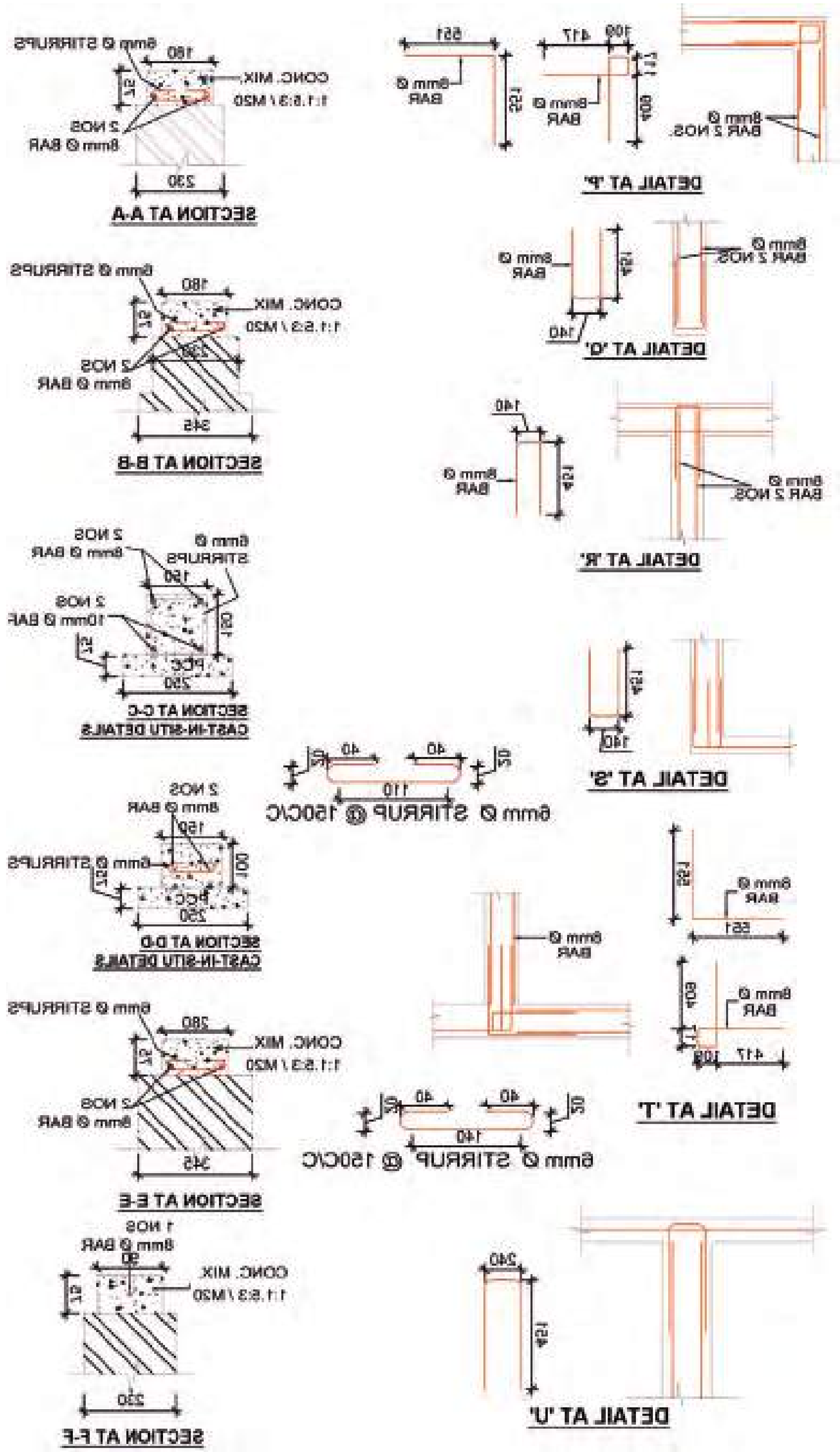
5.15 Grade Beam Plan Type III



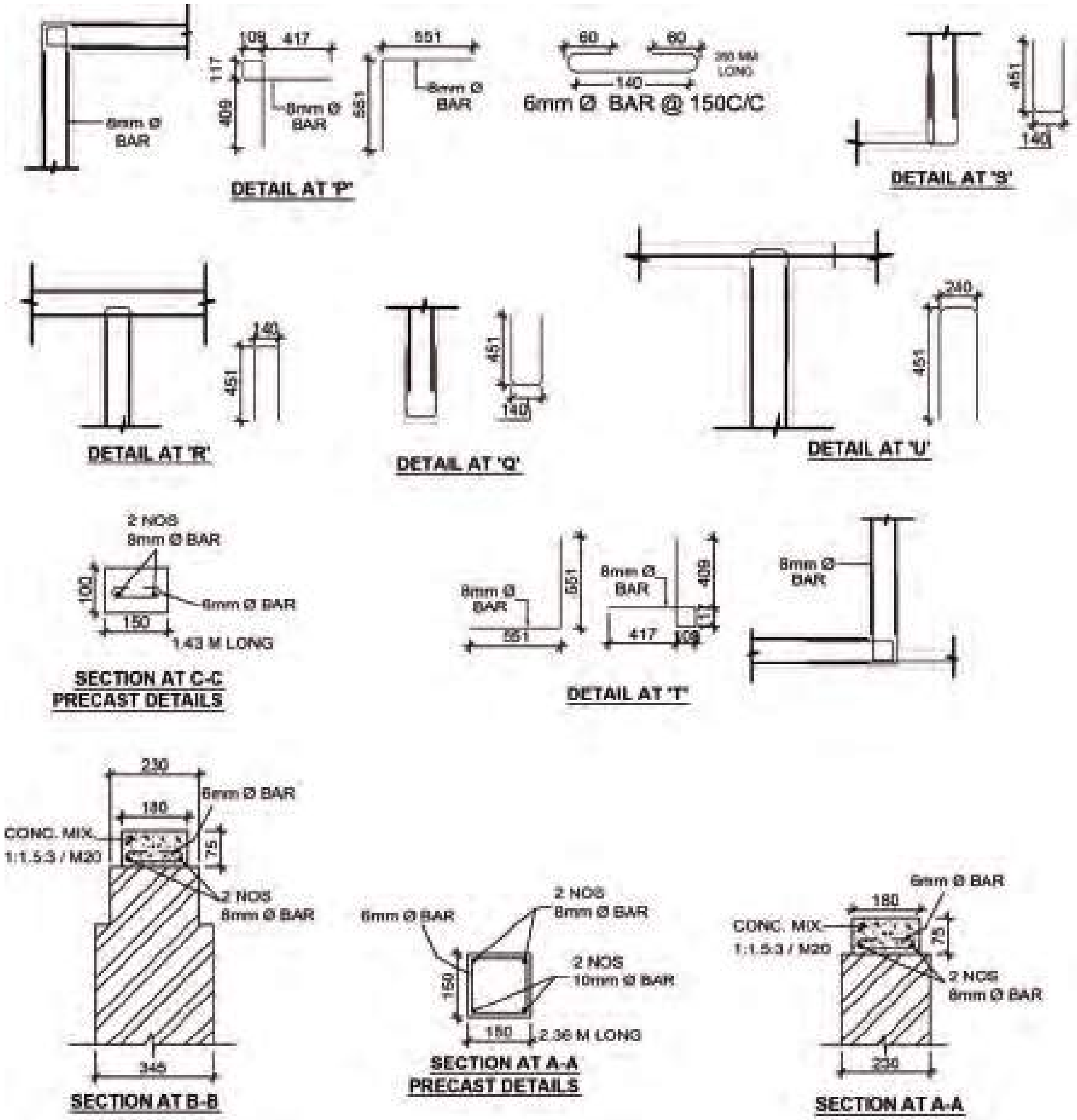
5.16 Plinth Band Detail Type I



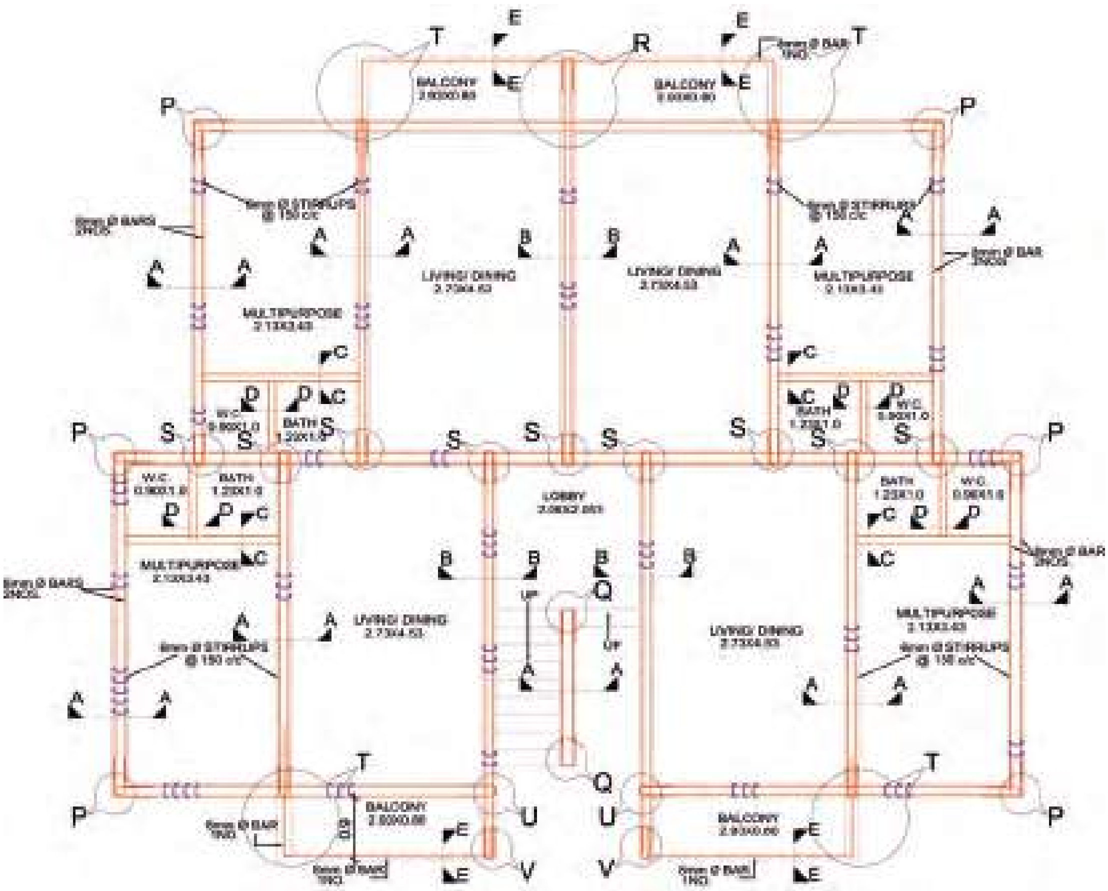
5.17 Plinth Band Detail Type II



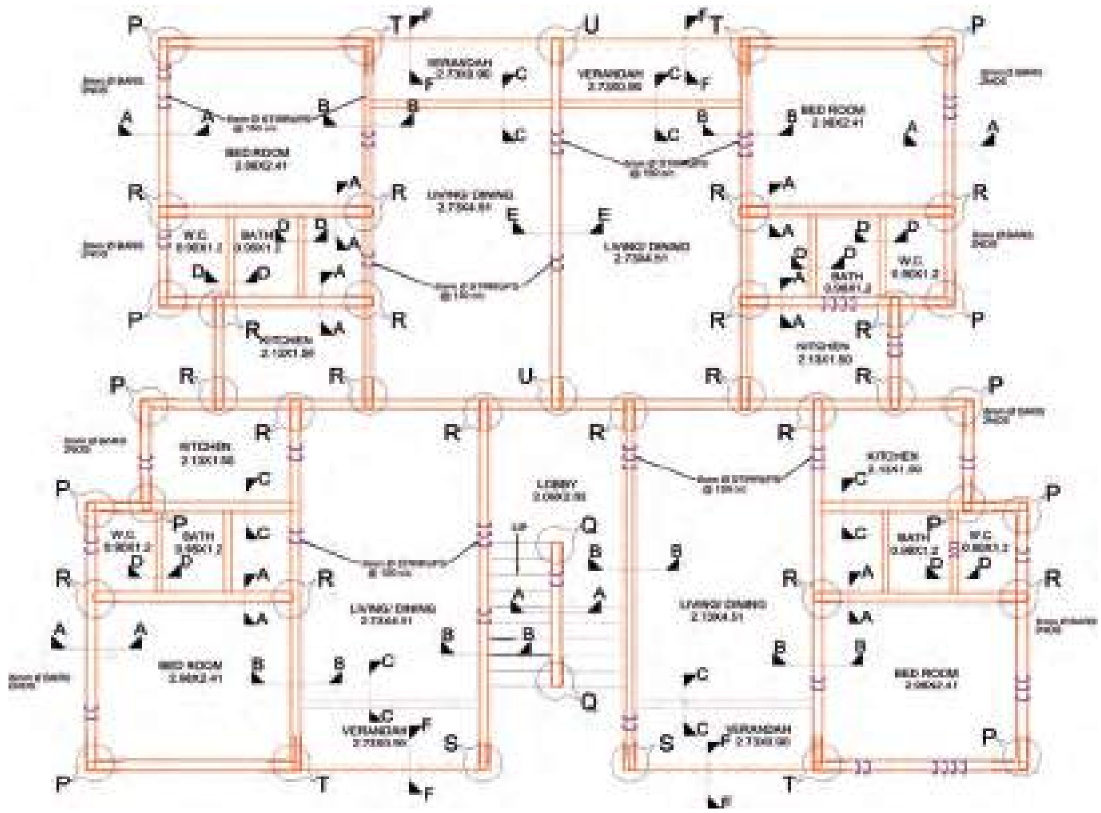
5.18 Plinth Band Detail Type III



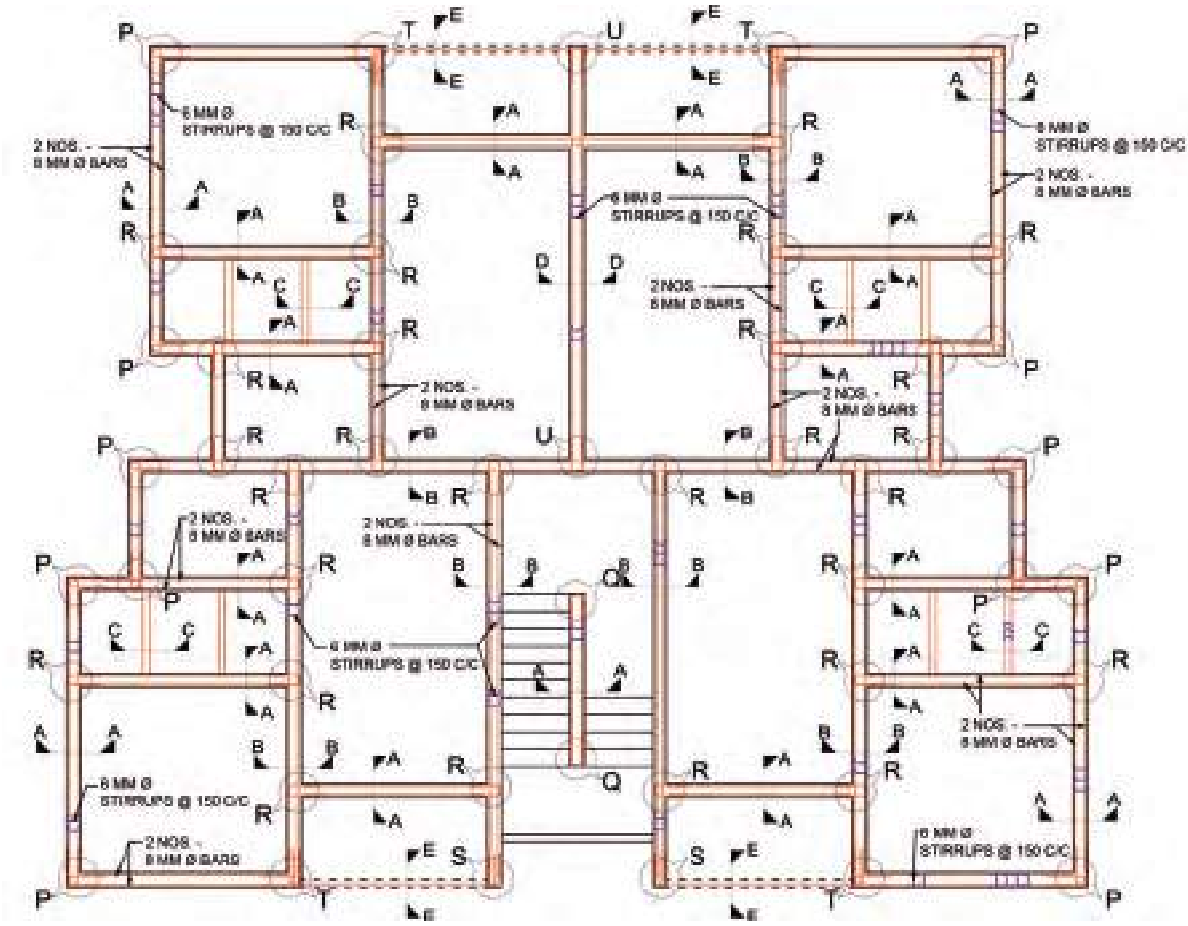
5.19 Plinth Band Plan Type I



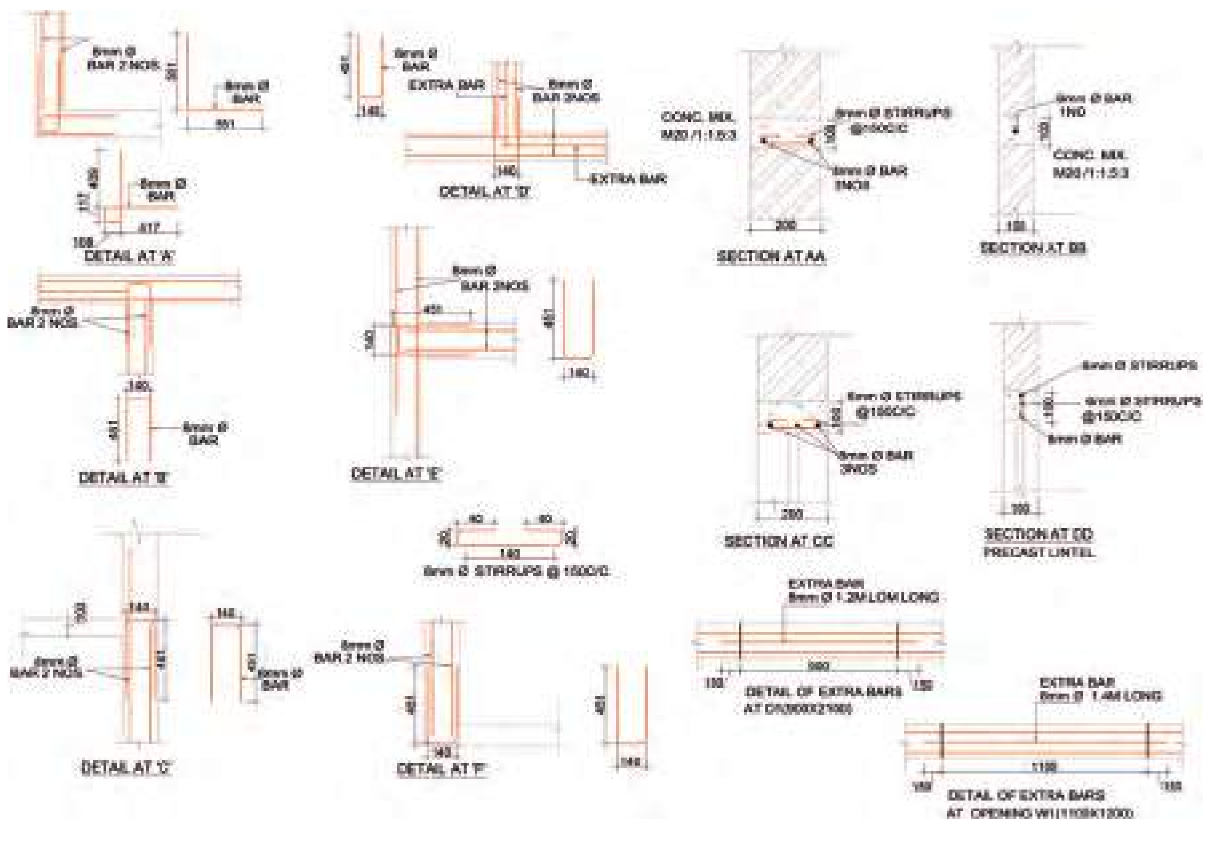
5.20 Plinth Band Plan Type II



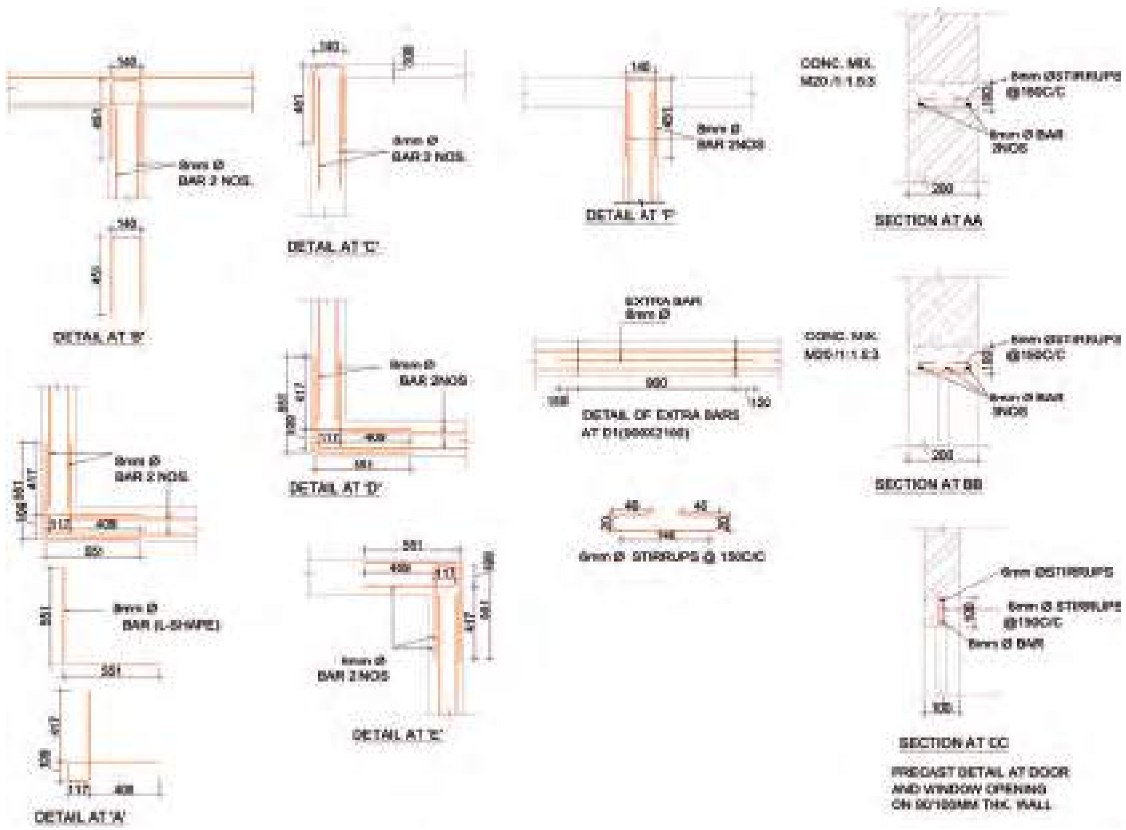
5.21 Plinth Band Plan Type III



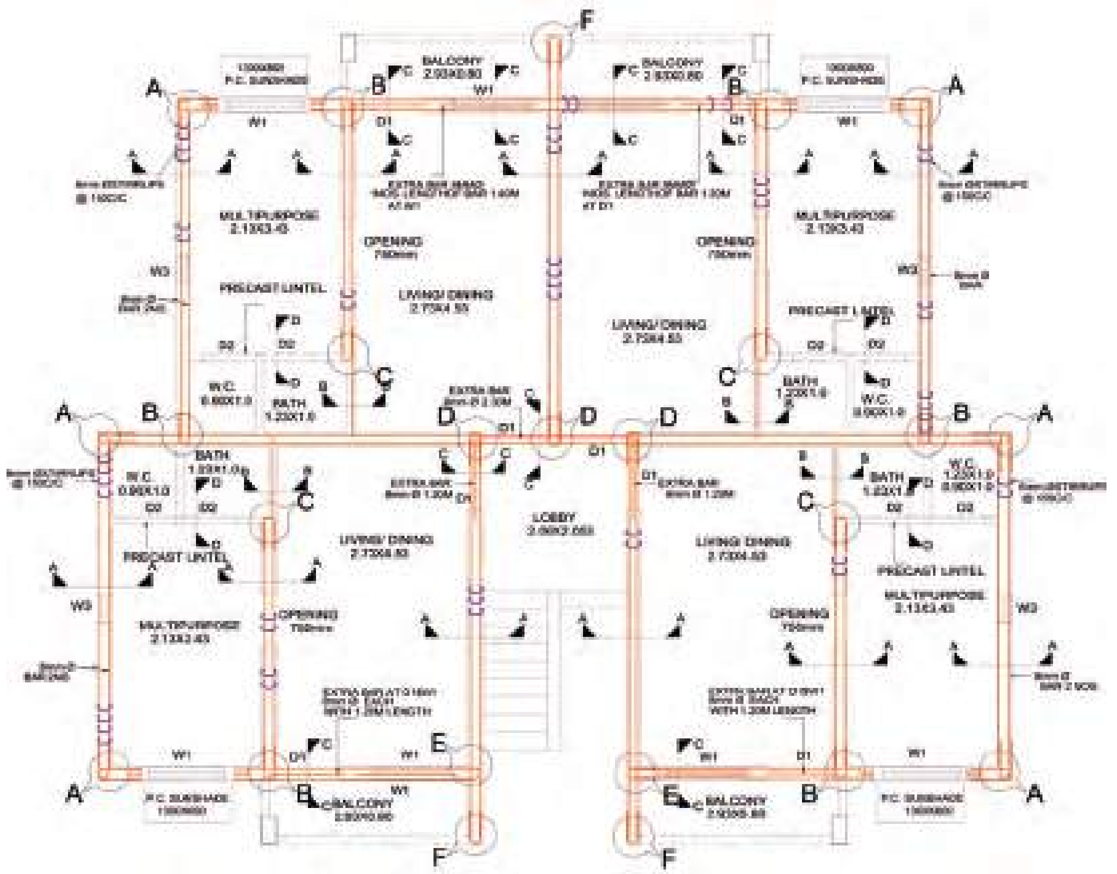
5.22 Lintel Band Detail Type I



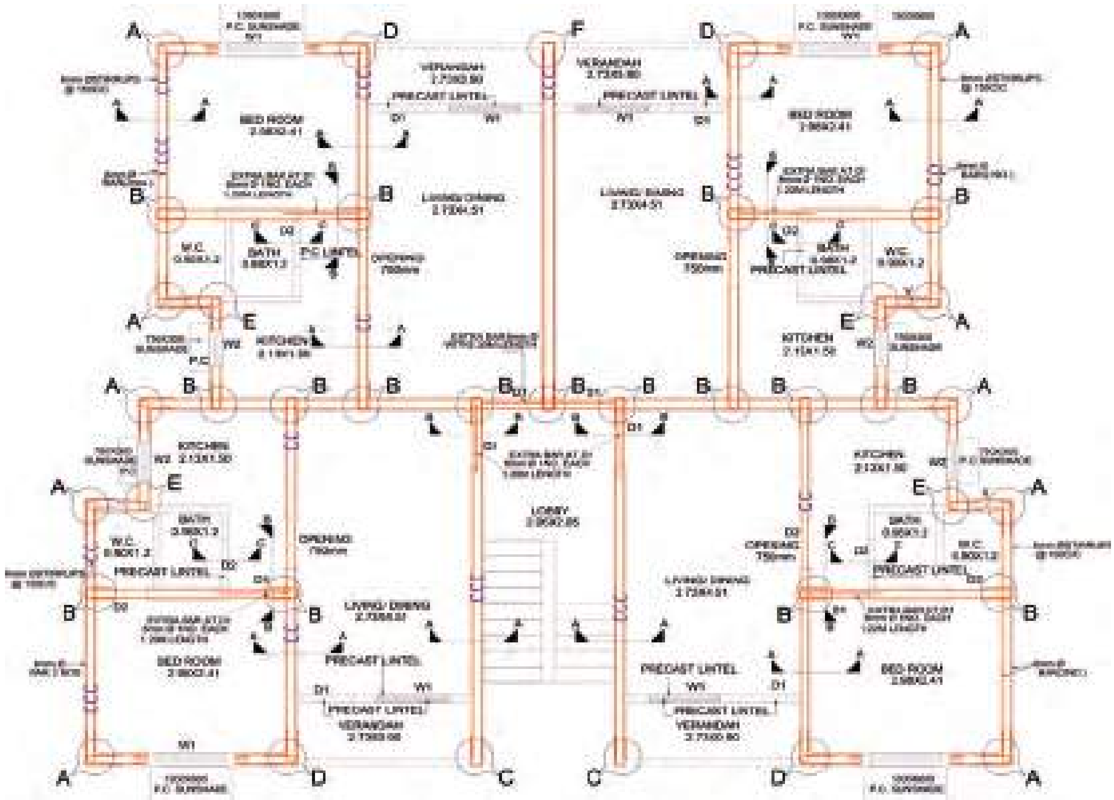
5.23 Lintel Band Detail Type II



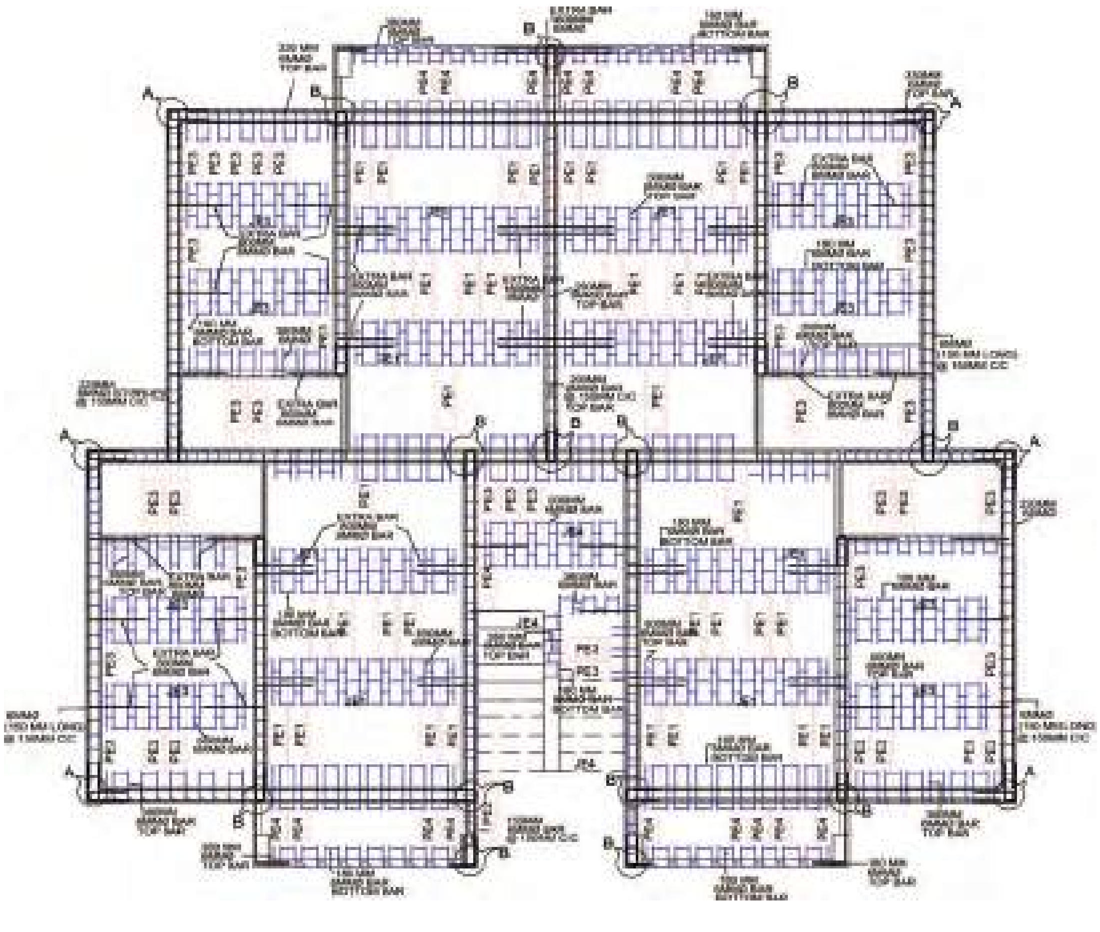
5.24 Lintel Band Plan Type I



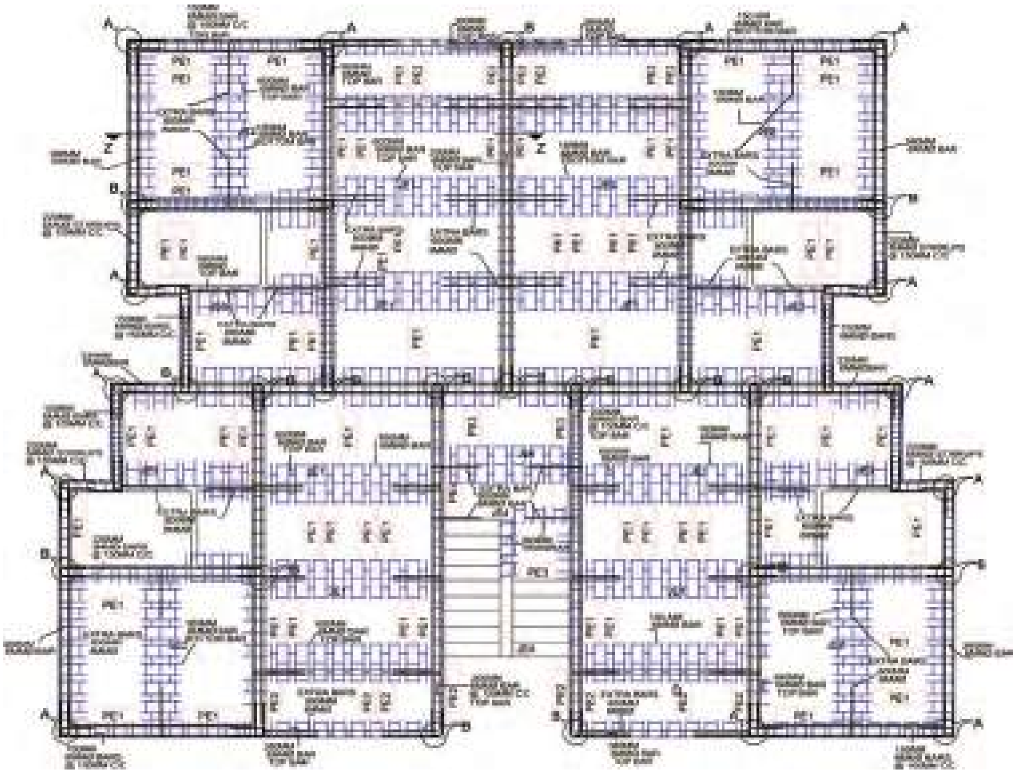
5.25 Lintel Band Plan Type II



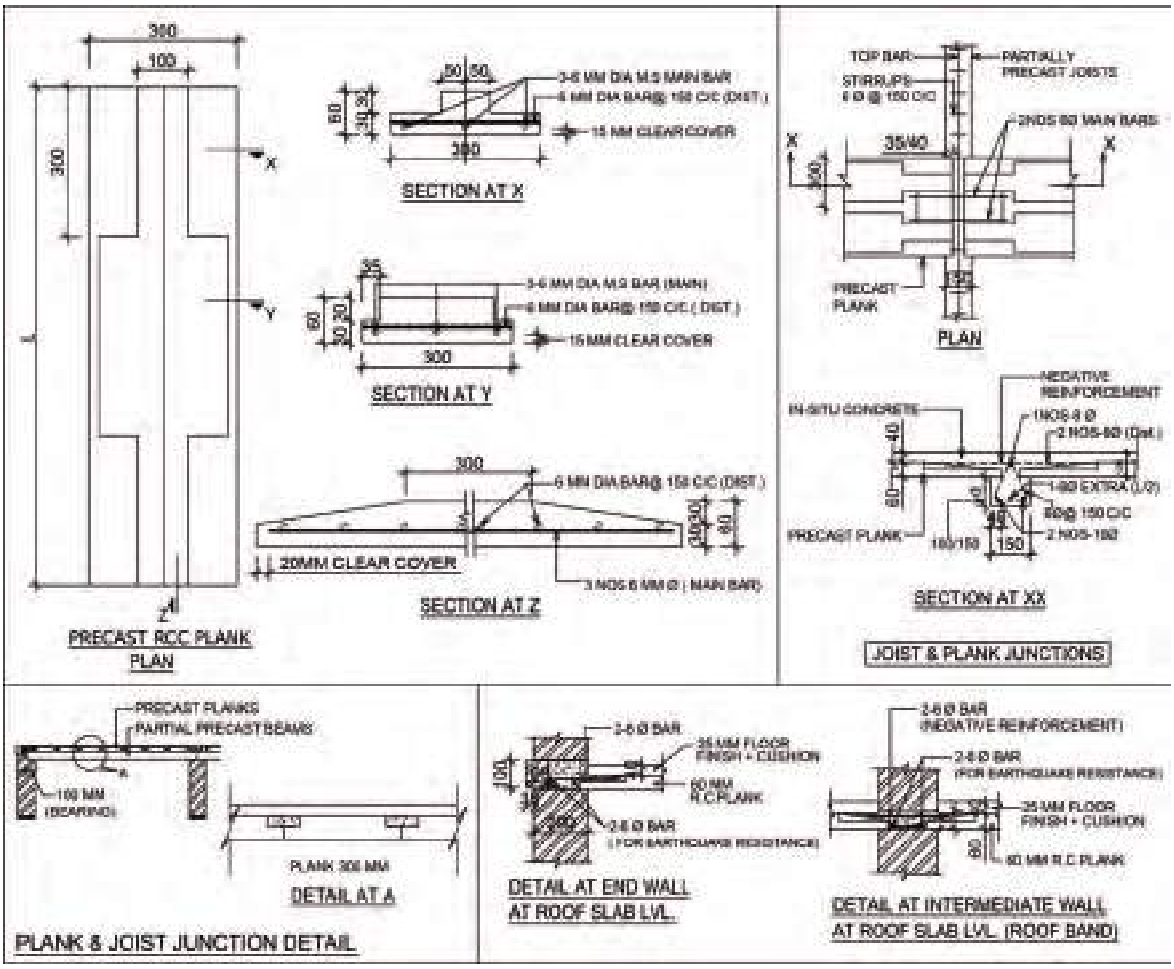
5.26 Precast Assembly Plan Type I



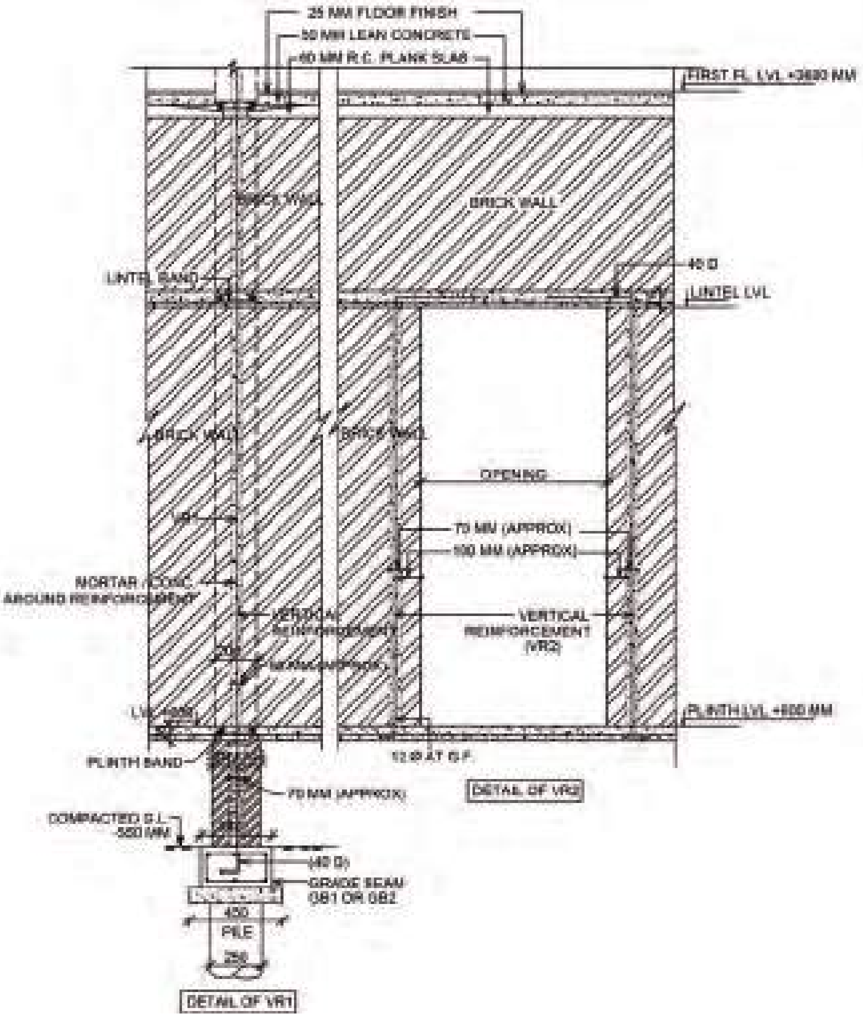
5.27 Precast Assembly Plan Type II



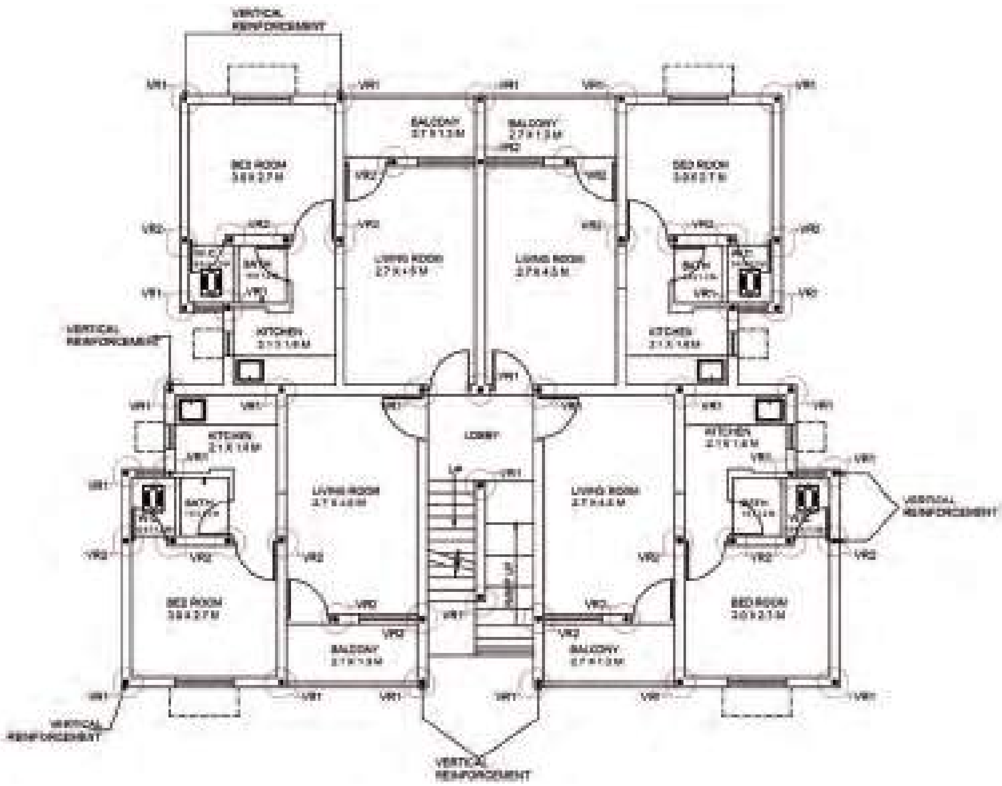
5.28 Precast roof Elements Part Details



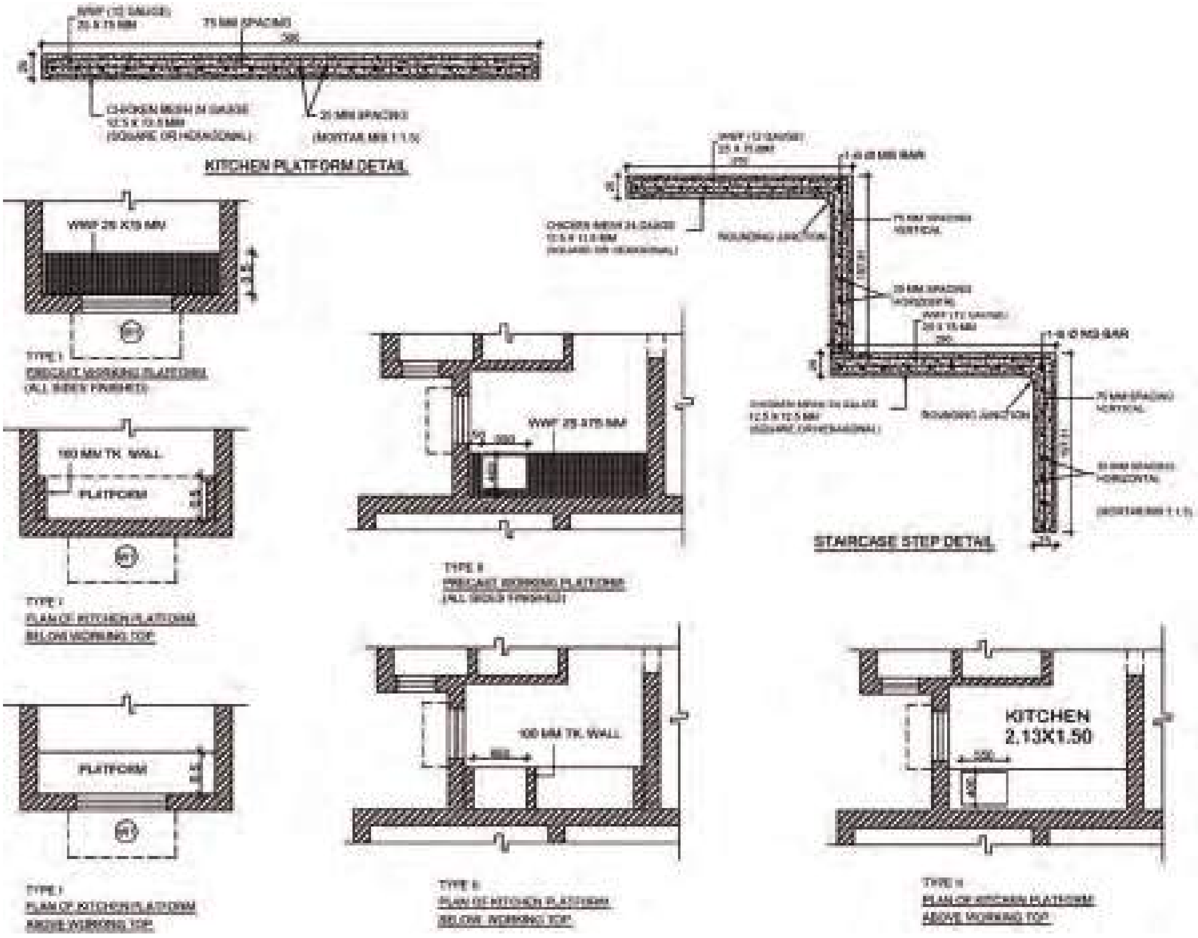
5.29 Vertical Reinforcement Detail for Earthquake Type III



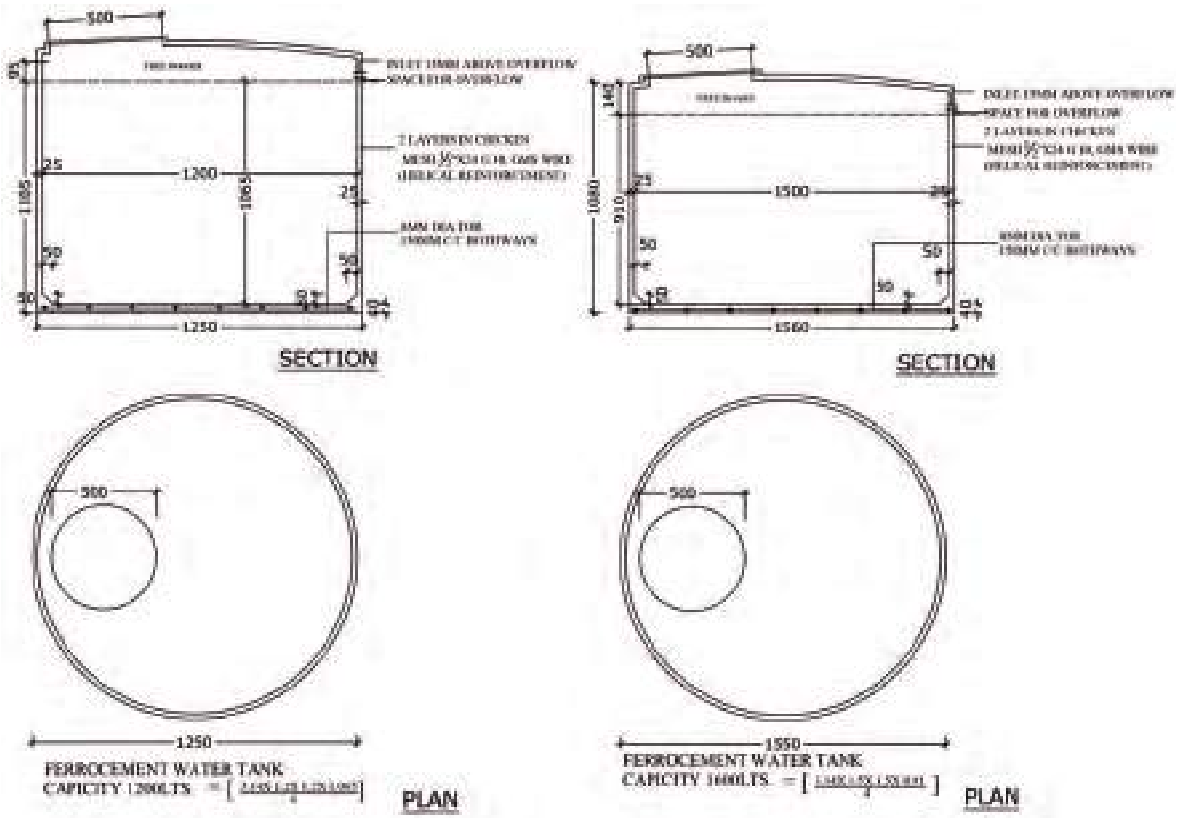
5.30 Vertical Reinforcement Plan for Earthquake Type III



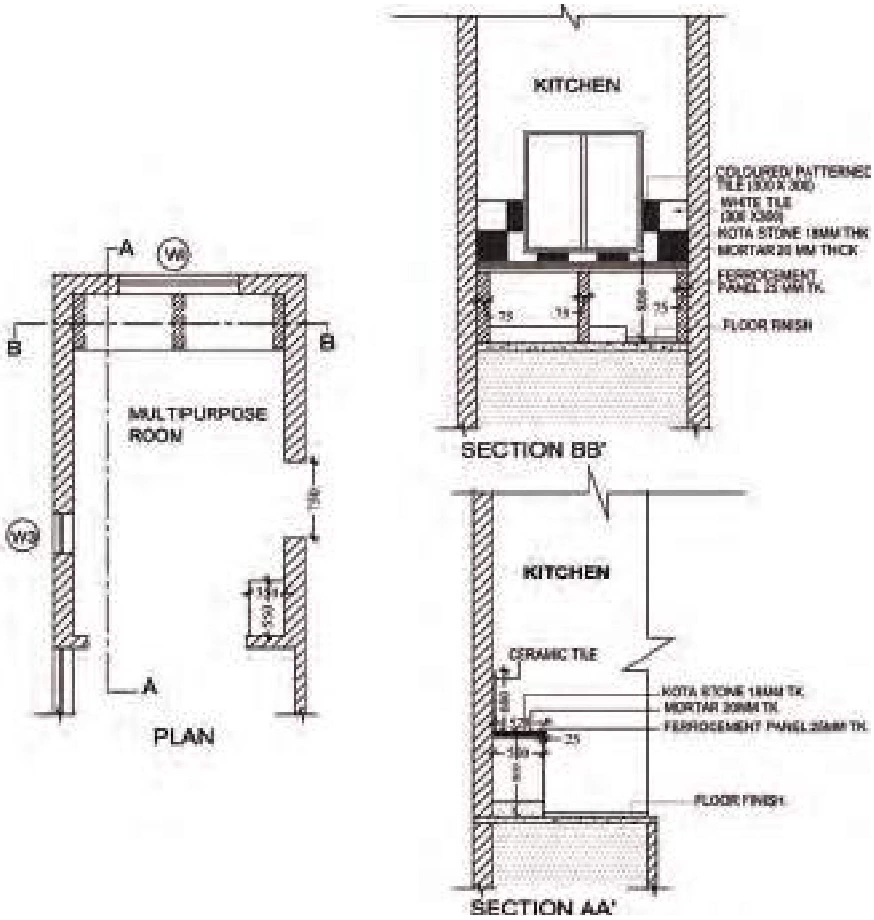
5.31 Ferrocement Kitchen Shelves, Step



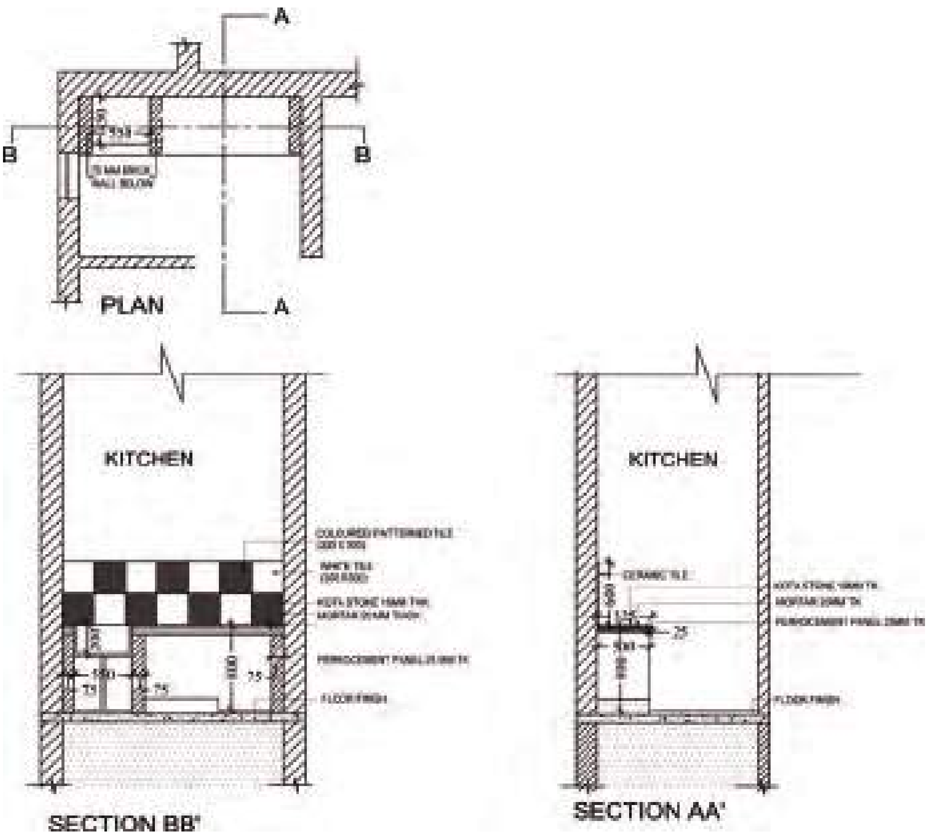
5.32 Ferrocement Water Tank Detail



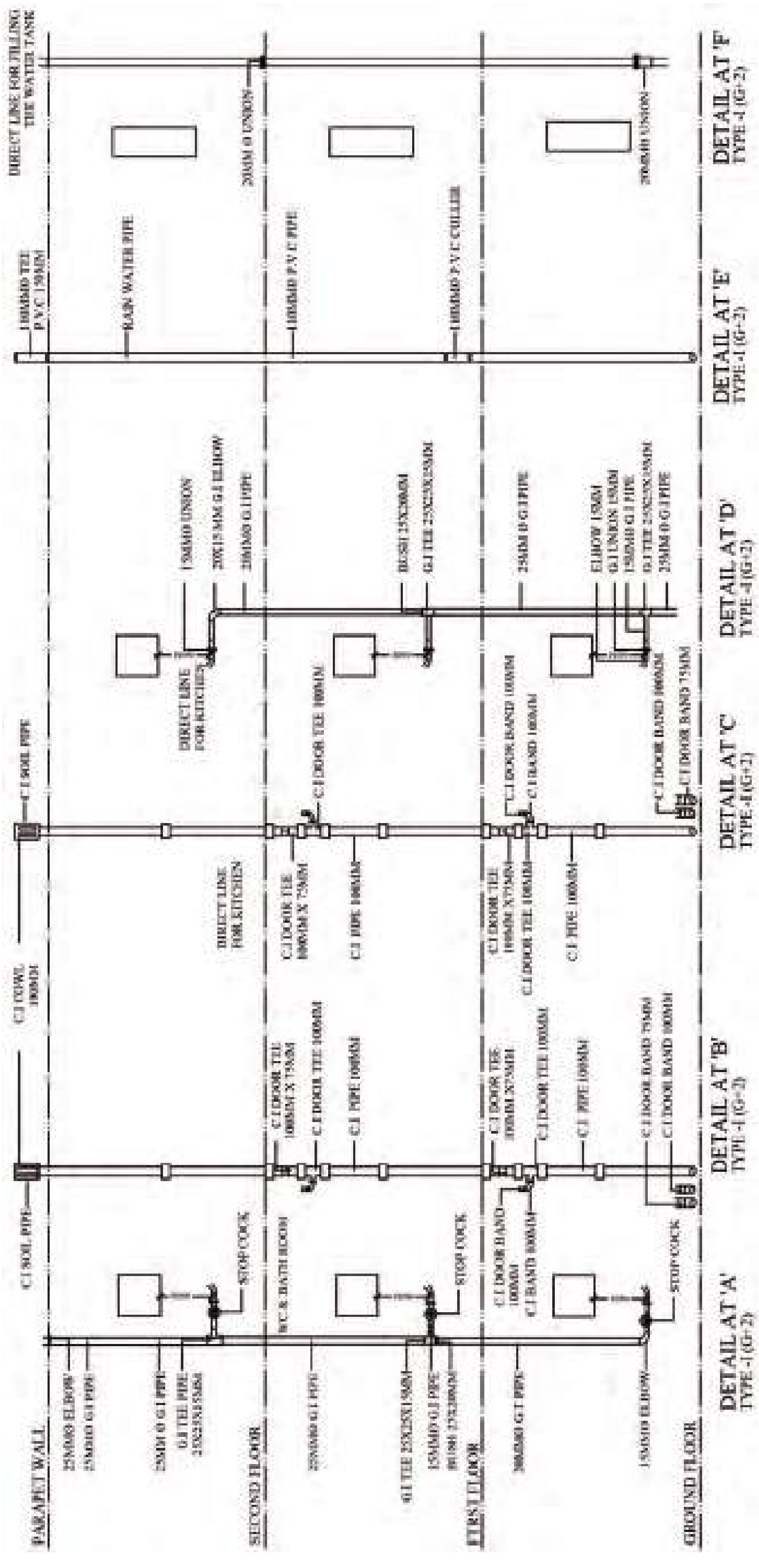
5.33 Architecture Kitchen Detail Type I



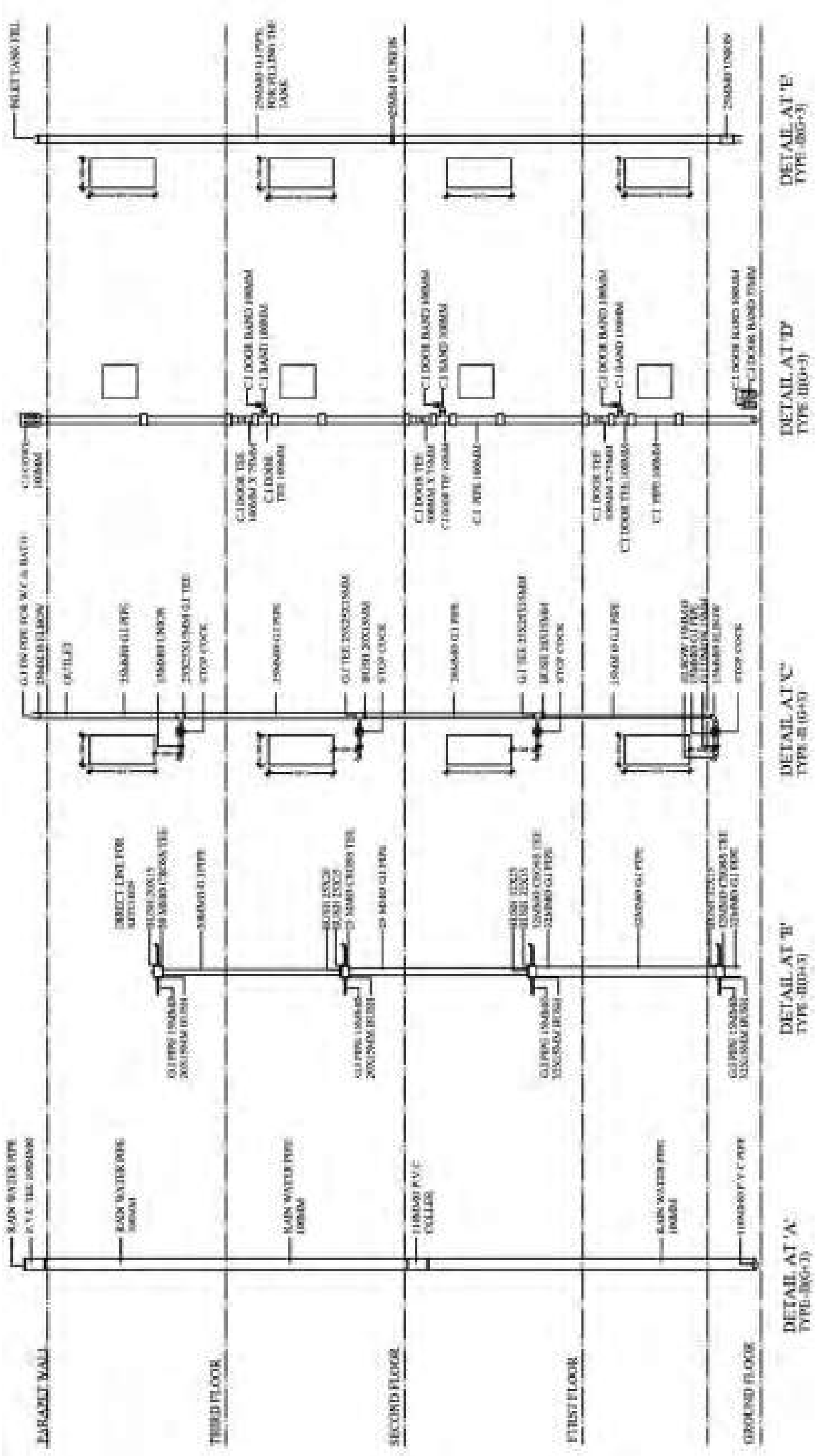
5.34 Architecture Kitchen Detail Type II



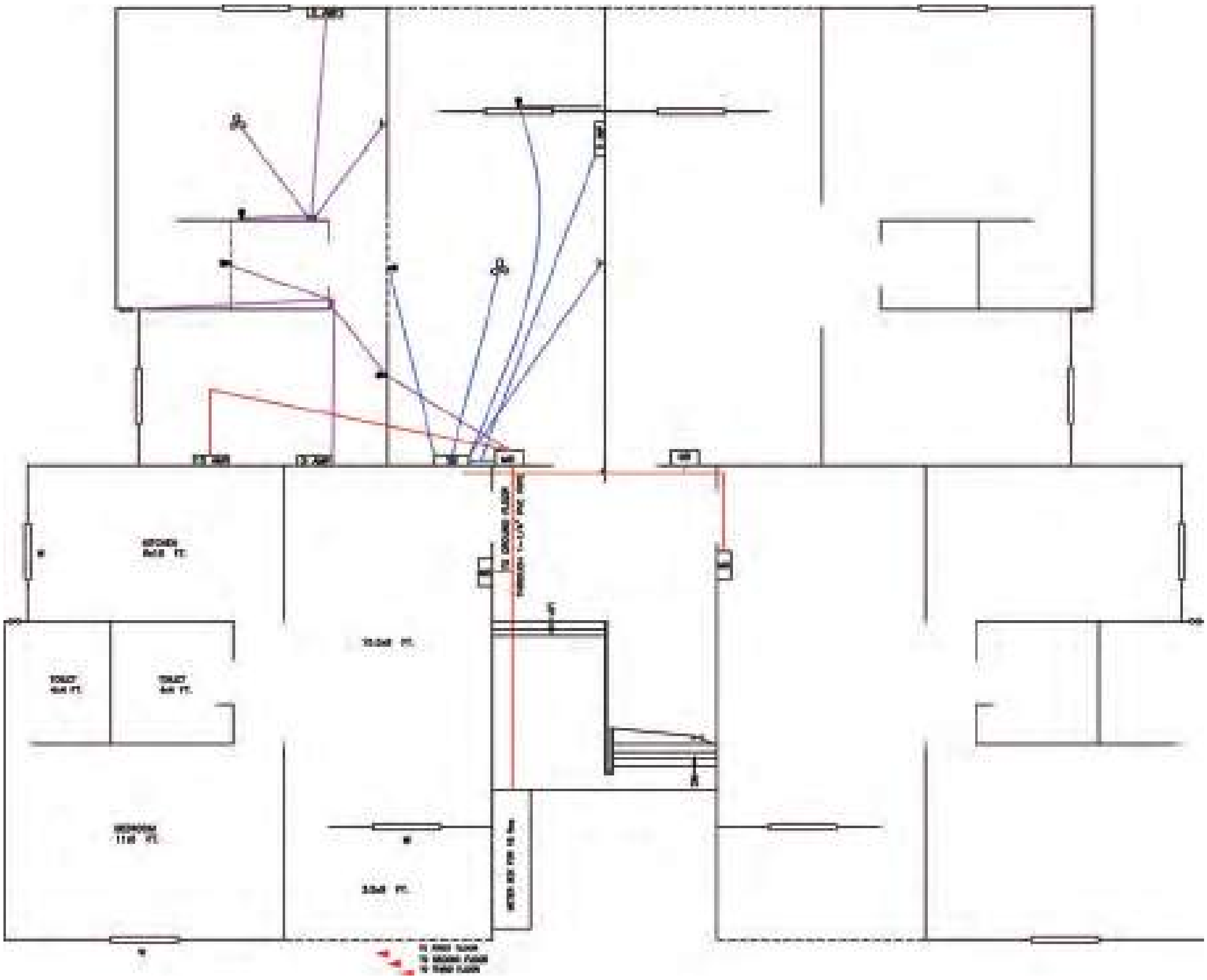
5.35 Sanitation & Water Supply System Type I



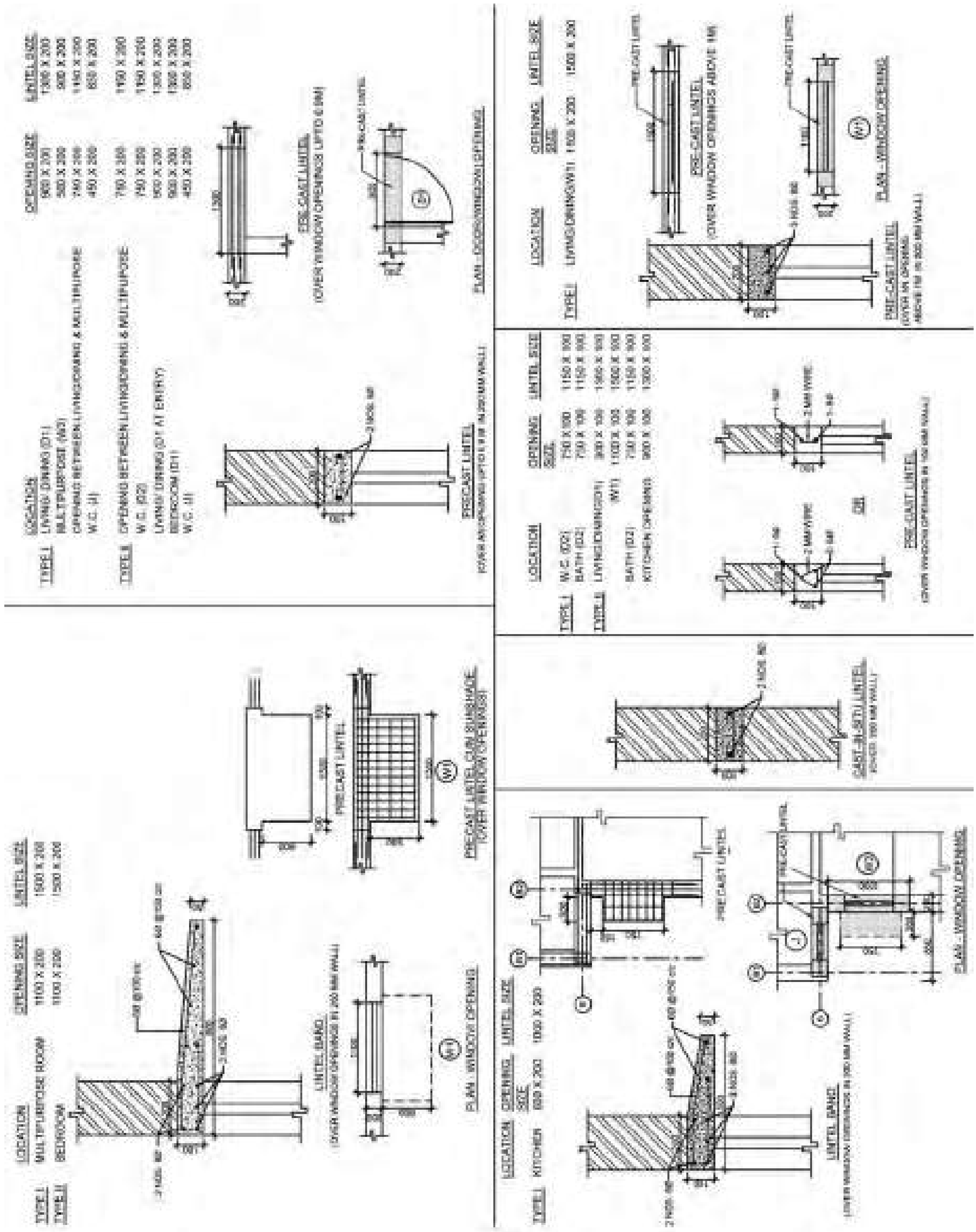
5.36 Sanitation & Water Supply System Type II



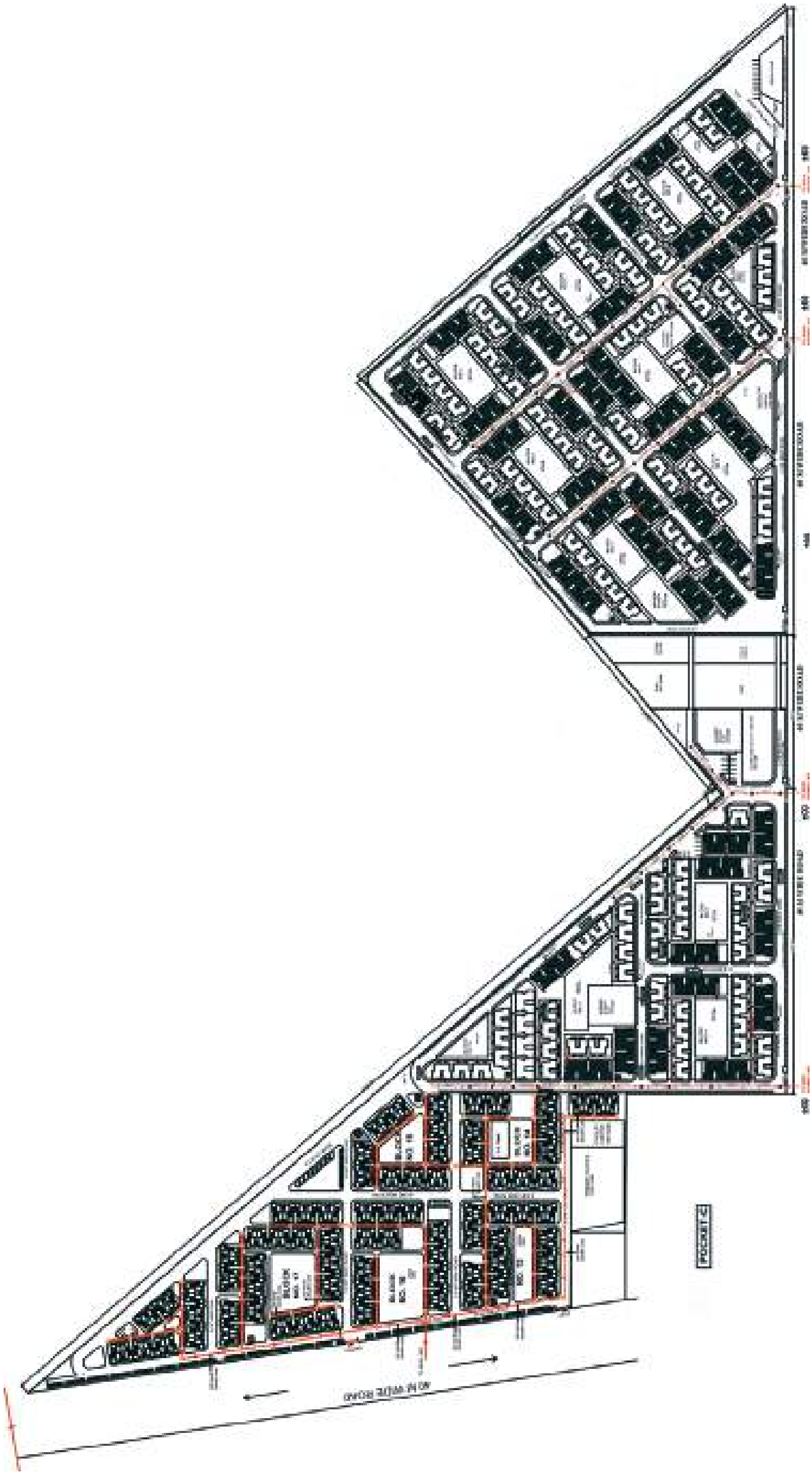
5.37 Electrical Plan Type II



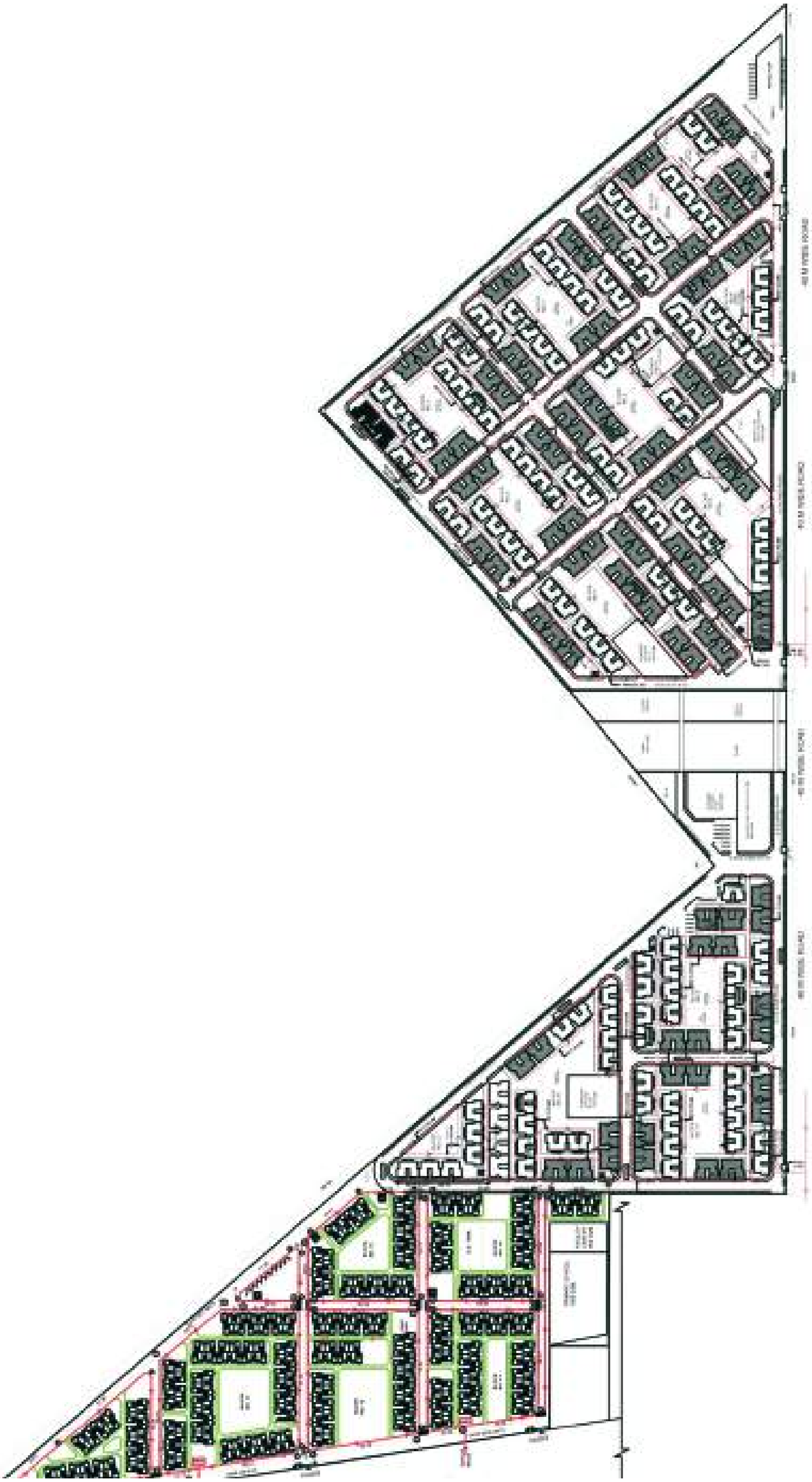
5.38 Precast Lintel & Sunshade Detail



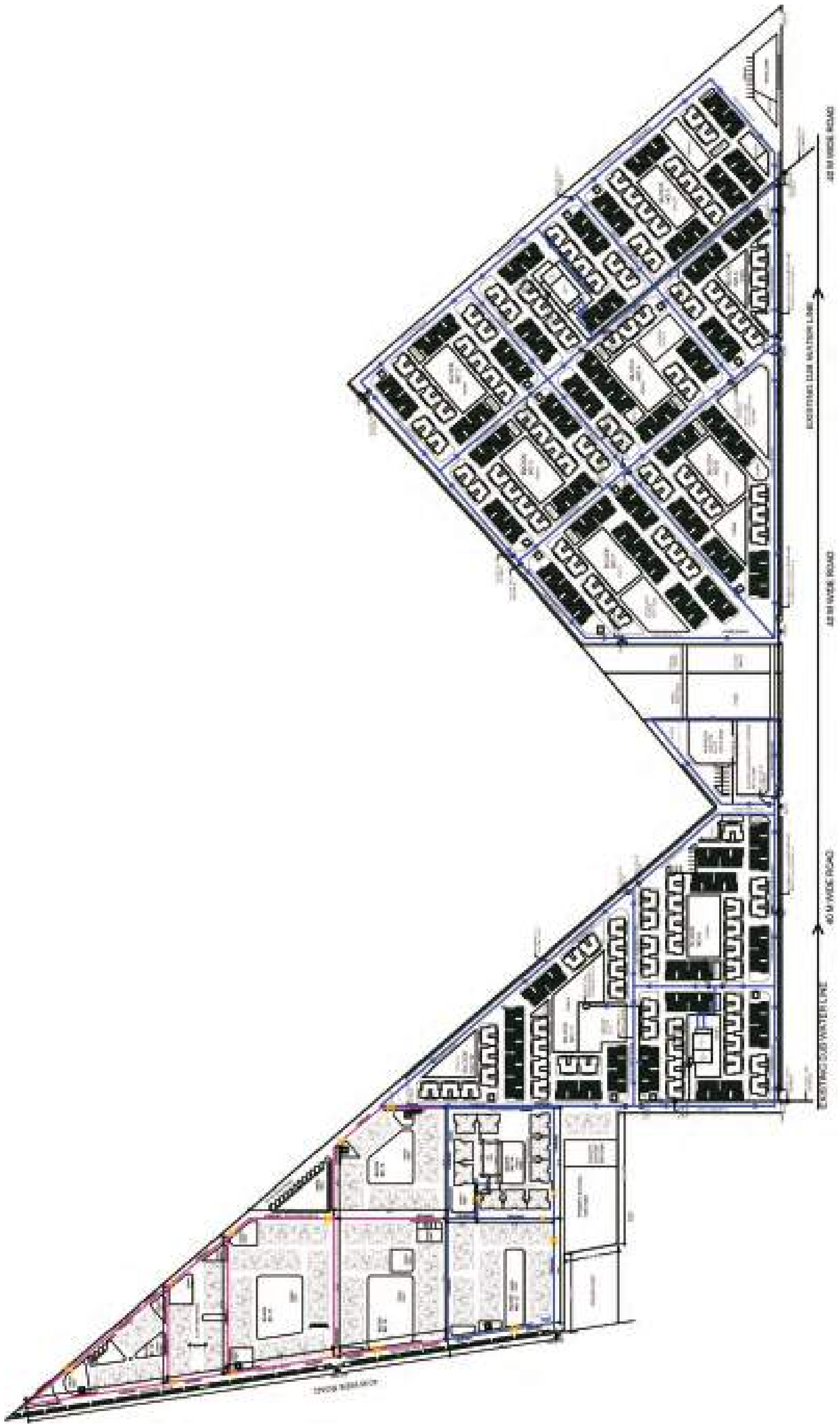
5.39 Sewerage



5.40 Drainage

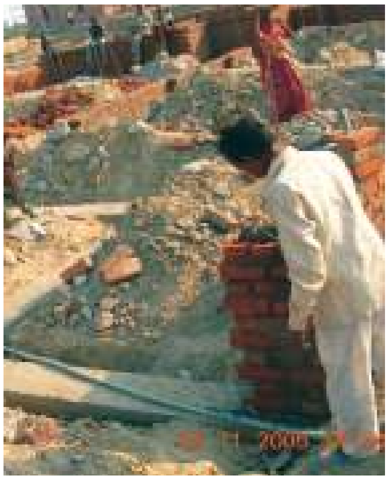


5.41 Water Supply



Chapter 6 : SNAPSHOTS OF THE PROJECT

6.1 Construction at Different Stages



Construction at Different Stages









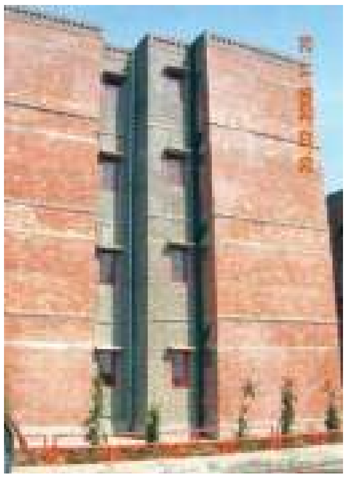

Construction at Different Stages

Construction at Different Stages

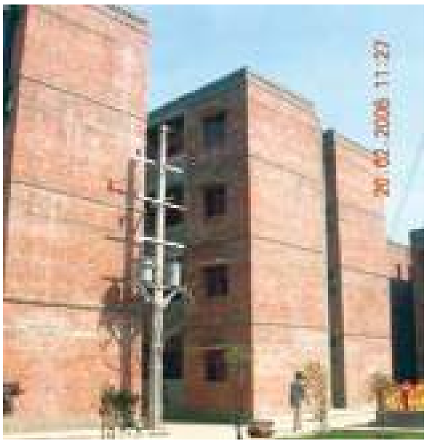
Construction at Different Stages

Construction at Different Stages

6.2 Views of Completed Buildings











6.3 Interior Views

Chapter 7 : CONCLUSIONS

The project was result of team work of DSIIDC, M/s Adlakha Associates Pvt. Ltd., BMTPC, CBRI and Era Construction (I) Ltd. Through this document it is shown that the technologies adopted here are eco-friendly, time saving, environmental friendly. The cost-effectiveness of the technologies is established as follows:

- Saving in consumption of cement (High energy based material)
- Saving in consumption of steel (High energy based material)
- Saving in centering shuttering material (High energy based material in case of steel shuttering and eco-friendly material in case of wooden shuttering)
- Standardization and repetitive use of Precast elements (Reduction in wastage of materials)
- Construction management (saving in construction time)
- Saving in consumption of power (emphasis on well oriented layouts and improved thermal conductivity because of use of perforated bricks)
- Consumption of waste by product 'Fly-ash' (Helps in protection of environment)
- On site production of Flyash bricks and precast RCC elements (Reduction in wastages / breakages and better quality control)
- Precast technology provide better quality

Tables given below show the savings in consumption of cement, steel and shuttering.

Table 42
Cement Consumption (1 Block – 16 DU)

Conventional Specifications	Cost Effective Specifications
Cement = 3012.40 Bags	Cement = 2024.84 Bags

Savings = 3012.40 – 2024.84 = 987.56 bags = 32.78%

Table 43
Steel Consumption (1 Block – 16 DU)

Conventional Specifications	Cost Effective Specifications		
TMT Bars = 18745.80 Kg	MS	=	3125.00 Kg
	TMT	=	2578.61 Kg
	Steel for piles (Single Section)	=	2165.22 Kg
			7868.83 Kg

Savings = 18745.80 – 7868.83 = 10876.97 Kg = 58%

Table 44
Centering Shuttering (1 Block – 16 DU)

Conventional Specifications				Cost Effective Specifications
(a)	Lintels, beams	=	628.93 sqm	Bands at Plinth level, lintel level and roof level, encasing of vertical bars = 263.37 sqm
(b)	Column footings	=	124.45 sqm	
(c)	Columns	=	337.80 sqm	
(d)	Slabs	=	584.36 sqm	
(e)	Stairs	=	18.94 sqm	
			1694.48 sqm	

Saving in shuttering area = 1694.48 – 263.37 = 1431.11 sqm (savings is almost 85%)
"Recron" fibres have been used during the midway of this project in the thin precast elements RC planks

and the ferrocement steps. The results show that it improves the strength and enhances durability.

An improvement in the technology has made subsequently, with the experience gained. The 'hooks' in the RC planks have been added which allow the distribution bar through and keep the planks intact during casting as well as provide extra safety.

The DSIIDC obtained the ISO Certificate for Rajiv Gandhi Housing Project. The First ISO Certified Low Cost Housing Project, which itself is the testimony to the professionalism and the management of the project at its best possible.

Above stated benefits are perhaps enough to encourage the multiple use of these technologies in the construction industry. There are few other projects by DSIIDC where these technologies are being repeated:

- Construction of 5568 houses for slum rehabilitation at Baprola
- Construction of 1652 Dwelling units for Urban Poor and Industrial Workers at Narela-II
- Construction of 1272 Dwelling Units at Bhorgarh
- Construction of 1892 Dwelling Units at Narela-I

The document would serve as a guiding Case Study for the construction industry who are willing to adopt cost effective technologies in their future projects.

Annexure - I

Table 45
Cement Consumption with Conventional Specifications (1 Block – 16 DU) 39.74 sqm

S. No.	DSR 2002	Description	Unit	Qty.	Co-efficient	Cement Qty. in qtl.
1	4.5.9	CC 1:4:8	cum	16.16	1.70	27.47
2	4.5.11	CC 1:5:10	cum	56.10	1.30	72.93
3	5.1.2	RCC 1:1.5:3	cum	43.69	4.00	174.76
4	5.2.2	RCC 1:1.5:3	cum	25.72	4.00	102.88
5	5.3 (modified)	RCC 1:1.5:3	cum	110.74	4.00	442.96
6	6.1.14	Brick work 1:6	cum	104.06	0.625	65.04
7	6.1.14 + 6.2A.2	Brick work 1:6	cum	277.84	0.625	173.65
8	6.15	Brick work 1:3 in ARCHES	cum	0.24	1.28	0.31
9	5.25.2	Cement Jalli 40mm (fixing only)	100 sqm	5.76	1.64	0.09
10	6.12.2	Half Brick work 1:4	100 sqm	24.5	10.64	2.61
11	11.3.2	CC Floor 1:2:4, 40 mm thick	sqm	516.66	0.17	87.83
12	11.6.1	Skirting Cement plaster 1:3 neat cement 18 mm	sqm	61.04	0.14	8.55
13	11.26	Kota stone	sqm	13.93	0.1491	2.08
14	11.19	Ceramic Glazed tiles	sqm	144.32	0.0942	13.59
15	13.2	12 mm Cement Plaster 1:6	100 sqm	3694.98	3.60	133.02
16	13.19	6 mm Cement Plaster 1:3	100 sqm	537.64	3.67	19.73
17	13.47	Grit Wash	100 sqm	671.93	17.472	117.40
18	22.5	Water proofing	sqm	79.36	0.0123	0.98
19	10.13	T-iron Door frame fixing	100 kg	2200.79	0.11	2.42
20	22.7	Brick Bat Coba	sqm	148.56	0.387	57.49
21	AR	Coping 25 mm thick 1:2:4	sqm	5.18	0.08	0.41
			Cement in Quintal			**1506.20**
			Cement in Bags			**3012.40**

Annexure – II

Table 46
Cement Consumption with Cost Effective Specifications (1 Block – 16 DU)

S. No.	DSR 2002	Description	Unit	Qty.	Co-effi-cient	Cement Qty. in qtl.
1		250 mm dia pile M25	m	721.05	0.19	137.00
2	4.1.4	CC 1:6:10	cum	46.73	1.30	60.75
3	5.1.2	RCC 1:1.5:3	cum	2.01	4.00	8.04
4	5.42.1	RCC 1:1.5:3	cum	8.67	4.10	35.55
5	5.2.2	RCC 1:1.5:3	cum	11.21	4.00	44.84
6	5.3 (modified)	RCC 1:1.5:3	cum	26.715	4.00	106.86
7	5.22 (modified)	RCC 1:1.5:3	cum	7.07	4.00	28.28
8	AR	RCC 1:1.5:3	cum	26.17	4.00	104.68
9	6.1.14	Brick work 1:6	cum	38.95	0.625	24.34
10	6.1.14 + 6.2A.2	Brick work 1:6	cum	61.12	0.625	38.20
11	6.48.3	Brick work 1:6	cum	48.26	0.625	30.16
12	6.44 c	Brick work 1:6	cum	151.54	0.625	94.71
13	6.12.2	Half Brick Work 1:4	100 sqm	132.12	10.64	14.06
14	6.22	Brick band 10cm / 7.0 cm thick x 5cm	100 m	197.60	0.38	0.75
15	6.15	Brick work 1:3 in ARCHES	cum	0.24	1.28	0.31
16	5.25.2	Cement Jalli 40 mm (fixing only)	100 sqm	5.76	1.64	0.09
17	11.3.2	CC floor 1:2:4, 25 mm thick	sqm	516.66	0.122	63.03
18	11.6.1	Skirting Cement plaster 1:3 neat cement 18 mm	sqm	61.04	0.14	8.55
19	11.26	Kota Stone	sqm	13.93	0.1491	2.08
20	11.19	Ceramic Glazed Tiles	sqm	144.32	0.0942	13.59
21	13.2	12 mm Cement Plaster 1:6	100 sqm	3512.70	3.60	126.46
22	22.5	Water Proofing	sqm	79.36	0.0123	0.98
23	10.13	T-iron Door Frame Fixing	100 kg	2200.79	0.11	2.42
24	22.7	Brick Bat coba Av 120mm thick	sqm	148.56	0.387	57.49
25	AR	Ferrocement shelves 25mm thick	sqm	13.02	0.23	2.99
26	AR	Ferrocement stair case 25mm thick	sqm	25.20	0.23	5.80
27	AR	Coping 25 mm thick 1:2:4	sqm	5.18	0.08	0.41
			Cement in Quintal			**1012.42**
			Cement in Bags			**2024.84**

ADLAKHA
ASSOCIATES
PVT. LTD.

bmtpc