

STUDIES ON RESIDENTIAL FLATS

PROJECT REPORT

Submitted By

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(Autonomous College of Bharathiar University)

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Certificate

This is to certify that the thesis entitled

Studies on Residential Flats

being submitted by

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External Examiner

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ABSTRACT

A brief study has been made on the multi-storeyed residential flats construction. A number of journals are studied regarding the residential flats and the salient points are collected and discussed. The existing system of residential flats construction and the techniques adopted are reviewed in this study.

The present method of construction and selling procedure by the government departments and private flat promoters are collected and reported. The practical difficulties experienced by various departments in the residential flats construction is collected and reported. The precautionary measures to be followed in Construction of flats are discussed.

The provision to be made by the National Building Code of India and rules and regulations stipulated by the Tamil Nadu Multistoreyed Building rule is analysed for residential flats/apartment construction.

The suitable foundation system to be adopted for flats are discussed as per the National Building Code of India and as per the I.S.I. Specification loading conditions for different soil strata. The superstructural system for construction of flats are analysed and new techniques that can be adopted to economise the construction cost and time is discussed.

The result of this studies are discussed and reported by graphs and tables which will be useful for future residential flat promoters.

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CHAPTER - 1

INTRODUCTION

1.1 GENERAL

As per latest census, the population in India is about 85 crores. Although only 25 percent of the total population is living in urban areas, in terms of magnitude, the urban population is about 200 million. India has the third largest urban population in the world. By 2000 A.D. India's population may reach upto 100 crores, and the urban population may increase by 300 to 400 million and perhaps the largest urban populated country in the world.

The massive increase in population has put a great pressure on land in our metropolitan cities like Delhi, Bombay, Calcutta, Madras etc. This calls for its optimum utilization. Tall multistoreyed buildings would be the inevitable answer. However, it is very strange to find that the building by laws in the metropolitan cities do not allow any advantage of additional built up area for high rise buildings.

In metropolitan cities it is the well planned taller multistoreyed buildings which are capable of housing the present population and hence it becomes essential to construct flat system with 3 or 4 storeys in all the major cities. The central and state governments with the aid of Hudco Housing Boards slum clearance Board Police Housing

Corporation, etc. arranging appropriate action to provide residential facilities for the growing urban population. In addition, the private flat promoters are also doing parallel residential accommodation for the urban population. In growing cities (like Coimbatore, Madurai, Trichy, Salem etc) the government department and flat promoters are mostly constructing only 3 or 4 storeyed residential buildings to accommodate the people with required facade and service facilities for peaceful living conditions, since the taller construction of building will increase the financial commitments. As the number of floors increase the cost will increase rapidly. Hence the government departments and private flat promoters used to restrict the number of floors within 3 to 4. The best way to ensure economical use of land in areas where land is scarce and to minimise cost of construction with the available building materials appears to be the construction of flats of few storeys.

1.2 HIGH RISE BUILDINGS IN INDIA

The major cities which contribute to the growth of high rise buildings in India are Delhi, Calcutta, Bombay and Madras.

The rate of construction of tall buildings in Calcutta is less, compared to the other metropolitan cities, due to the slow mode of transportation, frequent traffic jams and

clayey soil which is not particularly suitable for the construction of tall buildings.

Bombay, the second highly populated city in India can be considered the pacesetter in the construction of high rise buildings. The availability of rock strata along the shore has facilitated economical construction of foundation. In Bombay buildings up to 35 storeys have been built for residential and commercial purposes.

There has been a rapid growth in construction of Tall buildings in Delhi lagging only slightly behind that of Bombay. The number of storeys of tall buildings are generally restricted to around twenty in Delhi. Tall buildings constructed are mainly for hotels and offices, as many people prefer independent units of living rather than apartments.

Only few tall buildings have been constructed in Madras which is the third largest city in India. The number of storeys range from 8 to 14. The rates of construction of tall buildings is about the same compared to Bombay and Delhi.

The other cities where there is a rapid growth of tall building are Bangalore, Hyderabad, Ahmadabad and Coimbatore. Tall buildings in these cities are limited to 8 to 16 storeys only.

1.3 RESIDENTIAL FLATS IN INDIA AND IN WESTERN COUNTRIES

The world's first fifteen tallest buildings have been constructed in U.S.A; the first high rise building constructed in 1884. New York's highest residential building as well as tallest in R.C.C. is the Metropolitan tower, one of the 10 highest buildings in the world. Height 218 m, land area of 3250 m^2 , 46 storeyed and triangular in shape. Flat plates and flat slab for office and residential are used.

Sway $1/500$ to $1/600$ of highest is multiplied by providing increased mass for the building in typical floor slab with 215 mm thick. The foundation is to rest on independent spread footing on row having S.B.C. or 440 t/m^2 . The design strength varied from 28 to 58 N/mm^2 . Column concrete strength is restricted to 1.40 times of slab concrete.

Trump tower in New York, U.S.A. is of 58 floors with a plinth area of 3568 m^2 . The housing complex situated at Vlaardingen in Holland is 61.50 m height.

The high rise trend has now spread to all the other cities of the world. Even major cities of the world (London, Cairo, Moscow, Montreal, Berlin, Melbourne and in Bombay) can now boast of skyscrapers of 30-40 storeys for residential purposes.

In India the real era of high-rise buildings can be said to have been started around 1955-56. The L.I.C. building at Madras was the tallest in India when constructed in 1956. As in other fields Bombay took the lead. The removal of 27.40 m (90') height restrict in 1960 in this city has resulted in a spurt of tall buildings around. A fairly large number have come up in the last 25 years in the city. Our other major cities are also fast following suit and their activity is noticeable in all of them. Viz. Calcutta, New Delhi, Madras, Ahmedabad, Bangalore, Hyderabad, Secundrabad, Coimbatore etc.

Bombay has an edge over two of its rival Calcutta and New Delhi on account of availability of fairly good rock at many places. This makes foundations much cheaper as compared to the sandy strata of Calcutta and New Delhi. New Delhi has a further disadvantage of being located in an acute earthquake zone but which create additional structural problems.

1.4 RESIDENTIAL FLATS IN TAMILNADU

In Tamilnadu the flat constructions are growing in vast expansion in all the major cities like Madras, Coimbatore, Madurai, Trichy, Salem etc. The private flat promoters are keen in the construction of residential flats/apartments in all the cities and in Towns. There is urban land ceiling act in Tamilnadu, especially in cities and major towns it is imposed severely.

The private flat promoters used to purchase the vacant site, get lay out approved and propose construction of residential flats/apartments. They are used to construct the flats/apartments with a business motive. They are attracting the public by constructing flats proximity to the service like railway station, Bus terminus, Colleges, Schools, Cinema theatre, parking facilities, regular water supplies, drainage systems etc. Due to price hike in urban areas any individual family finds difficulties in purchasing land, getting approval and constructing the residence with the above facilities. Hence they go to purchase the residence from private flat promoters. In the prevailing market rates, it is difficult to purchase a residence from the flat promoters for middle income group family.

The Tamilnadu government has set up the Tamilnadu Housing Board, Tamilnadu Slum clearance Board, Tamilnadu Police Housing Corporation and many other housing societies to provide housing facilities for all the low income group, middle income group and High income group.

The Tamilnadu slum clearance Board construct residential flats for the slum area - living people who are below the poverty line. They allot the residential flats for the slum living people and collect nominal monthly premium so as to meet out the expences and for maintenance.

The Tamilnadu Police Housing Corporation construct the residential flats for the employees of Police Department only in the urban areas, in Police recruit training schools areas and in places where reserve police battallions are located.

The Tamilnadu housing Board is the main residential construction wing to provide housing facilities to all the public and government employees of Tamilnadu. This board used to acquire the lands in urban area giving notification well in advance to the land owners who are having lands more than ceiling limit, bearing in mind for the provisions made by the Town and country planning proposals.

The Tamilnadu Housing Board classifies people according to their living conditions in Tamilnadu as detailed below. dependinng on their annual income.

1. Economically weaker section.
2. Low income group.
3. Middle income group.
4. High income group.

The Tamilnadu Housing Board provides housing facilities for the people in Tamilnadu in the following manner.

1. By allotting the approved layout duly approved by the MMDA/corporatin, municipalities etc. The plot is got approved with all the service conditions like road, electricity, water supply, drainage arrangements, security facilities. Then the plot is sold to the public for all the categories of people as detailed above by instalment payment system.
2. By constructing individual residential houses for all the categories of people and selling by lot system and the money to be recovered by instalment payment system.
3. By constructing residential flat system for all the categories of people and selling by lot system with all the servic facilities by instalment payment system.
4. By constructing the residential flat system in Tamilnadu Government Rental housing scheme. In this type of construction the Tamilnadu Housing Board is constructing three types of flats. The flats are allotted to the government employees depending on their pay ranger and recovered through their monthly rent accordingly.

1.5 NEED FOR THE STUDY

Improvements in housing conditions are of fundamental importance. People are becoming aware of the need and

importance of housing and therefore the solution of the problem of housing has become a matter of great urgency. Housing however, forms one of the most complicated problems, the solution of which demands on a far better working method than hitherto available.

In developing countries whose national per capita income is relatively very low, housing cannot be looked upon purely from the economist's point of view as an investment which ought to be directly productive; but as the well-being and better living standard of the masses have great social appeal, improvements in housing have become a matter of necessity as well as urgency. House building is already behind to a lamentable extent and no developing country can afford to neglect the seriousness of the problem. If counter measures are not taken, the ever growing number of slum dwellings in urban areas in particular will seriously threaten the social system of our country and consequently the program of our development.

As housing building is concerned with social, economic, financial and technological matters, a rational approach suited to our conditions have to be evolved to find a satisfactory solution to the problem. The care of the problem, however, is to effect substantial reduction in house building cost. We should aim to provide a better

working method for achieving progressively, in successive stages, optimum quality of dwelling at lower cost.

1.6 AIM AND SCOPE OF THIS STUDY

The aims of this investigation may be briefly stated as:

1. To study some of the existing residential flats in detail in relation to their plan, structural arrangement and construction materials.
2. To identify and recommend salient features which will be useful for future flat promoters.

For this investigation, it is proposed to collect the drawings pertaining to a number of flats which have been already constructed, to visit few flats that have been constructed and to consult people who are living in various types of flats.

CHAPTER - 2

STUDIES ON SOME OF THE EXISTING FLATS

2.1 GENERAL

Every major city faces increasing urban population. To accommodate the urban people a number of multi storey buildings are being constructed. The multi storeyed buildings are constructed to provide office buildings, companies, banking, hotels, lodges, residential apartments etc. Some of the existing apartments in western countries and in India are discussed in this chapter.

2.2 REVIEW OF SOME OF RESIDENTIAL APARTMENTS

2.2.1. Wanamaker House in Philadelphia [1]

Wanamaker House is a 35 story residential high rise building mounted on a two level underground parking structure. The tower, smaller than the parking structure, is centered above the middle of the garage.

A cast in situ plate columnar structural system was placed to resist gravity and lateral loads. Wind loads are carried by exterior short shear wall combined with interior core configurations , stairs; elevators etc.

Along the roof's edge a parapet wall of cast-in-place concrete with an exposed aggregate finish provides a cap for the building top. Town houses were attached along the north and south peripheries of the site, also using cast-in-place concrete walls.

An unusual feature attached to the new townhouse-tower construction was the existing Wanamaker residence. The entire house behind the front facade was removed and replaced with four individual town house units. While the new house were assembled and attached to the front of the original Wanamaker residence was delicately broad. Naturally, the complex is called Wanamaker house. Engineer incharge in Betnard Schwartz and associates Architects are Barancike and Centre. The contractor was L.F. Driscall company.

2.2.2. Logan Square East Apartments [1]

Fire safety was a prime concern for this \$ 23 million, 24 story urban life-care community for the elderly. Using precast concrete for the top 20 stories was the most cost efective way to achieve the required fire ratings. All components with the exception of finishers, are of incumbustible materials. Precast concrete construction earned the project the highest incombustability rating used philadelphia code.

Of all the benefit precast prestressed concrete offered, the speed at which it was erected was the most dramatic. Fast erection minimised on site labour costs and reduced the cost of interium financing.

In addition to using a system with interior bearing walls and hollow cone floor and roof members, the exterior panels were produced with light weight glass fibre reinforced concrete.

Precast/prestressed concrete also offered maximum quality control. Under factory conditions, concrete mixturer, humidity, temperature and curing time were precisely controlled to ensure strength and durability of each member. The components met strict size, dimensions and colour specification. Engineer incharge was Joseph L. Hoffman. Architect incharge was Richard E. Martin associates and the contractors are Keating Construction Company.

2.2.3. Metropolitan Tower In New York [2]

Metropolitan Tower is the New York's highest residential building in R.C.C. and is one of the Ten highest building in the world. The height is 218 m, land area of 3250 m², 46 storeyed with triangular in shape. Flat plate and flat slab are used for this residential building sway 1/500 to 1/600 of height is nullified by providing increasing the mass of the building in typical floor slab in 215 mm thick. The foundation is rest on independant spread footing on rock having S.B.c. of 440 ton/m². The design strength varied from 28 to 58 N/mm². column concrete strength is restricted to 1.40 times of slab concrete.

2.2.4. Residential building complex at Milan in Italy [3]

Designing co-operative houses imposes limit on the creative process, both because of the functional requirements and used to keep the building cost lower. The above building is an example of creative architecture which satisfies both the functional requirements and low building cost simultaneously.

2.2.5. Alhali Bank Building in Kuwait [4]

Alhali Bank building is the tallest in Kuwait. The height of the building is 112 m. The banking hall is 25.50 m wide and 30m long. The total banking area of the building is 12500 m². This building describes successful and effective design solutions for three common structural problems. Composite construction (mixed systems) differential settlement compounded by large uplift pressure and control of deflection and other movements of main transfer girders were taken care of in the tallest building in Kuwait.

2.2.6. Architects Jain's award-winning [5]

Cost effective housing scheme at Rajkot. This is a composite housing scheme for the economically - weaker section, low-income group and middle income group. Seven residential units are designed for these three categories, totalling 400 houses in all. Additionally, provisions are made for community facilities as basic, as shopping and a school.

The local authority selected a 3.84 ha. plot at the edge of Rajkot town and linked to be town as well as to the highway to Ahmedabad. For us, this gradually slipping site with a rocky base, was ideal to develop. Although its narrow frontage to the access was not a plus point there was ample scope for us to orient the houses as we choose.

It is decided to identify key criteria before formulating a design concept. In the process, evolved several considerations that:

- The potential must aim for a density of atleast a 100 dwellings/ha. on its completion it realised 104/ha.
- In spite of aiming at reasonably high density, the scheme must remain a low rise construction.
- If possible ground and terrace must be provided to each and every family.
- The houses must be oriented North-South with common walls on the east and west, as is derived in lieu of the climate.
- All houses must be organised along the streets to achieve the orientation desired, cluster organisation is not feasible in this situation and climate.
- To simplify and accelerate construction, all the seven types of units must be co-ordinated, establishing a harmonious order in the overall scheme.

- All seven types should be given an identical external treatment and finish, achieving not only harmony in development but minimising obvious differences and classifications.

HOUSING CATEGORIES

Sl.No.		No. of houses
a.	Economically weaker section (1)	120
b.	Economically weaker section (2)	60
c.	Low income group (1)	80
d.	Low income group (2)	60
e.	Low income group (3)	40
f.	Middle income group (1)	25
g.	Middle income group (2)	15
	TOTAL	----- 400 Nos. -----

The concept: The basic concept arrived at was to develop compact and harmonious residential environment for various economic groups. Reporting to all the design considerations listed, it succeeded in optimising them and unifying the total environment.

It adopted a row house system with shared walls, realising economical construction and a climatic advantage. As few external walls exposed to solar radiation, a more

pleasant internal environment is nursed. The organisation of units along the streets modulated by widening the streets at places, gives way to open spaces for various activities. The terraces at first floor level also prove useful.

AREA - COST/UNIT

Type	EWS-1	EWS-2
Plot	37.84 m ²	Nil
Terrace	Nil	11.92 m ²
Built-up	21.26 m ²	29.79 m ²
G.F.	21.26 m ²	Nil
F.F.	Nil	29.75 m ²
Cost	Rs. 4,200	Rs. 6,300

Type	L.I.G.1	L.I.G.2	L.I.G.3
Plot	50.11 m ²	57.57 m ²	57.57 m ²
Terrace	11.92 m ²	11.92 m ²	15.63 m ²
Built up	41.32 m ²	49.80 m ²	63.76 m ²
G.F.	29.40 m ²	33.31 m ²	40.86 m ²
F.F.	11.92 m ²	16.49 m ²	22.90 m ²
Cost	Rs. 7,600	Rs. 10,700	Rs. 15,200

Type	M.I.G.1.	M.I.G.2
Plot	74.10m ²	74.10m ²
Terrace	18.02 m ²	11.92 m ²
Builtup	82.30 m ²	96.60 m ²
G.F.	49.58 m ²	53.36 m ²
F.F.	32.72 m ²	43.24 m ²
Cost	Rs. 17,450	Rs. 22,300

Year of Construction is 1990

The construction: A modular co-ordination system was followed for the entire scheme covering 400 houses. A spanning module 1.20 m x 1.20 m with a 23 cm wall or beam dimension, was selected for construction. Load bearing walls were installed, in local brick and a rubble masonry plinth, as its vertical support system.

Roof spanning followed the age old jack arch system but while be traditional jack arches or vaults, bridge over on M.S. joists, these settle on R.C.C. beam shaped as proper base. Part of the beam depth was inverted, reducing its width and cost. It also reduced the hanging depths of the room beams. Some of their sections filled within the valleys created by the vaults.

All the vaults parallel shared walls, but span the front and rear walls at right angles, inviting the construction signage on the facade itself. The exterior of all units is plastered, as are the interiors of units EWS-1 and 2 and L.I.G.-1, but only upto lintel level. In these, the flooring is left unfinished for occupants to do up at a later date. This has allowed the units to be a little largest at no extra cost.

Local brick construction in lime mortar, with minimum cement and steel was the via-media to economy in construction. The vaulted roofs also helped to save on cement and steel in short supply. Over all, the roofing cost was reduced by 17 percent.

Adopting cost-effective, but really effective construction techniques, and a simple but sound design system. It was possible to construct all the 400 houses in a year, three months beyond the time-period stipulated by the competition it had been entered it for. Only one scheme, somewhere in Uttar Pradesh, could be completed on time. This has succeeded second.

Its principal achievements stem from the set of predetermined design considerations. They rest in its modular coordination and low rise high density scale. In harmony.

Client : RajKot Municipal Corporation.
Financier : HUDCO, New Delhi.
Architects : Kulbhushan and Minakshi Jain
Structural Engineer : C.H.Shah.

2.2.7. Residential flat/apartments in Tamilnadu

In Tamilnadu a number of flat promoters are constructing flats/apartments in all the major cities like Madras, Madurai, Coimbatore, Trichy and in other towns. They are constructing the flats in large scale, medium scale and in small scales. They construct houses at the range of 30 m² to 120 m² depending on the plot value, access, facility and other service conditions. The value of the flat will be ranging from Rs. 4000/m² to 6000/m² including land cost. The private flat owners mainly constructing 3 to 4 floors only in order to avoid the excess expenditure involving lift facilities etc.

The Madras Metropolitan Development Authority and other Municipal Corporations permits only upto 4 floors, keeping in view the purchasing capacity by the public. The private flat owners prefer R.C.C. construction in order to minimise their expenditure and time and to gain more profit. They also arrange loan facilities from Housing development finance corporations, L.I.C., Banks and other building societies etc.

2.2.8. Saraswathi Apartments in Coimbatore

Location : 3rd Street, (opp. Road to Textool),
Gannapathipudur, Coimbatore - 641 006.

Flats Type and Price Details:

Type of Flat	Super Built Area	Rate per SFT	Total Cost of Flat	Initial Payment 30% approx.	Balance before possession
A,D,E,H	839 SFT	435	3,64,965	1,09,500	2,55,465
B,C,F,G	824 SFT	430	3,54,320	1,06,300	2,48,020

Payment Details:

1. On allotment 30%
 2. On Completion of Basement 10%
 3. On Completion of Ground Floor RCC Frame 10%
 4. On Completion of First Floor RCC Frame 15%
 5. On Completion of Second Floor RCC Frame 15%
 6. On Completion of Third Floor RCC Frame 15%
 7. On Handing Over Possession 5%
- * For those buyers who can make full payment (100%) on or before commencement of work, a discount of 10% is offered.
- * For those who can remit 30% of the cost before 30.11.1991 an amount of Rs.50,000 can be saved in Registration Charges.

Highlights of the Project

- * Project conceived to suit the middle income group.
- * Eligible for financial assistance from HDFC, CANFIN, LIC etc.
- * Plan approved by Coimbatore Municipal Corporation.
- * Just 2kms from Central Bus Stand, TTC & Crosscut Road
- * Simultaneous supply of SIRUVANI and borewell water.
- * Free ventilation, moving space, light and lift.
- * Letter boxes on the ground floor as per Government Rule.

For further details contact:

Rajananarayan Constructions

"Rajananarayan Towers"

70 Race Course

Coimbatore - 641 018

Phone: (0422) 36345, 36346, 36347

Architects and Engineers

Britto Ilango and Associates

167, West Sambandam Road

R.S.Puram

Coimbatore 641 012

Phone: (0422) 47406

SPECIFICATIONS

1. Number of Floors : Ground plus Three
2. Foundation : Conventional C.R. Masonary
in Cement Mortar
3. Superstructure : Load Bearing 9" Table Moulded
brick walls in Cement mortar
with RCC Frames
4. Flooring : Grey Mosaic Hydraulic pressed
tiles,
5. Walls : Oil bound distemper
for interior and waterproof
cement for exterior walls.
6. Skirting : 3" wide enamel paint
7. Kitchen : Marble Platform with built-in
sink and 18" high white glazed
tiles skirting.
8. Toilet : Marble Tiles Flooring
Walls with white colour
glazed tiles upto 4'6" height
Provided with 1 white colour
Indian Closet (I.W.C.) and
1 white wash Basin.
Provision for fixing geyser
with necessary plumbing line
and shower point.

10. Staircase : Mosaic chip matching grey tiles
11. Weather Proof Course : Surki Mortar
12. Wiring : Concealed copper wiring in PVC conduit 1/18 wire-5 Amps and 3/20 wire 15 Amps as per standards with sufficient number of points for TV Fridge, Mixie, Grinder etc.,
13. Windows : Aluminium Sliding type Windows
14. Grills : MS grills of standard specifications
15. Doors : TW outer frame of 4" x 3" with factory made flush doors, locking arrangements iron oxidise hinges and aluminium bolt and pad locks.
16. Provision for Loft in bedrooms
17. PVC pipes for plumbing and sanitary lines.
18. Lift of 5/6 passenger capacity as per I.S.
19. Common Staircase (area included in Super Built Area).
20. Separate EB meter in each flat.

2.3 TAMILNADU HOUSING BOARD FLATS

Tamilnadu Housing Board is a quasi Government body which construct nearly 4000 flats in a year throughout Tamilnadu. The board get loan from the World bank, HUDCO, LIC, etc for construction of flats and individual residential scheme.

The T.N.H.B. construct residential flats for L.I.G., M.I.G., and H.I.G. sections. They construct the residential flats whose plinth area varies from 22 m² to 80 m² for the above income group sections. Individual residential houses are constructed at the above plinth area level. The Housing Board selling the above flats/houses in a lot system at full or instalment payments basis. They also construct houses for Tamilnadu Government Employees to be allotted for rent and collect the rent from their monthly pay.

The T.N.H.B. provides maximum service facilities for the flats/houses. The flats are also constructed with maximum utility conditions for the family. The TNHB construct the flats/houses maximum with conventional load bearing walls and with R.C. structures in sea shores. The Board also utilise low cost housing materials thus reducing the house building cost by 13% in last few years. The building cost of flats constructed by Tamilnadu Housing Board works out to Rs. 2,400 to Rs. 3,000 /m² during the

current year and thus works out to Rs. 3000 to 3200/m² including land cost.

2.4 EXPERIENCE AND DIFFICULTIES IN FLAT CONSTRUCTION

2.4.1. Precautionary measures

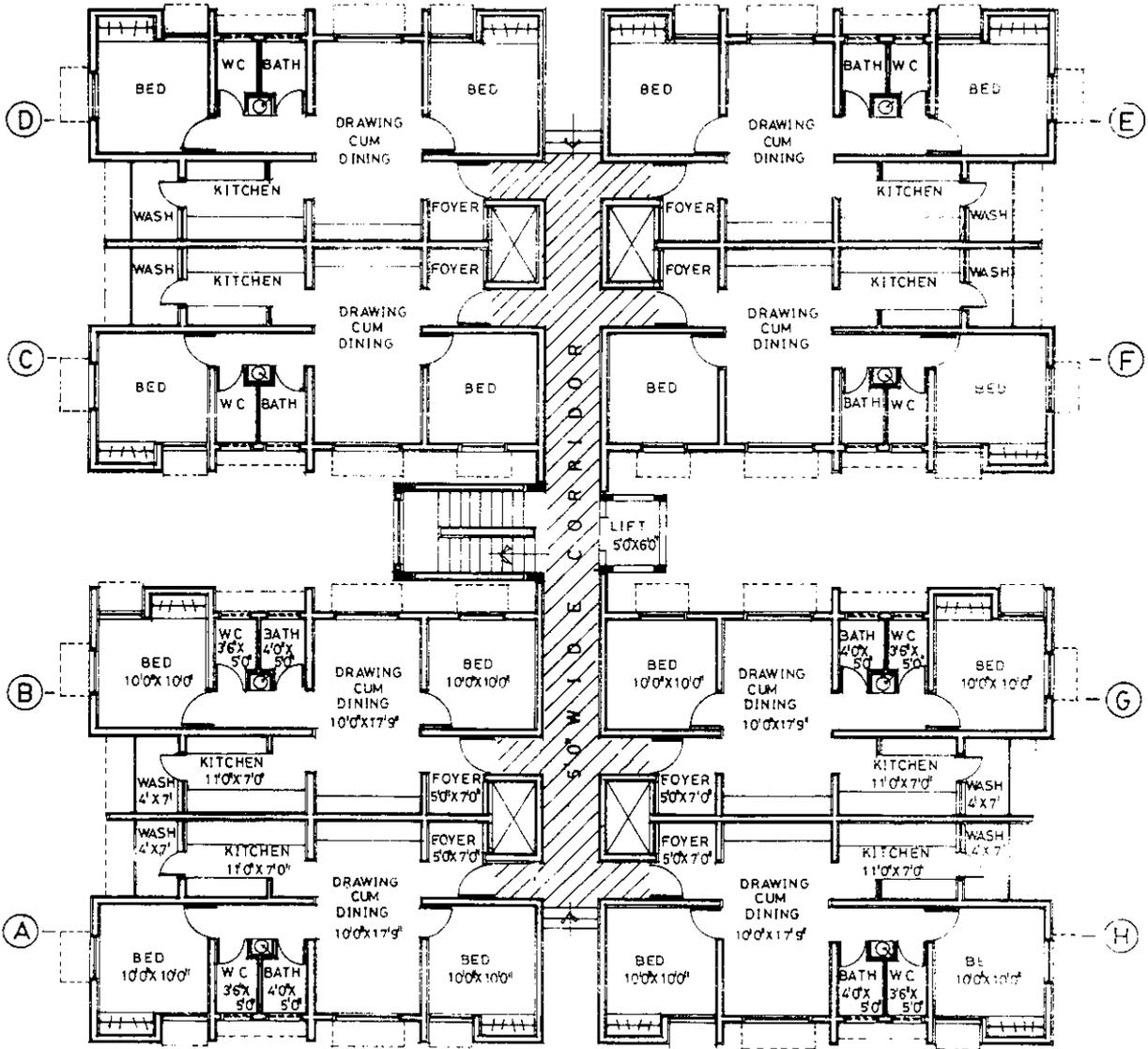
1. The form work construction and placing concrete is a problem during construction of flat construction. Hence machineries and equipments should be involved to a greater extent.
2. While fixing centre lines for load bearing walls and R.C. footings, care should be taken in the alignment and fixing the position on the ground.
3. During placing plinth beam and Damp proof course the level of adjacent ground is to be considered to ensure no water entry.
4. While increasing the storey height care should be taken to avoid shrinkage, temperature variation differential settlement etc.
5. Anti-termite treatment should be given for foundation, basement construction and for flooring during execution.
6. Adequate space should be provided for services at the planning stages itself to avoid additions and alterations at a later date.

7. The prefabrication techniques and required mechanised facilities should be developed.
8. Planning of the building is a must before starting execution giving enough time for all items to avoid delay in time.
9. In congested localities a proper side space planning may be done in advance and layout prepared showing areas for storage of various materials, excavated earth, construction equipment etc to ensure progressive execution.
10. A thorough soil investigation should be made before commencing works and dewatering arrangements to be made if there is water logging area.
11. Adjustable scaffolding, slip forms may be used subject to economy to achieve speedy execution.
12. Prefabricated concrete components may be used subject to economy to save time in execution.
13. A systematic agreement to be drawn with the contractor giving enough time limit for curing etc. in order to exercise good quality work.

2.4.2. Practical difficulties and experience in execution

1. During execution for foundation, cavity in soil mass was unnoticed by Tamilnadu Housing Board at Salem resulting casualties and injuries to the workers due to collapse of the structure.
2. If the subsoil is clay in nature proper chemical treatment has to be given for foundation. Due to such negligences, there is crack in foundation in P.W.D. building construction at Coimbatore area and in Tamilnadu Housing Board flats construction at Singanallur.
3. Proper care should be taken to extract quality work from the contractor and to be free from cracks in beams and slabs as at school building works at Ramanathapuram in Coimbatore.
4. There is peeling of plastering in walls at Tamilnadu Housing Board flats at Sowripalayam and Singanallur of Coimbatore town. To avoid this the water to be used for construction to be tested for salt content before commencing execution. Now this is being chipped off and replastered.

5. Proper cover for slab reinforcement has to be given before laying concrete. There is exposure of steel reinforcement in R.S.Puram Housing unit due to less ceiling plaster thickness. Now this has been replastered with rich mortar to proper thickness.
6. Similar defects have also occurred in Tamilnadu slum clearance board works at Madras. Cracking of exposed concrete in coastal areas is mainly result of reinforcement corrosion which is caused by either the penetration of chloride from sea water spray or the use of contaminated aggregates.
7. The form work should be carefully watched during laying concrete and ramming with vibrators to avoid tilting of beams and columns.
8. Careful specification for selection of installation of accessories such as railing and planters should be provided to ensure durability of concrete.
9. Proper supervision and quality control is a must during construction of flats to achieve a durable structure.



TYPICAL FLOOR PLAN

AREA OF BLOCK A.D.E.H. 839 00SFT

AREA OF BLOCK B.C.F.G. 824 00SFT

SARASWATHI APARTMENTS



CHAPTER - 3

GOVERNMENT RULES RELATED TO RESIDENTIAL FLAT CONSTRUCTIONS

3.1. TAMIL NADU BUILDING RULES [9]

The Tamil Nadu Government has prescribed some zoning regulations specifying the use of land and Buildings particulars in urban areas in G.O.MS.No:1730 Rural Development and Local Administration Department dated 24th July 1974. These regulations list out the uses permissible in each of the use zone and restrictions to be imposed. For the purpose of these regulations, it has been suggested that the urban areas may be divided into the following major use zones.

1. Residential use zone
2. Commercial use zone
3. Industrial use zone
4. Educational use zone
5. Public and semi-public use zone, and
6. Agricultural use zone

Of these, the residential use zone has been further sub-divided into two categories namely,

- a. Primary residential use zone and
- b. Mixed residential use zone

3.1.1. Primary Residential Use Zone

1. All residential buildings including single and multi family dwelling apartment dwellings and tenaments both appurtenances pertaining thereto:
2. Professional consulting officers of the residents and other incidental uses therefore;
3. Petty shops, dealing with daily essentials including retail provisions, soft drinks, cigarettes, newspapers, milk-kiosks, cycle repair shops, and single person tailoring shops.
4. Hair dressing saloons and Beauty Parlours
5. Nursery and Primary Schools
6. Taxi and Auto Rickshaws stands; and
7. Parks and Play grounds.

3.1.2. Mixed Residential use Zone

1. All uses permitted under Primary residential use zone
2. Hostels and single person apartments.
3. Community Halls, Kalyanamandapams, Religious buildings, Welfare centres and Gymanasiums;
4. Recreation clubs, libraries and Reading Rooms
5. Clinics, Dispensaries and Nursing Home;
6. Government, Municipal and other institutional sub offices

7. Police stations, post and Telegraph offices, Fire stations and electrical sub-stations.
8. Bank and Safe deposit vaults
9. Educational institutions excluding colleges.
10. Restaurants, Residential Hotels, and other Boarding and Lodging houses;
11. Petrol filling and service stations
12. Departmental stores or stores or shops for conduct retail business.
13. Vegetable, fruit, flower, fish, eggs and meat shops.
14. Bakeries and confectioneries
15. Laundry, Tailorings, and gold smith shops and
16. Cottages industries permissible in residential areas under G.O.MS.NO: 566 Dated 13.3.1962.

3.2. TAMILNADU MULTISTOREYED BUILDING RULES

The government Tamil Nadu has issued the Tamil Nadu Multi storeyed and Public Building Rules in G.O.MS.NO:1759 RD & LA Dated 24.8.1973.

RULES

1. Short Title:

This rule is called multi-storeyed and public building Rules 1973.

2. Definitions:

'Multi-storeyed Building' Means and included all buildings with more than three storeys or whose height is 15 meters or more.

3. Application of Rule:

Construct, reconstruct, add to or alter any multistoreyed building in addition to the general requirements laid down in this rules, shall also apply.

4. Area for the construction:

a. Only in approved areas for the construction of multi-storeyed buildings in

1. Town planning Scheme made under Twon planning Act 1920 (or)
2. Development plan under the Town and country planning Act 1971 (or)
3. Declared by a special Resolution by the council with approval of Director.

For such purpose and shall not exceed the minimum number of storeys or maximum height prescribed for the individual area.

- b. Extent shall not be less than 4 grounds. shortest side not less than 24.50 metres (80 feet). It should be about a street not less than 12.25 metres (40 feet in width).
- c. All aspects of structural design, building service, plumbing, fire protection, construction practices and safety, the specifications, standards and codes of practice recommended in the N.B.C. of India 1970 shall be fully confirmed to besides in these rules.

5. Engineer's approval:

The engineer while according approval of permission shall follow code of practice and standard requirements recommended in the NBC 1970.

6. Site plan, street and spaces:

The site plan to be submitted in triplicate under this rule shall also show the following:

- a. the existing and proposed building in relation to the boundaries of the site and in relation also to all adjacent streets, buildings (with number of storeys and height) and premises with a distance of 15 metres (50 feet) of the site.

- b. The means of access from the street or streets to all building existing and proposed in the site, to the parking spaces and facilities provided in the site within or outside the building and for scavenging and fire protection.
- c. The spaces to be left about the building for circulation, air, light, access parking and amenity, and
- d. The general layout of the columns and load bearing walls showing the estimated loads, including moments and torques coming on the foundation units.

7. Building Plans:

The building plans to be submitted to triplicate under the rules shall also show

- a. Floors plans of all floors and covered area, indicating clearly all the sizes and spacing of all framing members, and sizes and arrangement of rooms and the position of staircase, pumps and lift walls.
- b. Longitudinal and cross sections of the building to show size of footings, basement and superstructure, framing members and details of building and room heights and of staircases etc.

- c. In the case of constructions using steel structure complete design drawing showing sizes section and relative location of the various steel members floor levels, column centres and off-sets.
- d. In the case of prefabricated building, drawings describing the elements of the structures or assembly including all required data of physical properties of component, material with details of joints to an enlarged scale site or shop location of services such as installation of piping, wiring or other accessories and location of handling arrangements for lifting and handling the prefabricated elements and
- e. Plans and sectional details of water supply and sewage system for the building.

8. Specification:

The following detailed specifications shall be furnished with the application for permission under these rules.

- a. General and detailed specifications, giving type and grade of materials to be used.
- b. Detailed computations, free diagrams to show the sufficiency and correctness of design, and

c. Type and condition of soil or rock to which the foundation transfers the loads.

9. Floor Area Ratio and Maximum Plot coverage:

The maximum floor area Ratio and maximum permissible plot coverage for different occupancies shall be as in the following table.

The Table

Building Type (1)	Floor Area Ratio (2)	Plot Coverage (3)
1. Residential	150	35
2. Commercial		
(a) George town and other Special areas declared by council with approval of Director.	250	50
(b) Other areas of the city	160	40
3. Public and industrial		
(a) George Town and other special areas declared by council	150	50
(b) Other areas of the city	100	50

Explanation: (1) Floor Area Ratio Specified in the table may be increased by 20 per cent for the following services.

a. A basement or cellar and space under building constructed on stills and used as parking space, store room and air conditioning plant room used as necessary to the principle use:

- b. Electric cabin or sub-station, watchmens booth, pump house and garbage shaft and
- c. Staircase room and lift rooms above the top most storey, architectural features, chimneys and elevated tanks.

Explanation:(2)

The maximum plot covered specified in the table includes 5 per cent for covered parking and another 5 percent may be allowed for covered garges for car and cycle parking. This area for parking in ground floor will not be taken into consideration for calculating floor area ratio, but the space above it in first and upper floor will be counted.

10. Structural Sufficiency:

- 1. Foundation:
 - a. Foundation of concrete on rock, piles, piers, caissions or other foundation of such thickness projection as will be necessary to safety sustain and transmit all the dead and super imposed load without exceeding the limitations of permissible provided in these rules.

- b. All foundations, apart from those resting on bed rock, shall be carried down below the level of possible damage by frost or seasonal changes on soils possessing shrinking and swelling characteristics, such as clayey soils.
- c. Structural design of foundations shall be determined as per NBC of India 1970.
- d. Piles either friction piles or end bearing piles may be used for the foundation of a building when soil condition are suitable.
- e. All piles used to support any structure or part thereof shall be driven, fitted or otherwise embedded to such depth as is necessary to secure adequate soil or rock bearing capacity and in such a manner as not to impair their strength and shall be of sufficient strength to withstand also stresses resulting from handling and driving.

2. Walls and columns:

- a. the thickness of every load bearing non-reinforced masonry wall shall be sufficient at all points to ensure that the stresses due to the worst condition of loading for which the structure is designed are within the limits prescribed:

- b. Maximum slenderness ratio.
- Walls-Slenderness ratio = $\frac{\text{Effective height}}{\text{Effective thickness}}$ (or)
- = $\frac{\text{Effective length}}{\text{Effective thickness}}$
- Columns- Slenderness ratio = $\frac{\text{Effective height}}{\text{Lateral dimension (thickness or width)}}$

In case of

- i. Load bearing wall in cement mortar (1:6) (or) cement lime mortar (1:2:9)
- Slenderness ratio shall not exceed 18 and for those set in L.M. it shall not exceed 12.
- ii. Non-load bearing walls, the slenderness ratio shall not exceed 30 for panel walls and curtain walls and shall not exceed 24 for force standing walls and parapet walls.
- iii. Slenderness ratio for load bearing column shall not exceed 12.
- c. Solid wall or masonry wall-load bearing its thickness shall not be less than that determined by the calculated masonry method through the NBC 1970.

- d. Design loads and others forces to be taken from the NBC code-Vide part VI-section 1-Appendix L.
- e. Where a wall is subdivided into panels by adequate horizontal or vertical supports or both the individual panels shall be designed for structural sufficiency.
- f. Where reinforced concrete walls are intended to carry vertical loads, design should be done in accordance with design criteria for columns. the cross sectional area of vertical reinforcement and the lateral reinforcement parallel to the wall face may be reduced to not less than 0.2 per cent.
- g. The thickness of a reinforced concrete wall should not be less than 10cm.

3. Concrete and steel structure:

NBC-1970, Part VI section 5 for prestressed concrete, plain or reinforced concrete and section 6 part VI for steel has to be confirmed.

4. Prefabricated Building:

the modular Planning component sizes, joints manufacture, storage, transport and erection of prefabricated elements for use in the building shall conform to section 7-part VI of NBC '70.

5. Excavations:

- a. Protected from danger to life or property
- b. No excavation shall extend within 30 cm. or the angle or repose or natural slope of the soil.
- c. Where an excavation is back filled measures shall be taken to place the back fill so as to.
 - i. Maintain lateral support of the soil exposed by the excavation -
 - ii. have a bearing capacity adequate to support the anticipating surcharge, and
 - iii. Prevent detrimental settlement.

11. Open spaces:

1. Open spaces around and about building
 - a. These shall be permanent open air space, forming an integral part of the site and of minimum extent specified in this rule, between each boundaries of the site and every building proposed within the site.
 - b. Extent of open spaces (specified in the above sub-rule) which shall be co-existent with the site boundaries shall be as follows:

Buildings type	Minimum open yard from the Boundaries
i. Building upto a height of 10 metres	Three metres
ii. Building height above 10 metres upto 30 metres	Three metres & 1 metre for every additional 3 metres or fraction there-of over 10 metres.
iii. Building height over 30 metres.	Ten metres & 1 metre for every additional 5 metres or fraction thereof, subject to a maximum of 16 metres.
c. The space specified should be kept open to sky and free from any erection of any building other than a fence or compound, provided however, that parking gargarges not exceeding 3 metres in height and subject to compliance with stipulations of F.A.R. and access ways may be permitted in the open yards on the street or in the case of sites abutting more than one street, on the width of the streets, and provided also that these open yards may be used for the provision of open access way to the building and parking facilities.	

2. Open spaces for Amenity:

Where the building proposed in a residential building for accommodating multi-family dwelling there shall be also provided in the site a common amenity open space. The extent of this additional open space shall be 10 per cent of the site area.

12. Means of Access and circulation:

- a. There shall be provided from the street to the entrance door or doors of every building in the site a clear way of not less than 5 metres in width as means of access to such buildings which shall be maintained free from any erection or any overhang or projection from the building.
- b. The space so set apart as means of access shall be separately distinguished from any house fully or open space for amenity requirements prescribed under the rules.
- c. Every such means of access shall be made, drained and lighted to the satisfaction of the Engineer and a manhole core or other drainage, water any other fittings laid in such means of access shall be flush with the finished surface level so as not to be obstruct at safe travel over the same.
- d. Any person who undertakes construction work on building shall not reduce the access to any building previously existing below the minimum width prescribed under these rules.

2. Exits and means of egress:
- a. Every building meant for human occupation shall be provided with exits, sufficient to permit safe escape of occupants in case of fire or other emergency.
 - b. An exit may be doorway, corridor, passage way to an internal staircase or external staircase or to a verandah or roofs or terraces having access to the street.
 - c. Exits shall be so arranged and to provide continuous means of egress to the extent of the building or an extension open space leading to a street, without passing through any occupied unit.
 - d. Exits shall be located that the travel distance on the floor shall not exceed 22.5 metres in the case of residential and public buildings and 30 metres in the case of commercial industrial and other buildings. There shall be at least two exits serving every floor and at least one of which shall be stairway.

Note: Travel distance means the distance from any point in the floor area to any exits measured along the path of egress travel except that when floor areas are subdivided into rooms used single or suits of rooms and served by corridors or passages, the travel distance may be measured from the corridor entrance of such rooms or suits to the nearest exit.

- e. Width of any exit shall not be less than 100cm. and shall be determined for the total number of occupants as specified in the following table. The suit of exit width for measuring the capacity of exits shall be 50 cms. A clear width of 25 cm. shall be counted at an additional half unit and a clear width less than 25 cm. shall not be counted for exit widths.

S.No.	Occupancy	Number of occupants	
		Stairways	Door
(1)	(2)	(3)	(4)
1.	Residential	25	75
2.	Business	50	75
3.	Educational	25	75
4.	Other Public Buildings	60	90
5.	Industrial	50	75

13. Parking and parking facilities:

- 1 (a) For the use of the occupants and persons visiting the premises for the purpose of profession, trade, business recreation or any other work, parking space and parking facilities shall be provided within the site, to the satisfaction of the commissioner and conforming to the standards specified in Appendix-E to these Rules and,

- b. Necessary provision shall be also made for the circulation of vehicles gaining access to and from (i) parking spaces and facilities (ii) the premises into the street.
 2. the parking spaces and facilities provided under this rule shall be maintained as such to the satisfaction of the Engineer and conforming to any bylaw that may be made by the corporation in this regarding.
14. Fire safety:
1. All buildings in their design and construction shall be such as to contribute to and ensure individually and collectively the safety of life from fire, fumes and panic arising from these or similar other causes.
 2. Fire detecting and existing system
In building of such size, arrangements or occupancy that a fire may not itself provide adequate warning to occupants automatic fire detecting and alarm facilities shall be provided where necessary to waive occupants of the existence of fire, so that they may escape, or to facilities the orderly conduct of fire exit drills.
 3. Fire protecting and extinguishing system shall conform to accepted standards and shall be installed in accordance with good practice as recommended by in the NBC code of India 1970 and to the satisfaction of the Directorate of fire services.

15. Architectural control

1. The design and plans of the building shall be made and countersigned by a qualified architect who is an associate of Indian Institute of Architects.
2. The design and plans shall be scrutinized and approved by the panel comprising of the following members.
 - i. Engineer
 - ii. A Town planner of Government and
 - iii. A prominent private architect, provide that the architect member of the panel shall not have made the plans and designs for the building under consideration.
3. Any suggestion or alterations suggested by the panel shall be incorporated in the plans and shall be conformed to

PUBLIC BUILDING

16. Sufficient exits:

1. Every person intending to construct, reconstruct, add or alter any public building shall in addition to the general requirements laid down in Rules, also comply with rules, 9,11(a), (b) (c) 12 and 13 prescribed for multistoried building and also with the following rules.

2(a) Every place of assembly every tier or balcony and every individual room used as a place of assembly in a public building shall have exits sufficient to provide for the total capacity, those of leading directly outside the building or to stairway and ramps or both.

- b. There shall be atleast two separate exits as remote from each other as practicable for each room, hall or place of assembly with a capacity of 600 persons atleast three separate exits when the capacity is between 601 to 1000 atleast four separate exits when the capacity is over 1,000.

Provided that when the capacity is less than 100 persons and no part of the room or hall or place of assembly in 15 metres from the doorway in the line of travel, a single doorway of 100cm. May be permitted.

17. Aisles and spacing rows of seats:

- a. Clear aisles not less than 1.2 metres in width shall be provided at right angles to the line of seating in such number and manner that no seat shall be more than 3.8 metres away from an aisle measured in the line of seating.

- b. Where all the aisles do not directly meet the exit doors, cross aisles of minimum 1 metre width and at the sets of one cross aisles for every 10 rows of seat shall be provided parallel to the line of seating.
- c. Rows of seats between aisles shall not have more than 14 seats and in the case of such rows opening to an aisles at one end, shall not have more than 7 seats.
- d. There shall be a minimum space of 85 cm. between the back of any two rows of seats and a minimum of 35 cm. between the back of any set and the front of the seat immediately behind it as measured between plumb lines.

18. Fire detecting and extinguishing system:

Every public building having a capacity of 1000 person or more, shall be provided with either a manually operated fire alaram system coated to alert employees or attendants or with an automatic fire detection system to conform to the standards and recommendation laid down in the NBC of India 70 and to the satisfaction of the Directorate of fire services.

APPENDIX E

S.No.	Lane and Builind use	Area of parking unit in sq.metres	No.of units of parking spaces to be provided
1.	2	3	4
1. Residential			
	(a) single family House	17.5	One for every site with an area of 350sq metres and over
	(b) Apartment Flats	17.5	One for every two families.
2. Commercial:			
	(a) Shops	17.5	One for the first 200 sq.m. of floor area and one additional unit for every 100 Sq.m or part there of every 200 sq.meter.
	(b) Shopping centres	20	One for every 250sq.m of site area of part thereof.
	(c) Office and firms	20	i. For building with floor area less than 200 sq.m. ii. For building with floor and over 200 sq.m. or part there of upto 1000 sq.m. and one additional unit for every 100 sq.m. of floor area over 1000 sq.m.

(d) Restaurants	17.5	i. Restaurant with less than 50 seats - Nil
		ii. With 50 seats and over one unit for every 20 seat or parts of 20 seats.
(e) Hotels and lodges	17.5	One for every 6 beds
(f) Cinema and public halls including community hall	17.5	One for every 25 seats
(g) Kalyanamandapam etc	17.5	One for every 20sq.m of site area.
3. Ware housing and wholesale stores	40	One for every 500 sq.m of floor area or part thereof.
4. Public and semi public offices	20	i. For building with floor area less than 100 sq.m. - nil
		ii. For area of 100 sq.m and above one for every 200 sq.m. or part thereof.
5. Hospital and Nursing Home	17.5	One for every 15 beds
6. Industries	30	i. Upto 100 sq.m of floor area-Nil.
		ii. With floor area over 100 sq.m one for every 200 sq.m.
7. For other uses institution and transport and communication centres		Requirements to be assessed by commissioner in consultation with commissioner of police and Director of town Planning.

APPENDIX - I

Design Loads and other forces for design of masonry structure.

(See special rule 10(2) (d) of Multi storeyed building).

1. Dead Load
2. Live Load
3. Wind Load.

3.3. NORMAL REQUIREMENTS FOR RESIDENTIAL FLATS

The National Building code 1970 has recommends the following:

1. Plinth: The plinth area of the building shall be so located with respect to surrounding ground level that adequate drainage of the site is assured. Every interior court yard shall be raised at least 15 cm above the level of the centre of the nearest street and shall be satisfactorily drained.
2. Habitable rooms: The height of all rooms for human habitation shall not be less than 2.75 m. measured from the surface of the floor to the lowest point of ceiling (Bottom slab). The height can be reduced to 2.40 m in case the room is air conditioned. The area of the room should be not less than 9.50 sq.m. with a minimum width of 2.40m.

3. Kitchen: The area of the kitchen shall not be less than 5.50 sq.m. with a minimum width of 1.80 m. If the kitchen is used for dining also, shall have a floor area of not less than 9.50 sq.m. with a minimum width of 2.40 m.
4. Bath rooms and water closets: The height shall not be less than 2.20 m. The minimum floor area of water closet shall be 1.10 sq.m. and it should be minimum of 2.80 sq.m. if combined with bath room. A separate bath room should have minimum 1.80 sq.m. the bath room or water closet shall be so situated that at least one of its walls shall be opened to external air, should be enclosed with wall and shall be finished with smooth impervious material for height of 1.0m. above the floors. An impervious floor covering should be provided with slope towards the drain and not towards any room or varandah. The room shall not open directly into kitchen or a Cooking place by a joinery or a opening. The room accompanying water closet shall have a door completely closing the entrance to it.
5. Staircase: The minimum width should be 100cm. and width of treads without nosing can be 25 cm. Maximum height of riser shall be 19cm and should be limited to 12 per flight. Hand rails shall be provided with a minimum height of 100cms.

The external staircase used for fire escape shall have straight flight not less than 75 cm, wide with 15cm, treads and risers not more than 19cm. the number of risers per flight shall be limited to 16. The hand rails shall be not less than 100 cm height. If spiral stair case is used, then it should be connected to platforms like Balconies and terraces. The diameter of spiral staircase should be not less than 150cm.

If ramps are provided in place of staircase the slope should not be more than 1 in 10.

6. Roofs: The roof of a building shall be so constructed or framed as to permit effectual drainage of the rain water therefrom by means of sufficient rainwater pipes of adequate size, wherever required so arranged jointed and fixed as to ensure that the rain water is carried away from the building without causing dampness in any part of the walls or foundations of the building or those an adjacent building.

Rain water pipes shall be affixed to the outside of the external walls of the building or recesses or chases cut or formed in such external walls or in such other manner as may be approved by the engineer in charge.

6. Lighting and Ventilation: Opening on two opposite sides will give better day light than only on one side. The lighting will be ineffective if the effective width of the room is more than 2.50times the distance from the floor to the top of the opening and if the opening is one side. Cross lighting an adjacent walls will tend to increase the diffused lighting within a room. The glare effects can be minimised when the opening are deep.

The minimum aggregate areas of opening excluding doors inclusive of frames shall not be less than one tenth of the floor area for dry hot climate. In case the climate is wet hot, one sixth of the floor area will be required. Not portion of a room shall be assumed to be lighted if it is more than 7.50m. away from the opening assumed for lighting the portion.

Wind flows more freely entering through a smaller window and exit through a larger one. Accordingly the windows facing the direction of wind can be smaller and the ones on the opposite side larger.

Vertical windows allow more light to enter a room than a horizontal ones. Uniform spread of light can be obtained by providing two small windows than a single large window.

8. Provision for lifts: Provision for lifts shall be made for buildings more than 15.00m in height.
9. Parking space: For occupancies like multistory apartments, assembly and business buildings where large population is housed or accomodated, adequate parking space shall be provided within the building as specified by the authority.
10. Water supply arrangements: The requirements regarding water supply, drainage and sanitation for residence shall assume that a minimum water supply of 135 litres per head per day is assured together with a full flushing system.

Out of 135 litres per head per day, 45 litres per head per day can be taken for flushing requirements and the remaining for other domestic purposes. The water supply arrangements for residential flat system should be provided as per (Part IX. Plumbing services Section 1. Water supply) National building code. (Fig.3.1)

11. Drainage and Sanitation Arrangements: There should be at least one water tap and arrangement for drainage in the vicinity of each watercloset or group of water closets in all buildings.

In designing a drainage system for individual or housing colony the aim shall be to provide a system of self-cleansing conduits for the conveyance of foul, wastes, surface or subsurface waters and for the removal of such wastes speedily and efficiently to a sewer or other outlet. Typical drainage system is shown in Fig.3.2.

12. Electrification arrangements:

Recommended schedule of socket - outlets

Location	No. of 5 Amps Socket-Outlets	No. of 15 Amps Socket-Outlets
Bed Room	2 to 3	1
Living Room	2 to 3	2
Kitchen Room	1	2
Dinning Room	2	1
Garage	1	1
Refrigerator	-	1
Air conditioner	-	1
Verandah	1 per 10m ²	1
Bath Room	1	1

In all storeyed buildings irrespective of the number of floors all service connections will be effected only at the ground floor, and Electricity Boards meter, Cutout etc., will be fixed in the ground floor only with a main switch at the individual unit entrance.

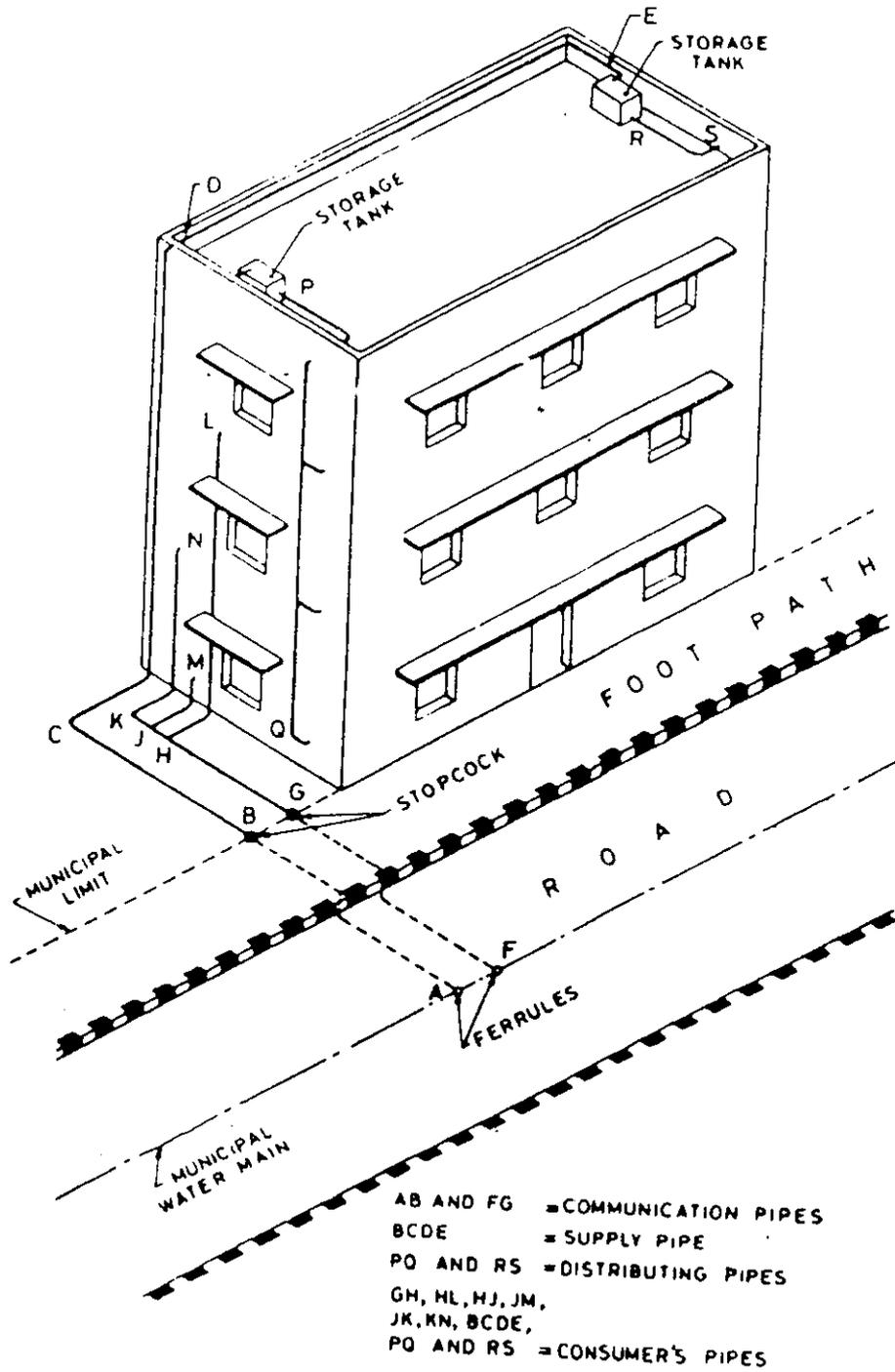


Fig. 3.1. Typical Sketch for Identification of Different Types of Water Supply Pipes

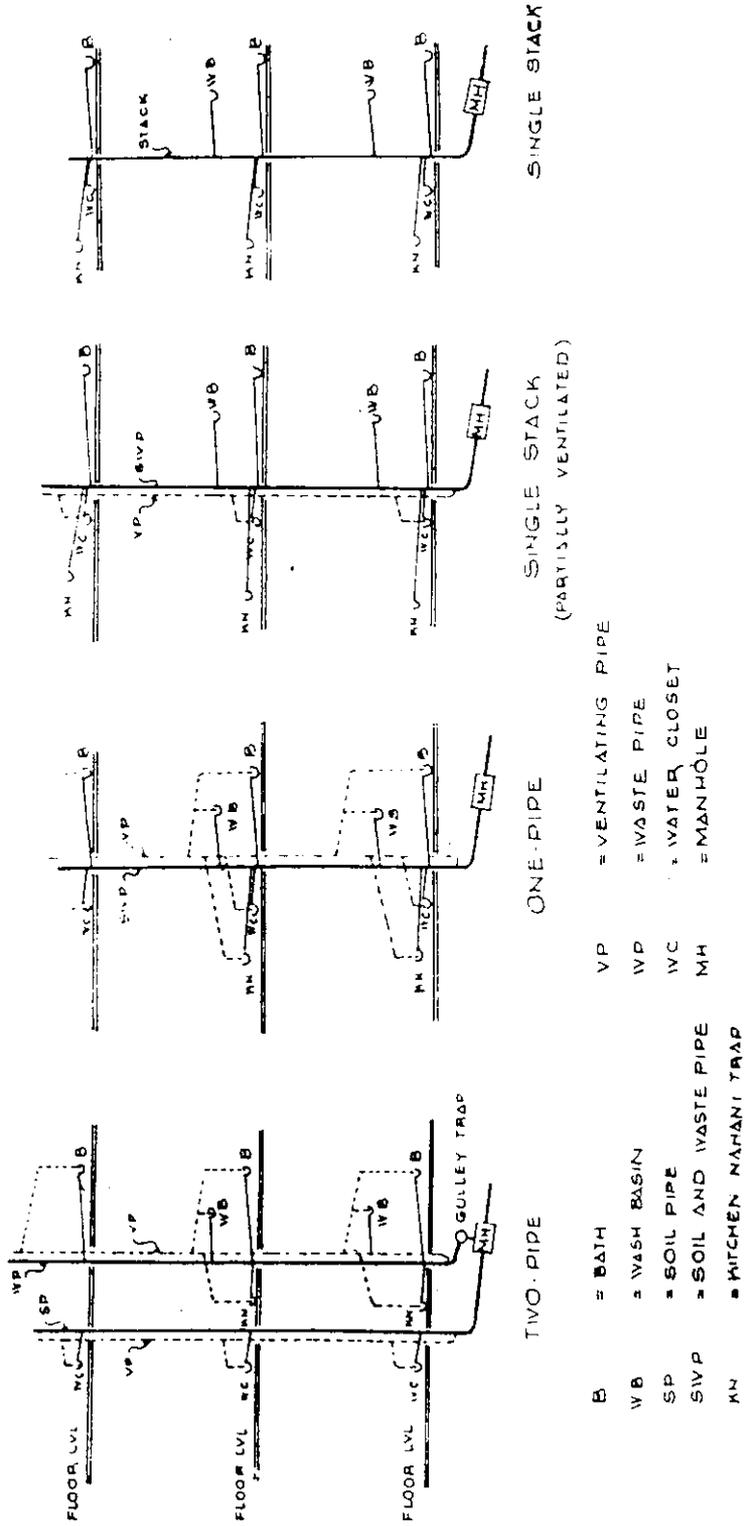


Fig. 3.2. TYPICAL DRAINAGE SYSTEM.

CHAPTER - 4
FOUNDATION SYSTEM FOR FLATS

4.1. GENERAL

For satisfactory design of foundation system for flats the following informations are necessary as per National Building Code of India.

- a. The type and conditions of the soil or rock to which the foundations transfer the loads.
- b. The general layout of the columns and load bearing walls showing the estimated loads, including moments and torques coming on the foundation units.
- c. The allowable bearing pressure of the soils
- d. The changes in ground water level, drainage and flooding condition and also the chemical conditions of the sub soil water, particularly with respect to its sulphate content and
- e. The behaviour of the buildings adjacent to the site, the type and depth of foundations and the bearing pressure assumed.

After studying the above information and ascertaining the classification and identification of soils the type of foundation system can be chosen as furnished below.

1. Simple spread foundations
2. Raft foundations and
3. Pile foundations.

4.2. SIMPLE SPREAD FOUNDATIONS

A foundation which transmit the load to the ground through footing is called spread foundation. Detailed design is not required for spread foundations for light structures, as normal requirements such as minimum width of footing specified below will generally be sufficient to bring the bearing pressure within the limit.

In Brick and stone masonry - $1/2$ Horizontal to 1 vertical

In Lime concrete - $2/3$ Horizontal to 1 vertical

In Cement concrete - 1 Horizontal to 1 vertical

However in the soils having very low bearing strengths, it may be necessary to design the width of footings. Essentially the design shall ensure the following.

- a. The pressure on the soil doesnot the exceed the allowable bearing pressure as given Table.
- b. Limitations of settlement shall be
 - i. the allowable pressures for structures on sand are generally governed only by settlement considerations. The allowable pressure shall be such tht the differential settlement does not exceed $1/300$. This condition is generally satisfied if the total settlement is limited to 50mm.

- ii. the allowable pressure on clayey soil are governed by the settlement considerations. The allowable differential settlement does not exceed 1 in 300. This condition is generally satisfied if the total settlement is limited to 75 mm.

Depth of foundation: For soils other than shrinkable clays, simple types of spread foundations shall be placed generally at a depth of not less than 50cm below finished ground level.

A spread footing is a type of shallow foundation used to transmit the load of an isolated column or that of a wall to the subsoil. This is most common type of foundation. The base of the column or wall is enlarged or spread to provided individual support for the load. Some typical spread footings are shown in Fig.4.1.

The spread foundations can be constructed using masonry and reinforced concrete according to the soil pressure and economy considerations.

4.3. RAFT FOUNDATIONS

Raft foundations or mat foundation is a combined footing continuous in two direction, covering an area equal to or greater than the base area of the building.

The raft may be analysed using the following basic assumptions.

- a. The foundation is infinitely rigid and therefore the actual deflection of the raft does not influence the pressure distribution below the raft and
- b. The soil pressure distribution is assumed to be planar such that centroid of the soil pressure coincides with the line of action of resultant force of all the loads acting on the foundations.

Ordinarily rafts are designed as reinforced concrete flat slabs. If the C.G. of the load coincides with the centroid of the raft, the upward load is regarded as a uniform pressure equal to the downward load, divided by the area of the raft. The weight of the raft is not considered in the structural design because it is assumed to be carried directly by the sub soil. Since this method does not take into account moments and shear caused by differential settlements, it is customary to reinforce the raft more heavily than required according to analysis.

The raft is subdivided into a series of continuous beam (strips) centred on the appropriate column rows. With the raft row a series of beams, the shear and moment diagrams may be established and that may be

designed. A conservative design generally results from this, since the effect of adjacent strip is neglected. the perpendicular direction is similarly analysed. The raft may also be designed as inverted slab using heavy beams from column to column. the portion between beam is then designed as conventional one or two way slab as shown in Fig.4.2.

I.S. 2950 -1981 gives the code of practice for design and construction of raft foundations. The maximum differential settlement should not exceed 40mm in foundation on clayey soils and 25mm in foundation on sandy soils. the maximum settlement should generally be limited to be following values.

- i. Raft foundation on caly : 65 to 100 mm
- ii. Raft foundation on sand : 40 to 65 mm

4.4. PILE FOUNDATIONS

Pile foundation is of different types of which the following five types only are used in building construction as per N.B.C.

1. Batter Pile (or Raker Pile): Pile which is driven in at an angle to the vertical.
- ii. End Bearing Pile: Piles with transmits the load primarily by resistance developed at its toe.

iii. Friction Pile: Piles which transmits the load primarily by friction developed along its surface. Friction piles in loose sand is some times called compaction pile.

iv. Pedastal pile: A cast in situ concret pile in which concret has been forced out into a pedastal or bulb-shape widening at its lower end.

v. Under-reamed pile: A bored pile with an enlarged base made by either cutting or scooping the soil out.

The choice of the type of pile is governed largely by the site conditions as tabulated below as per NBC.

S.No.	Site Conditions	Choice of Pile	Remarks
1.	Course sand or gravel	Driven Precast or cast in situ piles	Develops Point bearing and frictional resistance
2.	Firm stratum with soft material below	Provide enlarged base pile with piles spaced sufficiently apart.	Bearing capacity will be improved
3.	Fine sand and silt (Saturated)	Driven Cast in situ Piles	
4.	Expansive soils and poor soils of shallow depths overlying firm soil strata.	short bored piles with enlarged base	Base shall rest on stable zone.

The types of piles used as foundation for buildings are shown in Fig.4.3 Typical details of an underreamed pile is shown in Fig.4.4.

TABLE 4.1 PRESUMPTIVE SAFE BEARING CAPACITY

S.No.	Types of Rocks and Soils	Presumptive Safe Bearing Capacity (3) 2 Kg/cm ²	Remarks (4)
(1)	(2)		
A. ROCKS			
1.	Rocks (hard) without lamination and defects, for example, granite, trap and diorite	33	-
2.	Laminated rocks, for example sandstone and limestone in sound condition	16.5	-
3.	Residual deposits of shattered and broken bed rock and hard shale, cemented material	9.0	-
4.	Soft rock	4.5	-
B. NON-COHESIVE SOILS			
5.	Gravel, sand and gravel, compact and offering high resistance to penetration when excavated by tools	4.5	See Note 1

- | | | | |
|-----|---|-----|--|
| 6. | Coarse sand, compact and dry | 4.5 | Dry means that the ground water level is at a depth not less than the width of foundation below the base of the foundation |
| 7. | Medium sand, compact and dry | 2.5 | - |
| 8. | Fine sand, slit (dry lumps easily pulverized by the fingers) | 1.5 | - |
| 9. | Loose gravel or sand gravel mixture; loose coarse to medium sand, dry | 2.5 | See Note 1 |
| 10. | Fine Sand, loose and dry | 1.0 | - |

C. COHESIVE SOILS

- | | | | |
|-----|---|-----|---|
| 11. | Soft shale, hard or stiff clay in | 4.5 | This ground is susceptible to long term consolidation settlement. |
| 12. | Medium clay, readily indented with a thumb nail | 2.5 | - |
| 13. | Moist clay and sand clay mixture which can be indented with strong thumb pressure | 1.5 | - |
| 14. | Soft clay indented with moderate thumb pressure | 1.0 | - |
| 15. | Very soft clay which can be penetrated several centimeters with the thumb | 0.5 | - |

16. Black cotton soil or other shrinkable or expansive clay in dry condition (50 per cent saturation) - See Note 2. To be determined after investigation

D. PEAT

17. Peat - See Note 2 and 3. To be determined after investigation

E. MADE-UP GROUND

18. Fills or made-up ground - See Note 1 and 4. To be determined after investigation.

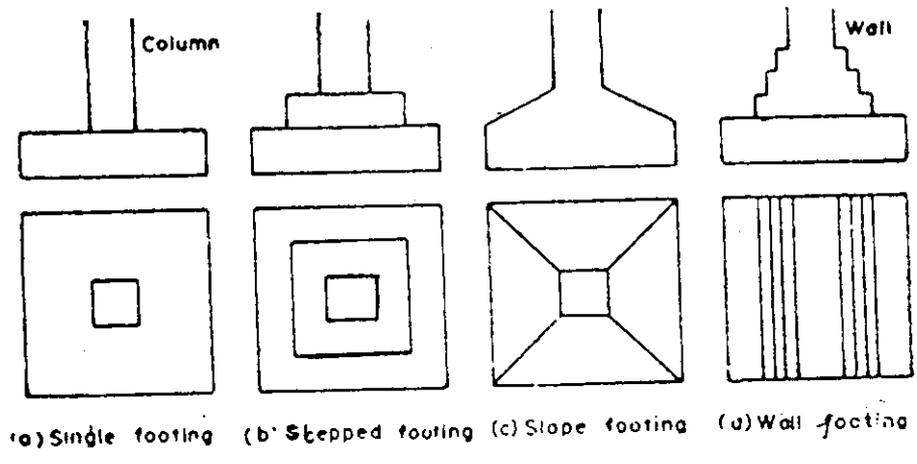


Fig. 4.1 TYPES OF SPREAD FOOTINGS

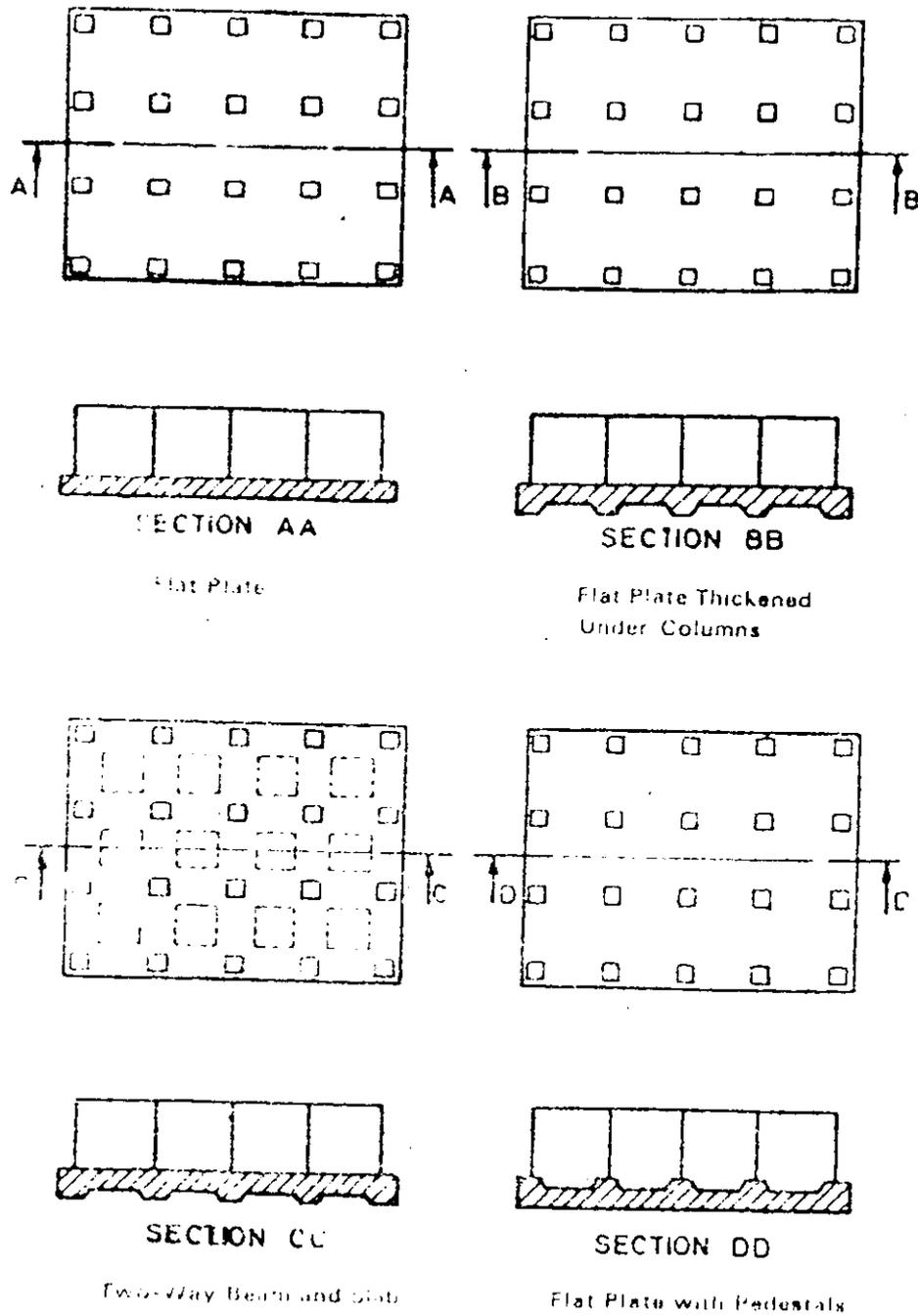


Fig. 4.2 COMMON TYPES OF RAFT FOUNDATIONS

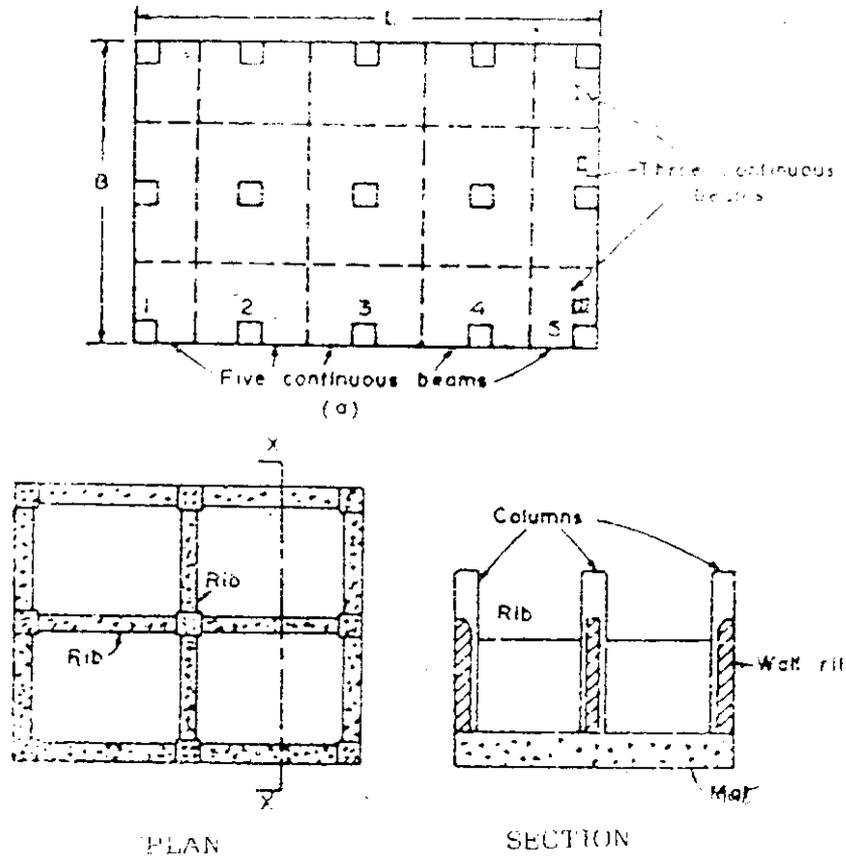


Fig. 4.3.a MAT FOUNDATION

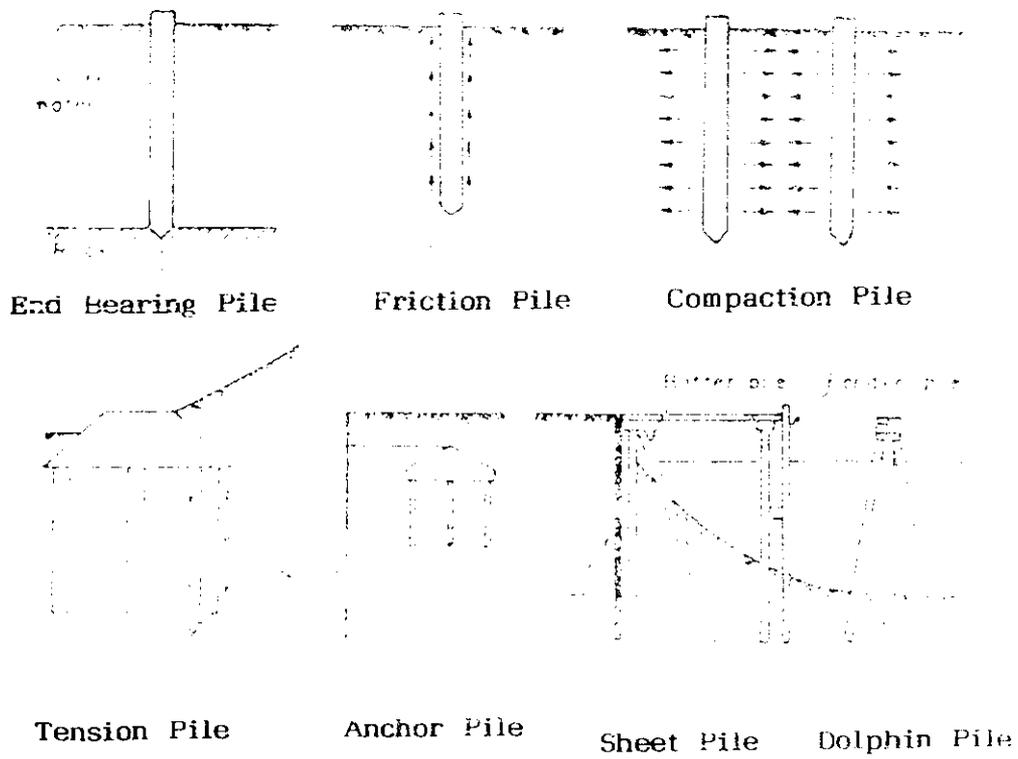
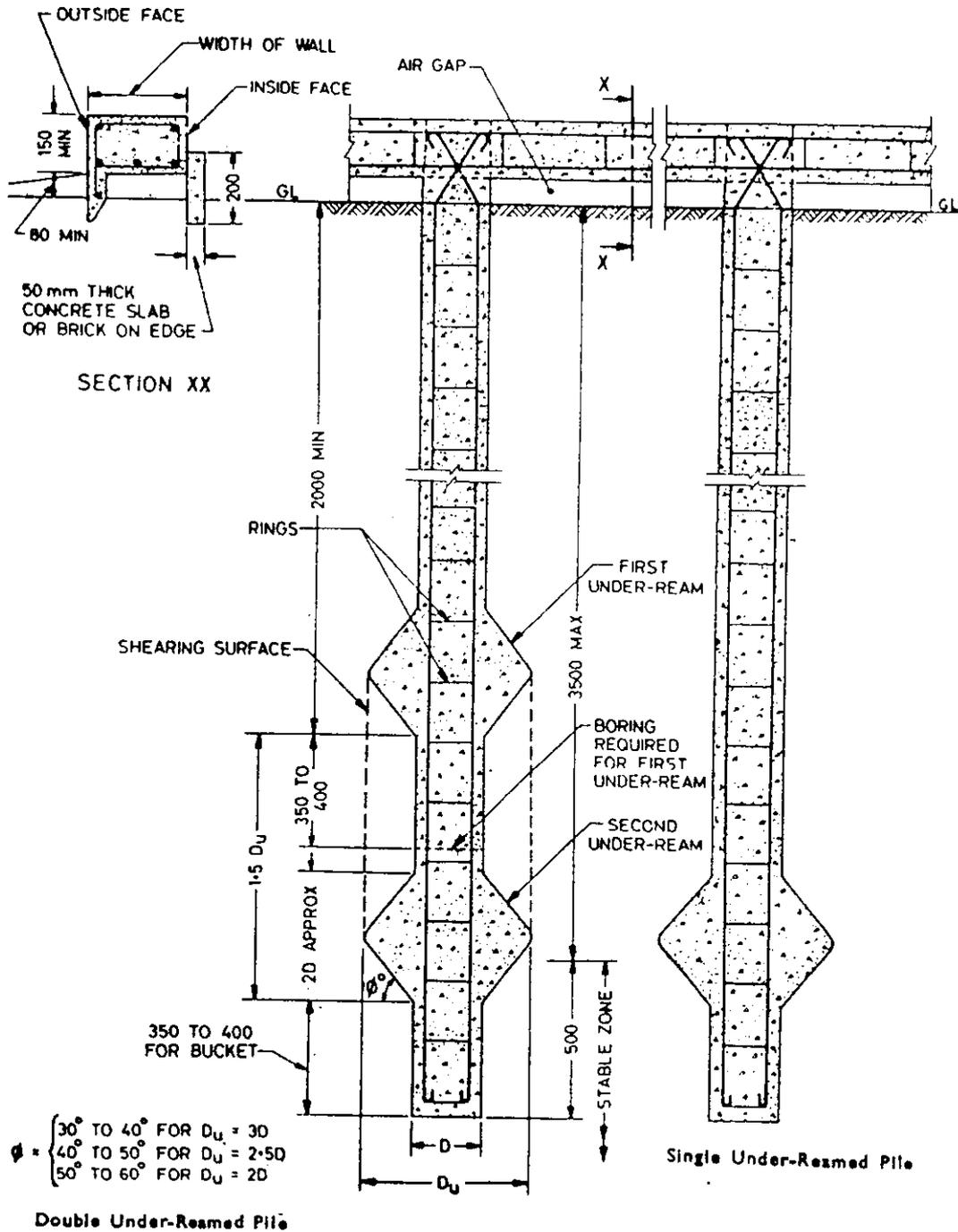


Fig. 4.3b. TYPES OF PILES



All dimensions in millimetres.

Fig. 4.4 Typical Details of Under-Reamed Pile

CHAPTER - 5

SUPER STRUCTURAL SYSTEM FOR FLATS

5.1. GENERAL

The super structure for residential flats should be finalised by the Engineer in-charge of the site depending on the site conditions and type of loading. The super structure of a residential flats may be one of the following.

1. Load bearing structure:

Load bearing walls are structurally efficient when the load is uniformly distributed and when the structure is so planned that eccentricity of loading on the wall is as small as possible.

2. Framed Structure:

In this type, the entire load of the building is transmitted to the column footing through the panel walls, floor slab and roof slab.

5.2. LOAD BEARING STRUCTURE

These are non reinforced masonry elements in buildings. Design of masonry elements is permitted both by normal structural analysis and "calculated masonry method". For the latter ready made nomograms are used to facilitate arriving at thickness of walls for different strength of

masonry, loading, spans and storey heights. Information is also available on the design features to be adopted against seismic forces.

5.2.1. Mortar: Mortar strength shall in general be not greater than that of the masonry unit; not greater than necessary in application.

5.2.2. Wall Thickness: The thickness of a load bearing wall shall be sufficient at all points to ensure that the stress due to the worst condition of loading for which the structure is designed are within the limits prescribed for that particular type of wall

5.2.3. Design method: Structural design of non reinforced masonry shall be based either on the calculated masonry method are if the requirements regarding inspection and workmanship are satisfied on the detailed structural analysis.

5.2.4. Design by calculated masonry method:

The thickness of masonry for different spans, storey heights and openings given by nomograms are worked out for the residential building are given in fig. 5.1 and 5.2. For residential building the live load can be taken as 200kg/m^2 up to six storeys height.

5.2.5. Design by Structural analysis

Design procedure: The building as a whole shall be analysed by accepted principles of mechanics to ensure safe and proper functioning in service of its component parts of relative to the whole building. All component parts of the structure shall be capable of sustaining the most adverse combinations of loads which the building may be reasonably expected to be subjected during or after erection.

The design load and other forces for the design of masonry structures shall be taken as 200kg/m^2 of floor area. The permissible compressive stresses recommended in the table 5.1. to 5.3 given below apply to masonry walls consisting of squarred units built to horizontal courses, with broken vertical joints. Permissible compressive stresses for other combinations of mortar not covered in the Table can be inter polated, which depends on (i) Eccentricity of flooring

ii. Slenderness ratio of masonry iii. Strength of masonry units iv. Mix of mortar v. C/S. area of masonry and vi. Shape factor.

5.2.6. Brick Masonry walls

Brick is the most common building material used for the construction of walls. Until recently the design of walls was based on rules of thumb rather than on any rational

basis. This produced massive structure, which due to their bulk, were uneconomical, particularly in multi-storeyed construction. However, based on the research work done in other countries, it is now possible to design brick masonry like any other structural materials. Thickness of a brick wall can be computed considering the loads acting on it.

In areas where bricks of strength of 10N/mm^2 are available it is possible to construct 4 or more storeyed residential buildings, using single brick thick (200 or 230 mm) walls in all floors. The designed Brick masonry concept in case of a 4 storeyed building gives a saving of above 20 percent in materials and cost of the wall and increase the usable area of rooms by about ten percent compared to the walls designed by rule of thumb. A number of 4 and 5 storeyed residential flats building have been constructed in our country, using single brick thick walls. In Tamil Nadu all the housing corporation are using only single brick walls up to 3 floors for residential flats.

5.2.7. Typical Design of Load Bearing wall

For type D2 (For M.I.G. Group)

Select the most Critical wall (Central wall between two living Rooms)

Let the wall thickness be 230mm

Consider a wall width of 1.0m

Loads:

$$\begin{aligned} \text{a. Self weight of wall} &= 3(1.0\text{m} \times 0.23 \times 2.75) \times 1800 \text{ kg/m}^3 \\ &= 3416\text{kg}. \end{aligned}$$

$$\begin{aligned} \text{b. Dead weight of floor and roof slab} &= 3[0.12 \times 1.0\text{m} (4+0.23\text{m})] \times 2400 \text{ kg/m}^3 \\ &= 3655 \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{c. Live load of floor slab} &= 2 \times 1.00\text{m} (4\text{m}) \times 200 \text{ kg/m}^2 \\ &= 1600 \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{d. Live load of roof slab} &= 1.00\text{m} (4\text{m}) \times 150 \text{ kg/m}^2 \\ &= 600 \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{e. Roof finish} &= 1.00\text{m} (4\text{m}) \times 75 \text{ kg/m}^2 \\ &= 300 \text{ kg} \end{aligned}$$

$$\begin{array}{r} \text{Total load} \\ \hline 9571 \text{ kg} \\ \hline \end{array}$$

Compressive stress developed at the base of the wall

$$= \frac{9571}{23 \times 100} = 4.16 \text{ kg/cm}^2 = 0.416 \text{ N/mm}^2$$

Assuming a burnt brick strength of 5.00 N/mm^2 and the wall is built in C.M.1:5 construction

$$\begin{aligned} \text{Basic compressive in masonry} &= B = 0.50 \text{ N/mm}^2 \\ &\text{(from NBC code)} \end{aligned}$$

$$\text{Clear Wall height} = 2.75\text{m}$$

$$\text{Effective wall height} = 0.75 \times 2.75 = 2.06\text{m}$$

$$\text{Slenderness ratio} = 2.06 / 0.23\text{m} = 8.96$$

$$\begin{aligned} \text{Stress reduction factor for slenderness} & \\ \text{ratio} & \quad K_s = 0.85 \quad \text{(from Table)} \end{aligned}$$

Stress reduction factor for Zero eccentricity $= K_e = 1.0$

Permissible compressive stress in the wall $= B \times K_s \times K_e$
 $= 5.00 \times 0.85 \times 1.00$
 $= 0.425 \text{ N/mm}^2$

This is greater than 0.416 n/mm^2

Hence O.K.

Adopt wall thickness of 230mm in cement mortar 1:5.

5.3. FRAMED STRUCTURE

5.3.1. R.C.C. Framed Structure

The RCC framed structures have made it possible to construct taller buildings. In the framed structure the internal and external walls serve only the purpose of enclosures for creation of rooms and protection from weather. The RC framed structure can be used for residential buildings, where the load bearing foundation cost differs very much.

In RC framed structure for residential buildings the width has to be restricted to 22.50 cm. to 30cms. to prevent excessive projection in the rooms. In our country M15 concrete is used for columns and beams (15N/mm^2) for residential framed structure to 3 floors. In developed countries in order to reduce the percentage of steel rich mix concrete M35 to M40 is adopted for multi-storeyed

buildings. This is mainly due to strict quality control and skilled supervision. The concrete mix is controlled as to gradation and workability.

The central PWD has adopted RCC framed structure with brick panel walls for residential flats constructed at the Forest college campus, Coimbatore.

5.3.2. Precast Framed Construction

In this system, the different components of the structure such as columns, beams, flooring/roofing units in parts or in combination are precast. The infill walls can also be precast. In this case the construction can proceed at a faster rate.

The frame must be subdivided into separate elements. This subdivision is influenced by the general arrangement and shape of the frame. As a rule, the girders are subdivided into straight units fit between the faces of the columns, the columns in their turn being divided into corresponding lengths that are jointed at sections, somewhat above the level of the floor. Under combined vertical and horizontal loads the points of contraflexure are in the lower one third of storey height and hence the joints can be made in this portion. If live load of the floor is high column are designed with brackets. Column components can be made two or more storeys in height; if allowed by weight and

length. Under certain condition and circumstances, girders with projection, cross shaped coloumns etc. may be provided. Some of the other schemes may comprise of two span beams and single storey columns, two storey columns and two span beams or precast columns with composite beams.

Precast framed construction is used widely in the developed countries for the construction of residential buildings hopsital, school, office and commerical buildings. The components are mostly produced in steel moulds in the factories and steam cured for high turn over. They are trnsported to the sites in trucks and erected using cranes. The joints are usually welded. The infill wall panels are of precast dense or light weight concrete or made in situ with concrete blocks or bricks.

In India also precast framed construction has been done on a limited scale. A few thousands of 4 storeyed houses have been built up at Delhi by Hindustan Prefab limited using precast framed construction. The types of framed buildings designated M1 and M2 are adopted by HPL. The basic difference between the two is that while in Type M1, the Cross Beams act as main beams, in Type M2, the longitudinal beams act as main beams with corsss beams as stiffeners.

In Both the schemes, two storey high precast reinforced concrete columns and prestressed concrete l-beams are Used. The stair cases and door and window frames are also precast. The infill walls are built insitu with bricks. The components are precast at factory, steam cured and transpored to the construction site in trucks. Errection is done with derrick cranes.

Another Indian Firm uses a precast framed construction with hollow RCC column and partially precast beams. The floor/roof slab are made of reinforced light weight concrete and the filler walls are made of hollow concret blocks.

5.4. FLOOR SYSTEMS

5.4.1. GENERAL

Floor divide a building into different levels, one above the other for the purpose of creating accomodation within restricted space. The bottom most floor of a building above the ground level is called the ground floor. It provides an impervious and durable surface for performing the activities and to support the furniture, equipments etc., The top floors, in addition to the above objectives have to be sufficiently strong so as to transfer the loads to their supporting structure. The selction of a suitable type of construction for upper floors of a building depends upon a number of factors, such as floor loads, size and

shape of the floor, availability of construction materials availability of skilled labour and equipment, initial cost of construction, maintenance cost etc. Some of the types of floors used in the construction of buildings are

1. Wooden floors resting on wooden joists
2. Flagstone floors resting on steel joists
3. Jack arch floor of brick or concrete
4. Hollow tile ribbed floors
5. Reinforced cement concrete floors
6. Prefabricated flooring/roofing schemes.

Among the above types of floors the following types of floor/roofing systems are adopted for the residential buildings.

1. Reinforced cement concrete floors
2. Prefabricated roofing schemes

The Private flat/apartment promoters are executing the reinforced concrete floors/slab only in their construction due to urgency aesthetic and false ceiling finishes etc. The Tamil Nadu Housing Board is using both the above two systems of floors in their construction depending upon the availability of funds, systems of housing and site conditions.

5.4.2. Reinforced cement concrete floors

RCC slabs are the most widely used structural elements forming floors and roofs of buildings for supporting loads normal to its surface. It may be supported on walls or beams or directly on the columns as shown in fig. 5.3. The beams supporting the slabs are considered stiff with deflection relatively very small as compared to that of slab. Usually slabs are rectangular in shape, but it can be of any shape. The loads are transferred from slab by flexure, shear and torsion to the support.

Slab supported on two parallel sides, Fig.5.3. Carry loads by bending in the direction perpendicular to the supports. Such slab are known as one way slab and are virtually shallow beams with large width. Slab supports on four sides behave as one way slab if the length is very large as compared to the width of slab.

Rectangular slab with length not very large as compared to its width or square slabs supported on four sides carry loads by bending in two perpendicular direction. Such slab are known as two way slab (Fig.5.3.) Triangular or Trapezoidal slab supported on all sides have usually two way slab action. Slabs supported on two adjacent sides have also two way slab action. Slab supported directly on the columns without beams are known as flatslabs (Fig.

5.4). In such such slab large bending moment and shear forces are induced in the vicinity of columns. Therefore the columns are flared at the top, called column head or capital and slabs are thickened surrounding the column capital called drops, for reducing the stresses due to shear and flexure.

Since slabs are highly indeterminate, its elastic analysis is complex. The use of finite difference and finite element methods for analysis is helpful for slab with complex loading and boundary conditions. The yield line theory and strips methods are used for determining the collapse load. The deflection and cracking of slab are important design considerations since they affect the appearance and performance of slabs. Usually the depth of slab is governed by the serviceability requirement of deflection than by the strength of slab.

Slabs in multistorey buildings also act as deep horizontal girders to resist wind and earthquake forces in addition to supporting normal loads on its surface. Slab acting as rigid diaphragm of large stiffness reduces lateral deformation of multistorey frames.

The RCC slabs may be designed as one way slab or two way slab depends on the support conditions and short and long span dimensions. If the long and short span ratio

exceeds 2, the slab may be designed as one way slab. If the ratio is less than 2 the slab may be designed as two way slab.

The design of slab is made to satisfy both serviceability and strength requirements. The serviceability requirement for deflection is controlled by effective span to effective depth ratio. Generally, the depth of slab is small and is governed by the serviceability requirement for deflection. The serviceability requirement for crack is controlled by the spacing of reinforcement. Usually, the spacing of reinforcement is smaller than the maximum spacing for crack control. The reinforcement is provided to satisfy strength requirements. The design of reinforcement is made for maximum bending moments.

The imposed live load on floors due to use and occupancy is given below vide Table 5.4 of I.S. 875 (Part 2) -1987 for residential buildings.

The imposed live load on different types of roofs are given below vide Table 5.5 of IS. 875 (Part 2)-1987.

5.4.3. Prefabricated roofing systems

Prefabricated roofing systems are being done using concrete, bricks, structural clay products, ferrocement etc.

5.4.3.1. Thin R.C. Ribbed Slab for Floors and Roofs

Thin R.C. ribbed slab consists of precast R.C. ribs 110 mm x 200 mm provided at a spacing upto 1.2m C/C with 50mm thick cast-insitu R.C. flange above. It can be used for floors and flat as well as sloping roofs in single and multistoreyed residential and other types of lightly loaded buildings.

The precast ribs are designed to act as rectangular beams during the construction to support the weight of concrete in the flange, the shuttering and the live load of workmen and equipment. The ribs along with the flange are designed to act as Tee beams for the full design loads, after the concrete in the flange has attained strength. The flange is designed as continuous slabs spanning over the ribs. To ensure monolithic action of precast ribs with cast-in-situ flange, stirrups in the ribs are kept projected into the cast-in-situ concrete of the flange.

CONSTRUCTION

The ribs are precast in steel/timber moulds with concrete of grade M 15. To provide holes in the ribs, 25 mm square M.S. hollow box sections are inserted through square holes in the longitudinal members of the mould before casting. The precast ribs, after curing and drying, are placed in 115 mm wide recesses in the wall at the specified spacing. Plain simple shuttering panels made of

timber framing and plywood panneling covered with G.T. sheets are used for casting the flange portion. The length of shuttering panels are kept in modules of 300mm and the width of the panel is kept as the clear distance between the ribs. The panels are kept supported on wooden battens resting on 20 mm sq. M.S. bars projecting out of holes left in the precast ribs. After placing the reinforcement cage at the middle of the flange thickness, M 15 concrete with 12 mm and down graded coarse aggregate is laid and compacted to a thickness of 50 mm by a plate vibrator. The shuttering panels can be removed and reused after three days. Fittings and fixtures like fanhooks, electrical junction boxes, conduits etc. should be preplanned and provided in the precast ribs or over them. As the thickness of ribbed slab is only 50 mm, for better thermal insulation, roof treatment should be provided over the slab. In case the construction of ribbed slab floor/roof with precast ribs and ready made shuttering panels is not possible due to some reason or other, the construction of ribbed slab maybe done with the traditional shuttering. In such cases, the ribs need not be designed as rectangular beams to carry the load at the construction stage. They should be designed as 'Tee' beams for the final stage of loading. However with the use of traditional shuttering, overall cost of construction will be more than that with precast ribs and ready made shuttering.

Compared to conventional in-situ RC slabs, use of thin precast ribbed slabs will result in a saving of 26 to 47 per cent in concrete, 4 to 14 per cent in steel and 22 to 30 per cent in overall cost of construction. Thus RC ribbed slab scheme is ideally suited for repetitive type of construction of floors and roofs for low cost houses and other buildings.

5.4.3.2. Prefabricated Construction

In India and other developing countries, to accommodate the spiralling population, there is a need to construct more and more houses, and other buildings at a faster speed. Traditional insitu construction is too slow to cope up with this ever increasing demand. By prefabrication, better quality buildings can be constructed at a faster rate.

Most of the European countries and U.S.A. have set up efficient concrete industries with large scale mechanisation of precasting operations and site erection. The introduction of large panel and other techniques by these countries has revolutionised the building industry and an unprecedented rate of construction has been achieved. Prefabrication has made considerable headway in countries like U.S.S.R., Poland, Hungary, Germany and Sweden. In Asia, Japan, Hongkon and Singapore has made progress in this direction. Prefabrication has made only a beginning in India. For prefabrication to become a success, the people

connected with work, viz, the Architects, Engineers and Contractors will have to reorient themselves to adjust for the same. Thus, plans will have to be made more streamlined. Modular coordination leading to standardisation is must for the success of prefabricated construction. To attain the advantages involved in mass production, the building construction should be planned in such a way that there is demand for standardised building components over a long period of time. With such measures, prefabrication can become popular and economical in the country. The advantages of prefabrication are discussed below:

1. In prefabricated construction, as self supporting readymade components are used, shuttering and scaffolding are eliminated completely or to a great extent. Apart from saving in the cost of shuttering, elimination of props gives clear space for other building activities such as installation of building services and finishes to be done immediately after the floor above is constructed.
2. In the traditional construction, the shuttering can be used only a few times, as the damage to shuttering is more and as it involves cutting of planks and props every time. On the other hand, the moulds for precast

components can be used a large number of times. For example, the timber moulds can be reused at least 100 times and the metal moulds, 1000 times or more. As the reuse of mould is more, the cost of mould per precast unit is less.

3. Compared to insitu construction, it is easier to produce components with structurally efficient shapes in precast construction. Hence, the consumption of scarce materials like cement and steel can be reduced.
4. In precast construction, same type of components are produced again and again. This will result in increased productivity and economy in cost.
5. In case the production is done in factories or at site under covered sheds, production can be done independent of the weather conditions. Thus components can be produced even during rainy season or when the climate is extreme.
6. It is possible to produce the components under close supervision and to test them periodically. Hence the products will be of better quality and more reliable.
7. In prefab, construction, the work at site is reduced to the minimum and the work site will be clean.

8. By adopting precasting techniques, the construction is speeded up.
9. As the buildings are completed faster, they can be occupied earlier. this will means early return of the capital invested.
10. In cases of prefabricated construction, as the precast components have undergone most of the shrinkage before they are used in the construction, the stresses due to shrinkage on the structure are much less compared to insitu construction.

However, prefabricated constructions have certain disadvantages also as metntion below

1. To ensure monolithicity and to take care of free ended conditions, more reinforcement may be necessary in some cases.
2. In case handling and erection stresses are excessive, extra reinforcement may be needed.
3. To avoid damage and breakage, special care is needed in handling annd erection.
4. Temporary supports may be necessary in some cases, before the insitu joints attain strength.

5. Unless adequate quantity reinforcement is provided across the joints between precast components and insitu concrete or other precautionary measures taken cracks may develop at the joints between precast components and insitu concrete.
6. As there is chance of leakage/seepage through the joints between precast components, extra care should be taken to make them leadproof.

No precast component can be manufactured exactly to the stipulated dimensions, nor can be erected in its notional space. Hence, some degree of deviation has to be tolerated both in production as well as assembly of the components. The range of deviation with respect to design dimension of a component is known as tolerance limit. Inaccuracies in dimensions may be due to manufacturing errors, positional inaccuracies, dimensional changes subsequent to erection or other factors. Inadequate mould design and use of inferior and short life moulds appear to be the most significant factors influencing dimensional accuracy during manufacture. Materials used, mix proportion, nature of compaction and degree of supervision can also cause dimensional deviation. At construction site, dimensional inaccuracies could occur, while transferring measurements and datum points and while positioning and assembling the

components or by the use of inaccurate instruments or lack of any systematic approach to setting out and transfer of measurements. After erection dimensional changes may occur due to inherent material properties or due to loads, settlement of soil etc. National Building Code of India has specified the following tolerances for precast components.

1. Length: Plus/minus 10mm or plus/minus 0.1 percent, whichever is greater.
2. Cross sectional dimensions: Plus/minus 3 mm or plus/minus 0.1 per cent of the dimension, whichever is greater.
3. Straightness or bow (deviation from the intended line or plane): Plus/minus 5mm or 1 in 750 of the measured length, whichever is greater.
4. Squareness: When considering the squareness of a corner, the longer of the two adjacent sides being checked should be taken as the base line. The shorter side should not vary in its distance from a perpendicular, so that the difference between the greatest and the shortest dimensions exceed 5mm.
5. Twist: Any corner should not be more than the tolerance limit stated below, from the plane containing the other three corners.

saving of about 20 per cent in voerall construction time.

Considering the equipment normally available at site for handling and erection of components, the size and weight of the components have to be kept small. The width of the components have been kept as 300, 600 or 900 mm, the length upto 4.2. m and the weight upto 200 kg, so that they can be erected manually or with light equipment, even in the case of multistoreyed buildings.

In a building, about sixty five percent of the cost of construction goes to materials. The shape of the components can be chosen to have maximum saving in materials without loosing the structural efficiency. for example, concrete near or below the neutral axis which as not stressed to the full extent can be eliminated, resulting in components having through shaped, L shaped or hollow cross sections. By giving such shapes, the weight of the component is reduced and their handling and erection become easy. The reduction of self weight also results in saving in supporting structures like beams, walls and foundation.

For short spans and light loads, reinforced concrete components are suitable, while for longer span and heavier loads, prestressed components are advisable.

Labour intensive schemes are preferable in developing countries due to easy availability of labour and social demand for providing employment. The precast schemes developed are labour-intensive.

Considering bottlenecks in transporting the precast components over long distances and other factors, a system of casting the components at site of construction or at a centralised location in case of small constructions spread over a number of sites, is preferable in Indian conditions compared to factory production.

Some of the flooring/roofing schemes developed in this country are discussed in this chapter.

5.4.3.3. Precast R.C. Channel Unit Flooring/Roofing Scheme

Precast R.C. channel unit is a reinforced concrete element, through shaped in section. The units are 300/600 mm wide, 150/200 mm deep with a flange thickness of 30/35 mm. The length of unit may be kept to suit the span to be covered, but is generally kept between 2.5 to 4.2 m. Corrugations are provided on the sides of the unit to ensure that the floor/roof acts monolithic after the concrete grouted in the joints between the units attains strength. Normally structural deck concrete is provided over the units. Channel unit floor/roof has a ribbed ceiling.



The precast flooring/roofing scheme is designed considering various stage of loading and support conditions. In the first stage, the units should be checked for handling stresses considering the permissible stresses in concrete at the time of handling. At the stage of laying, the units should be designed as simply supported elements for the self weight, the weight of concrete in the joints between the units and live load during construction. In the final stage, the floor/roof is designed as continuous or single spans for the load coming after the insitu concrete has attained strength.

The units are cast manually in timber/steel moulds on levelled concrete casting platform. Concrete of grade M 15 with 10mm and down graded coarse aggregate is used and is compacted using a plate vibrator. The units are demoulded about 3 hours after casting. They are cured for two days at the casting platform itself by covering them with wet gunny bags. The units are then transported to the curing yard, stacked and cured by ponding water in the troughs. The units are water cured for two weeks and allowed to air dry for another two weeks. Once the super-structure has reached the floor/- roof level, the precast units are lifted up manually or with the help of chain pulley blocks or light hoists and placed side by side across the span to be covered. After aligning and levelling the units,

reinforcement for taking negative moments at supports are placed in the joints between the units. The joints are filled up with concrete and cured properly. On the joints between the units in the ceiling, 1:4 cement:sand mortar is applied with the help of a piece of wet gunny bag, filling all the linear joints and finishing them with deep rules lines for better appearance. Electric conduits, junction boxes etc. could be embedded in the cast insitu concrete of the joints. Fan hooks can also be kept in the joints by slight chipping of the edge of the unit. For short cantilever projections in the same direction as the length of units, the unit itself can be kept projected out by properly designing them. Alternatively the cantilever is cast insitu with the reinforcement from the units or from the joints between the units kept projecting out. Cantilever across the span can be provided by projecting the beam supporting the units and then placing channel units over the projected beams.

Use of channel unit floor/roof will result in a saving of 35 per cent in concrete, 5 per cent in steel, 20 per cent in overall cost and 20 per cent construction time compared conventional construction with insitu RCC slab.

5.4.3.4. Precast R.C. Cored Unit Flooring/Roofing Scheme

Precast RC cored unit reinforced concrete units 300/600 mm wide, 130/150 mm thick and upto 4.2 m in length having two circular hollows of 90mm diameter. The unit is structurally complete by itself and does not require any type of temporary support or propping during construction. It provides a flush ceiling. It can be used for floors and roofs in load bearing walls and framed structures. No deck concrete is required in this scheme. The corrugations on the sides of the unit, when filled with insitu concrete develop monolithicity and help in transferring the load transversely.

The units are cast manually in timber/steel moulds G.I. pipes are used to form the hollows in the units. A bond release agent is applied on the surface of the pipe and the sides of the mould coming in contact with concrete. During casting, the pipes are rotated a few times so as to break the bond between concrete and the pipes. About half an hour after casting, the pipes are withdrawn by rotating them radially and pulling out axially after providing support to see that the pipes remain in level. The mould is dismantled about 4 hours after casting.

The units can also be cast by a mechanised process using pressure-cum-vibration technique. The set-up consists

of steel moulds, G.I. pipes with high frequency vibrators fixed inside the pipes, mechanical winch for pulling the pipes, a fixed gantry to handle the unit and the dead weight used for applying pressure the mould along with the reinforcement cage is placed on the casting platform and the pipes, which are mounted on a trolley moving on rails, are introduced into it. An initial charge of concrete is poured into the mould and the pipes are vibrated making the concrete flow around the pipes to the soffit of the unit. An additional charge of concrete is then added and a reinforced concrete beam is placed over the concrete to apply the dead weight. The vibrations of the pipes at this stage effect full compaction of the concrete. After the vibrations are stopped, the pipes are withdrawn by the winches. The dead weight is then removed with the help of a hoist slug from the gantry. The cast unit along with the mould and the bottom pallet is then transferred to a trolley and transported to curing beds. The sides of moulds are stripped after two to three hours and the bottom pallets are removed the next day. the units are stacked on over the other upto 5 units in height and cured by sprinkling water.

The construction is done similar to construction with precast RC channel units. The channel units. The scheme provides a flush ceiling. Compared to insitu RCC slabs, use of cored unit floor/roof will result in a saving of

about 20 per cent in concrete, 4 per cent in steel and 15 per cent in over all cost. The construction time will also be reduced by about 20 per cent.

5.4.3.5. Precast R.C. Plank Flooring/Roofing Scheme

The scheme consists of precast RC planks supported over partially precast R.C. joists. To provide for Tee - beam effect with the joist, the plank is made partly 30 mm and partly 60 mm thick. A 100 mm wide tapered concrete fillet is provided for strengthening the haunch portion during handling and erection. The planks are 300 mm wide with a maximum length of 1.5 m. They are made of concrete of grade M 15 and are reinforced with 3 numbers 6 mm dia M.S. bars along the span and 6 mm dia. M.S. bars at 200 mm C/C across the span. The partially precast joists are 150mm wide and 150mm deep with stirrups projecting out on the top side. Simple timber/steel moulds can be used for casting the planks and joists.

During the construction, the joists are first erected and propped at mid span. 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 the planks and finished level. After the insitu concrete has attained strength, the props are removed. No structural deck concrete is provided over the planks. the scheme provides a ribbed ceiling.

The R.C. planks are designed as simply supported for self weight including insitu concrete in haunches and as continuous slab for live load and dead load of floor finishing or water proofing treatment. For continuity, reinforcement to take negative moments are provided over the haunch portion of the planks at their supports. The partially precast RC joists, in general, are to be designed as simply supported Tee-beams with R.C. planks. In case of continuous spans, the joists are designed as continuous beams and reinforcement of joists of adjacent spans are welded together. Reinforcement to take negative moments are provided in the insitu concrete over the joists.

Compared to conventional RC slabs, use of precast RC plank flooring/roofing schemes will result in a saving of about 14 per cent in steel, 27 per cent in concrete and 21 per cent in over all cost. Because of prefabrication, the construction time of floor/roof is reduced by about 20 per cent.

5.4.3.6. Precast Joist and Filler Block Construction for Floors and Roofs

Floor and roof construction using precast reinforced or prestressed concrete joists and hollow cement concrete filler blocks is advantageous because of their durability, fire resistance, thermal insulation, lower dead load and

higher speed of construction. The construction is simple and quick and also eliminates use of shuttering. However this type of construction is not recommended where the floor is subjected to heavy impact loads or vibration and to constant wetting as in bath rooms etc. The floor/roof consists of precast reinforced/prestressed concrete joists spaced at about 600mm C/C and precast cement concrete hollow blocks laid over in the space between the precast R.C. joists with reinforced deck concrete provided over it. For normal residential spans, reinforced concrete joists can be used while for longer spans or heavier loads, prestressed concrete joists are used. The joists are designed as Tee-beam with the structural deck concrete acting as the flange of the beams.

The precast joists are about 150mm wide and 150/200 mm deep depending upon the spans and loads. The joists are cast preferably in steel mould over a concrete casting platform. The concrete used is of grade M 20 and is compacted using needle vibrators. The stirrups are left projecting out of the joist to provide composite action with the deck concrete. The sides of mould can be released a few hours after casting. The joist should be kept covered with wet gunny bags for 2 to 3 days at the casting platform itself, before transporting them to the curing yard. The joists are water cured for one week and

air dried for another three weeks before using them in the construction. The precast hollow cement concrete block have a wall thickness not less than 25 mm, a length of about 600 mm and width depending upon the spacing of the joists. The blocks can be made of lean cement concrete or cement mortar.

The joists are provided over supporting beams/walls at the specified spacing. Concrete bed block may be provided over load bearing walls, where necessary. The joists are supported at middle third points for atleast 7 days after laying the concrete. The joists are provided with a minimum bearing of 75 mm over the walls and should be aligned and levelled properly. The hollow blocks are placed in between the joists in such a way that they get a minimum bearing of 25 mm over the joists. Nominal reinforcement with spacing not exceeding 300 mm should be provided over the joists and blocks to take the shrinkage and temperature stresses. In case the joists are designed as continuous, reinforcement to take negative moment should be provided over the joists at the supports. The deck concrete may be of grade M 15 or higher, and should be laid to a thickness of 50mm and compacted preferably with plate vibrator.

5.4.4. Economical Floor System for Multi-Storey Residential Buildings

Concrete is the predominant choice for floor and roof systems in multi-story residential construction because of its inherent benefits over other materials. These benefits include fire transmission control, energy conservation, sound transmission control, and economy. Several types of cast-in-place concrete floor systems are in current use, each with different structural costs and economical span length.

Types of slab systems

The cost of the floor system is often the major part of the overall structural cost of building. This is especially the case for buildings of low or medium heights and for buildings in zones of low seismicity or wind loads, since the additional cost of resistance to lateral forces is minimal to non-existent. Thus, economical building costs are dependent on the selection of the most cost efficient floor system.

The flat plate system (Fig.5.7) is concrete slab directly supported on columns, without any interior column-line beams, and with steel reinforcing in two orthogonal directions. The flat plate has the advantage of low forming costs and a flat ceiling, which reduces ceiling finishing costs. Even more important, low story heights are made

possible by the shallow slab system, which amounts to significant savings in the costs of cladding, piping, telephone and electric cables, and so on. In cases where the total building height may be restricted, the shallow story height would translate into a larger number of stories in the building.

The flat slab (Fig. 5.7) is similar to the flat plate, but has locally thickened portions, called drop panels, around the columns to accommodate high punching shear stresses caused by long slab spans and/or heavy loads on the slab. The drop panels increase formwork costs, but provide a relatively shallow slab system in situations where the shear stresses preclude the use of a flat plate.

A two-way joist system (Fig. 5.7) consists of evenly spaced concrete joists spanning in both directions. A one-way joist system (Fig. 5.7) is similar, except that the joists only span in one direction. In both systems, a reinforced concrete slab is cast integral with the joists to form a monolithic floor system. Two-way and one-way joist systems give very rigid floors. These floor systems are able to span long distances with acceptable deflections, and they also minimize floor vibrations. The disadvantage of these systems is their high formwork cost.

Slab thickness

The thickness of the slabs and the depth of the beams is controlled by deflection limitations and fire rating requirements. Requirements for controlling deflections are given in Section 9.5 of the ACI Building Code. This section prescribes a minimum thickness for floors to be able to provide rigid systems with acceptable deflections. Minimum thickness code requirements are given in Table 5.6 for one-way systems and by equations through Table 5.6 and for two-way systems. Floor systems with Grade 60 steel and continuous construction have a required minimum thickness ranging from 1/20th of the clear span for one-way construction to 1/36th of the longer clear span for two-way slabs with drop panels. It should be noted that the minimum thickness requirements are independent of concrete strength. They are also independent of slab loading, and are largely independent of restraints at the supports.

Floor systems must be designed for live loads, superimposed dead loads, and the floor weight. Live loads for residential dwelling units are 40 psf (1900 Pa) under all three of the model codes (BOCA/NBC, SBC, and UBC). Superimposed dead loads typically used are 10, 15, or 20 psf (480, 720, or 960 Pa). A live load of 50 psf (2400 Pa) and a superimposed dead load of 20 psf (960 Pa) was used for the current investigation. The slightly larger live load was

used to account for corridors, as well staircase and elevator landings.

Slab thickness based on fire resistance criteria is a function of the hourly rating required by the governing building code and the concrete aggregate type. Required fire resistance ratings for floors range between one and two hours depending on which code is used. These hourly ratings result in minimum slab thicknesses between 3.5 and 5.0 in (89 and 130mm) for siliceous aggregate and 3.2 and 4.6 in. (81 and 120 mm) for carbonaceous aggregate. In nearly all cases, the minimum thickness required for flat slabs and flat palates exceeds 5 in. (130mm) in fact, 5 in. [130 mm]) is the absolute minimum thickness for a flat plate prescribed by ACI 318-89, unless computations are made to show that deflections are made to show that deflections are within tolerable limits); thus the fire resistance requirements are easily met. For two-way and one-way joists, because the slab span short distances, the fire resistance requirements will control the slab thickness.

Cost Comparison

The relative costs of each floor system include all material and labour for the concrete, reinforcing steel, and formwork (Fig. 5.6). Architectural finishes for the underside of the floor are not included. These expennses vary greatly, depending on the type of finish and the floor

system to which it is applied. A bar chart showing the cost-effective span lengths for each floor system is shown in Fig.3.

In most buildings, the distance between columns is 30 ft (9.1 m) or less. Residential structures do not require as much open space as commercial buildings, and the column spacing is typically less than 30 ft (9.1 m). The flat plate is the most economical floor system for buildings with square bays having plan dimensions less than 20 ft. (6.0 m). Not only are the material and labour costs for the floor less than those for other systems, but the cost of providing an architectural finish is also lower than that for systems without a flat underside. For square bays with plan dimensions between 20 and 30 ft. (6.0 and 9.1m), both the flat plate and the flat slab are equally viable choices, based on their structural costs. The flat plate, however, is the better choice for residential buildings, because of its totally flat underside. Therefore, for residential structures (live loads = 50 psf (2.4kPa), superimposed dead load = 20 psf [0.96 kPa]. and square bay dimensions under 30 ft (9.1m), the flat plate is the economical choice.

Economics of flat plate concrete floor systems:

The design of a floor system can involve several variables. Some of these are concrete strength, slab

thickness, column height and dimensions, and floor aspect ratios. Quantity summaries for flat plate slab systems are given for a variety of bay sizes.

Floor slab thickness for flat plates under residential loading conditions is usually controlled by deflection considerations. ACI 318-89 requires that the slab thickness for flat plate floors without edge beams be greater than $1/30$ th of the longer clear span length (for Grade 60 reinforcing steel).

Because deflection controls the slab thickness, the required reinforcing steel for bending moments is usually about the minimum required by code. An increase in slab thickness beyond the code-prescribed minimum is not economical. A thicker slab will increase the concrete quantity, and not reduce the reinforcing steel quantity. Also, as previously discussed, the minimum code-prescribed slab thickness is independent of the specified concrete strength. A higher concrete strength will increase the unit cost of the concrete without reducing its quantity. The most economical flat plate floor for residential loadings is one with the minimum allowable thickness and a concrete strength of 4000 psi.

The height and cross-sectional dimensions of the columns above and below a slab will affect the resulting

shears and bending moments in the floor slab. Column heights can range from 10 to 30 ft (3.0 to 9.1 m), but typically are between 10 and 13 ft (3.0 and 4.0m). A column height of 12ft (3.7m) was used in this investigation, except where the column height itself was a variable. Column stiffness is a function of column height. Flexural stiffness is determined as EI/L , where E is the modulus of elasticity of the column material, I is the moment of inertia of the column cross sections, and L is the column height. Since stiffness is inversely proportional to column height, it follows that a longer column is more flexible. A flexible column will allow greater rotation at the slab-column joint, and larger bending moments in the slab. Analyses were performed for a variety of bay widths and column dimensions, with column heights varied between 10 and 15 ft (3.0 and 4.6m). Increasing the floor height from 10 to 15 ft (3.0 and 4.6m) resulted in an increase of the slab moment of less than 4 per cent. This small increase has a minimal effect, if any, on the material quantities. The flat plate floor quantities, for all practical purposes, are independent of the floor height under normal loading conditions.

Column cross-sectional dimensions will determine the clear span between the column faces. The bending moments are determined using this clear span length. The shear

resisting properties are also related to the column cross-sectional dimensions. A larger column width or depth will result in a larger shear carrying capacity of the slab. In the analyses for this investigation, the column cross-sectional dimensions used for the different bay sizes were chosen to be representative of the column sizes used in buildings of 10 to 20 stories.

If a structure has column widths and depths considerably different from those used in the table, adjustments should be made. Adequate adjustment is provided if the same formwork and concrete quantities are used with an increase or decrease in the reinforcing steel. The steel reinforcing quantities should be increased by 1 percent for each 2 in (50mm) decrease in square column dimensions, or decreased by 1 percent for the same size increase in square column dimensions.

The aspect ratio is defined as the larger dimension of a slab panel divided by the smaller dimension of the slab panel. As previously discussed, the flat plate slab thickness is controlled by the span length. For a building with square bays (aspect ratio=1.0) the slab thickness requirement is the same in both directions. A slab with an aspect ratio other than 1.0 has different thickness requirements in two orthogonal directions. Obviously, the larger of the two must be used in design, resulting in a

loss of economy. For example, a bay with 625 ft² (58 m²) of floor area with an aspect ratio of 2.0 will cost 20 percent more than a square bay with the same floor area. Unless there are other controlling factors, square bays are the most economical.

CONCLUSION

The cost comparison shows that for the floor loads and span lengths typically used in multi-story residential construction, the flat plate system is the most cost effective choice. Minimum slab thickness, as prescribed by ACI 318-89, and 4000 PSI (30 MPa) concrete strength should be used. The bays should also be made as square as possible to achieve the maximum economy.

TABLE 5.1
BASIC COMPRESSIVE STRESSES FOR MASONRY MEMBERS (AT AND AFTER
THE STATED TIMES)

Sl.No.	Description of Mortar	Cement	Lime	Pozzolana Mixture	Pozzolana Sand	Mix (Parts by volume)	Hardening Time After Completion of Work
1.	Cement	1	0.1/4C	-	3	-	7
2.	Cement	1	1/2C	-	4	1/2	14
3.	Cement-lime	1	1C	-	6	-	14
4.	Cement-lime	1	2B	-	9	-	14
5.	Cement	1	-	-	6	-	14
6.	Lime pozzolana	-	-	1	1.5	-	14
7.	Cement-Lime	1	3B or C	-	12	-	14
8.	Hydraulic Lime	-	1A	-	2	-	
9.	Lime Pozzolana	-	1C	-	2	1	
10.	Lime	-	1B	-	3	-	28

Note 1 - This table is valid for slenderness ratio 6 and the loading with zero eccentricity.

Note 2 - Linear interpolation is permissible for units whose crushing strengths are intermediate between those given in the table.

Note 3 - It is advisable to use plasticizers for cement mortars in order to improve properties of the mortar, such as flow and water retentivity. Plasticizers should be used according to manufacturers instructions.

Note 4 - Masonry cement mortars are also advisable and shall be used according to manufacturer's instructions. The mix proportions of masonry cement: sand shall be such as to give comparable mortar crushing strengths with the cement:lime:sand mortar or Cement:sand mortar of the particular grade.

Note 5 - Lime classification (Classes A, B and C) and building lime shall conform to accented standards [1-4(2)].

Note 6 - For mortar under s.No.6 lime pozzolana mixture shall be of Grade LP 40 conforming to accepted standards [VI-4(2)].

Note 7 - These periods should be increased by the full amount of any time during which the air temperature remains below 4.5 C plus half the amount of any time during which the temperature is between 4.5 C and 10 C.

* The inclusion of lime in cement mortars is optional.

Basic Stress in Kg/cm² Corresponding to Masonry Units with
Crushing Strength (Kg/cm²)

Sl.No.	Description of Mortar	35	70	105	140	175	210	280	350	440
1.	Cement	3.5	7.0	10.5	12.5	14.5	16.5	21.0	25.0	30.5
2.	Cement	3.5	7.0	10.0	11.5	13.0	14.5	17.5	21.0	25
3.	Cement-lime	3.5	7.0	10.0	11.0	12.0	13.0	16.0	19.0	22
4.	Cement-lime	3.5	5.5	8.5	10.0	11.0	12.0	14.5	16.5	19
5.	Cement	3.5	5.5	8.5	10.0	11.0	12.0	14.5	16.5	19
6.	Lime pozzolana	3.5	5.5	8.5	10.0	11.0	12.0	14.5	16.5	19
7.	Cement-Lime	2.5	5.0	7.0	8.0	9.0	10.0	12.0	14.0	16
8.	Hydraulic Lime	2.5	5.0	7.0	8.0	9.0	10.0	12.0	14.0	16
9.	Lime Pozzolana	2.5	5.0	7.0	8.0	9.0	10.0	12.0	14.0	16
10.	Lime	2.5	4.0	5.5	6.0	6.5	7.0	7.5	8.5	9.5

TABLE 5.2
STRESS FACTORS FOR SLENDERNESS RATIO AND ECCENTRICITY OF LOADING

S.No.	Slenderness ratio	Stress Factor for Equivalent Eccentricity of Loading Divided by the Thickness of the Members						
		0	0.04	0.1	0.2	0.3	0.33	0.50
1.	6	1.000	1.000	1.000	0.996	0.984	0.980	0.970
2.	8	0.920	0.920	0.920	0.910	0.880	0.870	0.850
3.	10	0.840	0.835	0.830	0.810	0.770	0.760	0.730
4.	12	0.760	0.750	0.740	0.706	0.664	0.650	0.600
5.	14	0.670	0.660	0.640	0.604	0.556	0.540	0.480
6.	16	0.580	0.565	0.545	0.500	0.440	0.420	0.350
7.	18	0.500	0.480	0.450	0.396	0.324	0.300	0.230
8.	21	0.470	0.448	0.420	0.354	0.276	0.250	0.170
9.	24	0.440	0.415	0.380	0.310	0.220	0.190	0.110

Note 1: Linear interpolation between values for the stress factors is Permissible.

Note 2: The values are for linear interpolation only for eccentricity between 0.33 to 0.50.

TABLE 5.3
MODIFICATION FACTOR FOR SHAPE OF UNIT

Ratio of Height to Thickness of Brick or Block	Factor
0.75	1.0
1.0	1.2
1.5	1.6
2.0 to 3.0	2.0

Note: Linear interpolation between values is permissible.

Table 5.4. IMPOSED FLOOR LOAD FOR DIFFERENT OCCUPANCIES

S.No.	Occupancy classification	Uniformly Distributed Load (UDL)	Concentrated Load
1	2	³ kN/m ²	4 kN
i. RESIDENTIAL BUILDINGS			
a. Dwelling houses:			
1.	All rooms and kitchens	2.0	1.8
2.	Toilet and bath rooms	2.0	-
3.	Corridors, passages, staircases including fire escapes and stores rooms	3.0	4.5
4.	Balconies	3.0	1.5 per metre run concentrated at the outer edge
b. Dwelling units planned and executed in accordance with IS: 8888-1979 only			
1.	Habitable rooms, kitchens, toilet and bathrooms	1.5	1.4
2.	Corridors, passages and staircases including fire escapes	1.5	1.4
3.	Balcones	3.0	1.5 per metre run concentrated at the outer edge

c. Hotels, hostels, boarding houses,
lodging houses, dormitories,
residential clubs:

1. Living rooms, bed rooms and dormitories	2.0	1.8
2. Kitchens and laundries	3.0	2.7
3. Billiards room and public lounges	3.0	2.7
4. Store rooms	5.0	4.5
5. Dining rooms, cafeterias and restaurants	4.0	2.7
6. Office rooms	2.5	2.7
7. Rooms for indoor games	3.0	1.8
8. Baths and toilets	2.0	-
9. Corridors, passages, staircases including fire escapes, lobbies -as per the floor serviced (excluding stairs and the like)	3.0	4.5
10. Balconies	Same as rooms which they give access with a mini- mum of 4.0	1.5 per metre run concen- trated at the outer edge
d. Boiler rooms and plant rooms -to be calculated but not less than	5.0	6.7

TABLE - 5.5 IMPOSED LOAD ON VARIOUS TYPES OF ROOFS

S.No.	Types of Roof	Uniformly distributed Imposed Load Measured on Plan Area (3)	Minimum imposed Load Measured on Plan (4)
(1)	(2)		
i.	Flat, sloping or curved roof with slopes up to and including 10 degrees	1.5kN/m ²	3.75 kN uniformly distributed over any span of one metre width of the roof slab and 9 kN uniformly distributed over the span of any beam or truss or wall
b.	Access provided	0.75 kN/m ²	1.9 kN uniformly distributed over any span of one metre width of the roof slab and 9 kN uniformly distributed over the span of any beam or truss or wall
ii.	Sloping roof with slope greater than 10 degrees	For roof membrane sheets or purlins-0.75 kN/mm ² for every degree increase in slope over 10 degrees	Subject to a minimum of 0.4kN/mm ²

iii. Curved roof with slope of line obtained by joining springing point to the crown with the horizontal, greater than 10 degrees

(0.75 - 0.52) kN/m² Subject to a minimum of 0.4kN/mm²

where = h/l

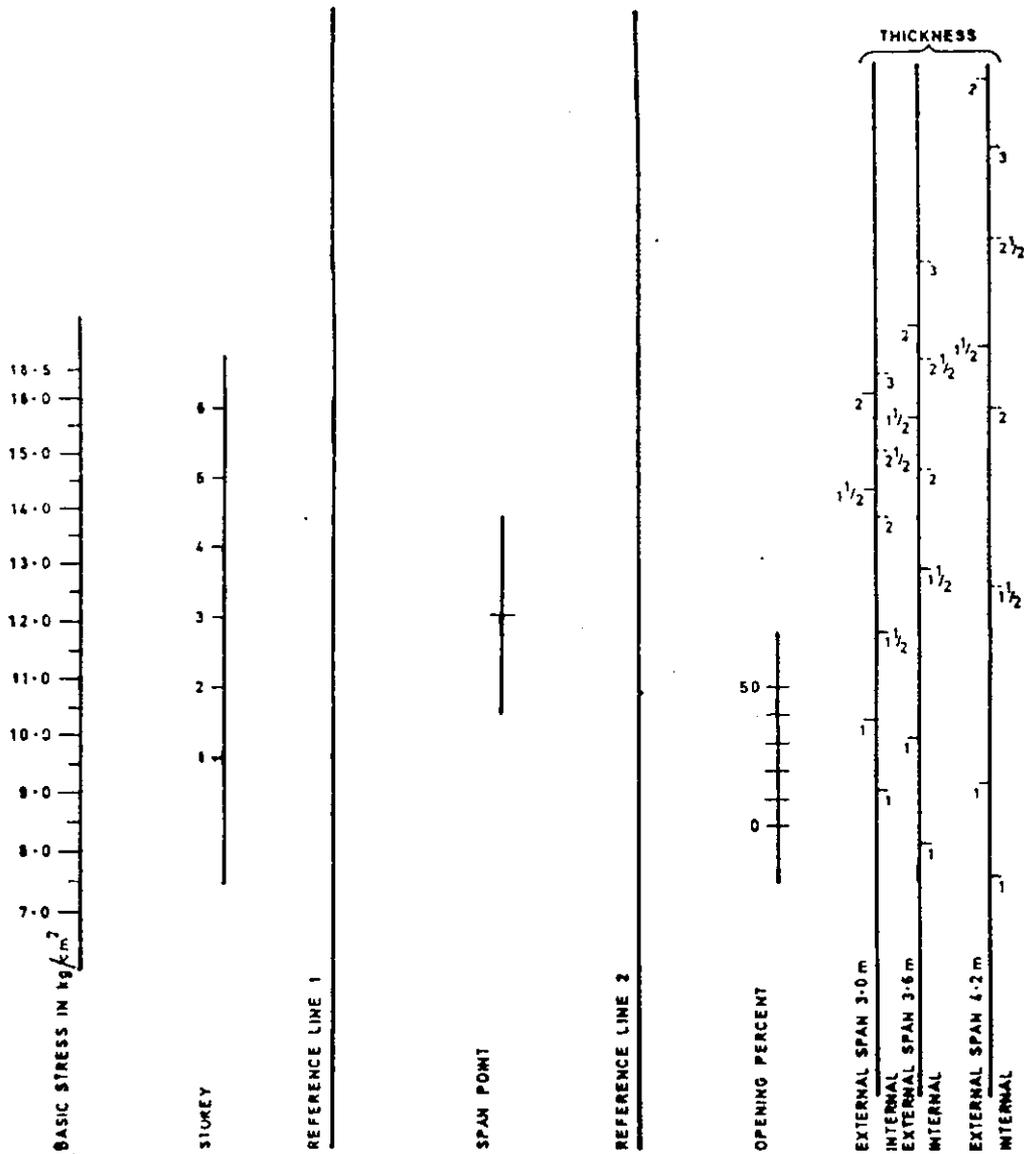
h=the height of highest point of the structure measured from its springing; and

l=Chord width of the roof if singly curved and shorter of the two sides if doubly curved

Alternatively, where structural analysis can be carried out for curved roofs of all slopes in a simple manner applying the laws of statistics, the curved roof shall be divided into minimum 6 equal segment and for each segment imposed load shall be calculated appropriate to the slope of the chord of each segment as given in (i) and (ii) above.

Note 1: The loads given above do not include loads due to snow, rain, dust collection, etc. The roof shall be designed for imposed loads given above or for snow/rain load, whichever is greater.

Note 2: For special types of roofs with highly permeable and absorbent material, the contingency of roof material increasing in weight due to absorption of moisture shall be provided for.

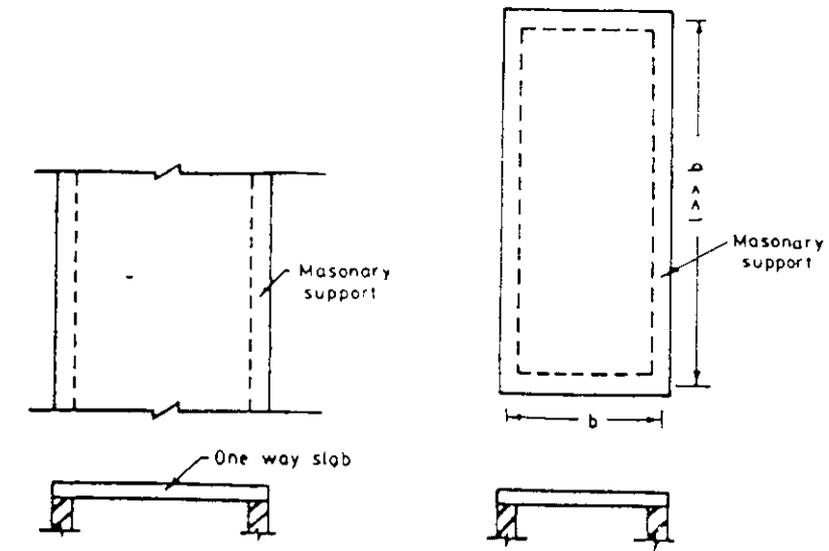


This nomogram is valid for the following conditions:

- i) Buildings (residential):
 - Live loading ... 200 kg/m²
 - Dead loading (assumed) ... 415 kg/m²
- ii) Storey height ... 3.2 m

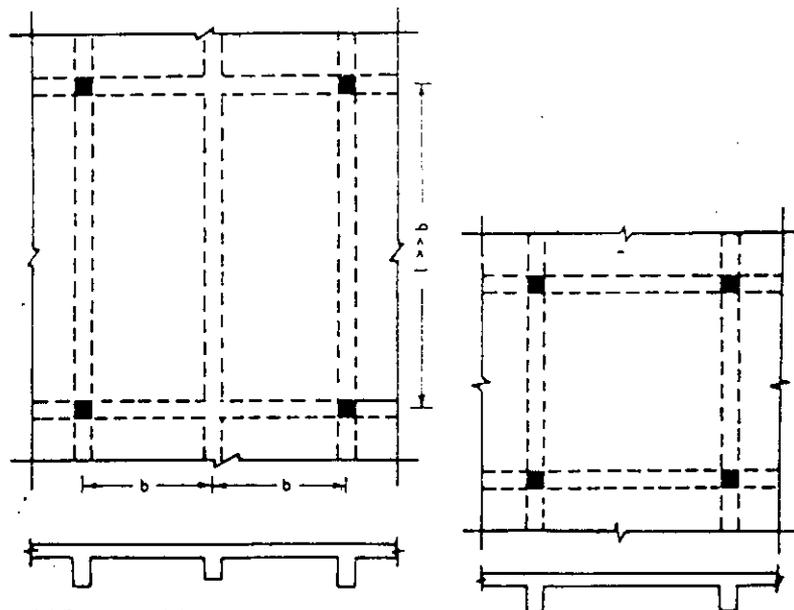
For Residential Buildings (Class 200 Loading) of 3.2 m Storey Height

Fig. 5.2. *Nomograms for Thickness of Brick Walls* — Contd



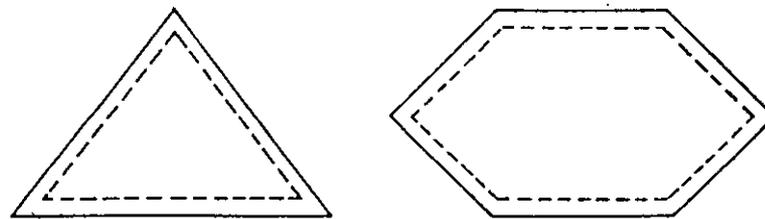
(a) One way slab supported on brick walls on two parallel sides

(b) One way slab supported on brick walls on four sides

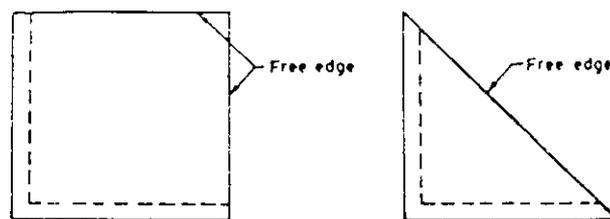


(c) One way slab supported on beams on four sides

(d) Two way slab supported on beams

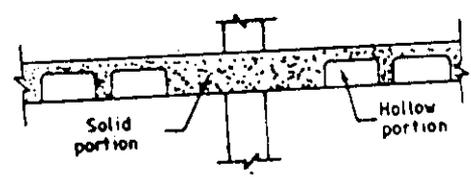
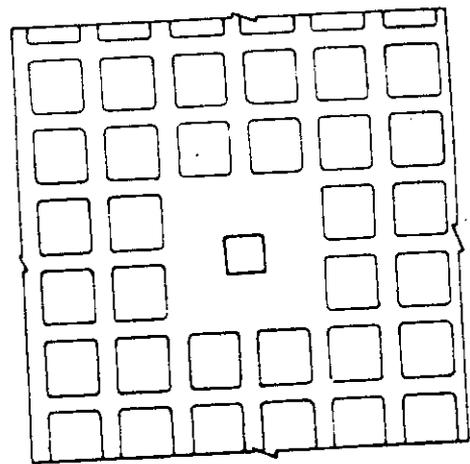
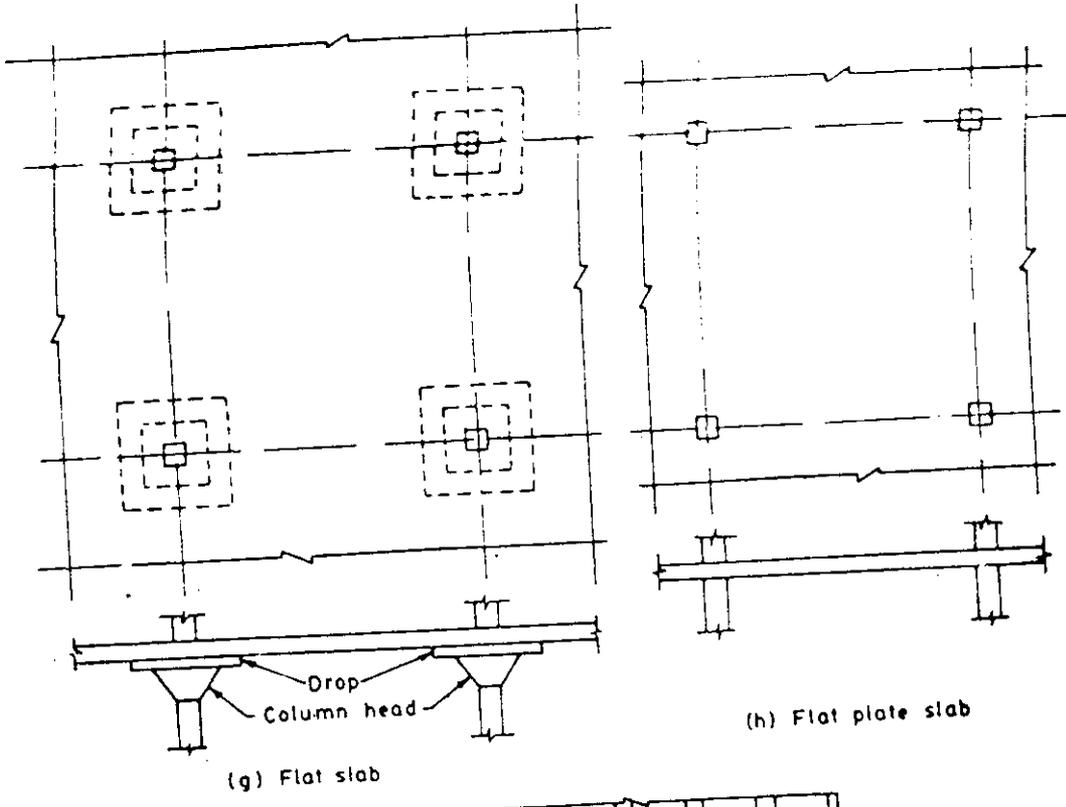


(e) Two way triangular and trapezoidal slabs supported on all edges



(f) Two way slabs supported on adjacent edges

Fig. 5.3 TYPES OF ROOF SLABS



(i) Waffle slab system

Fig. 5.4 TYPES OF FLAT SLAB

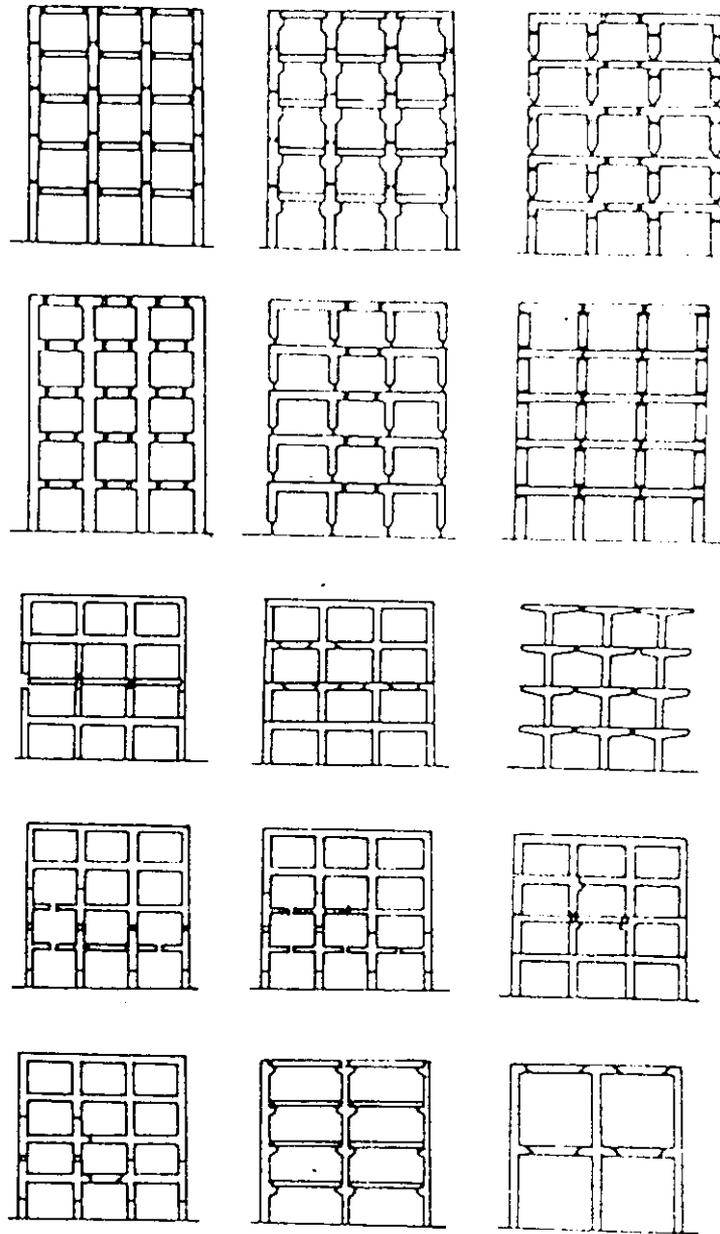
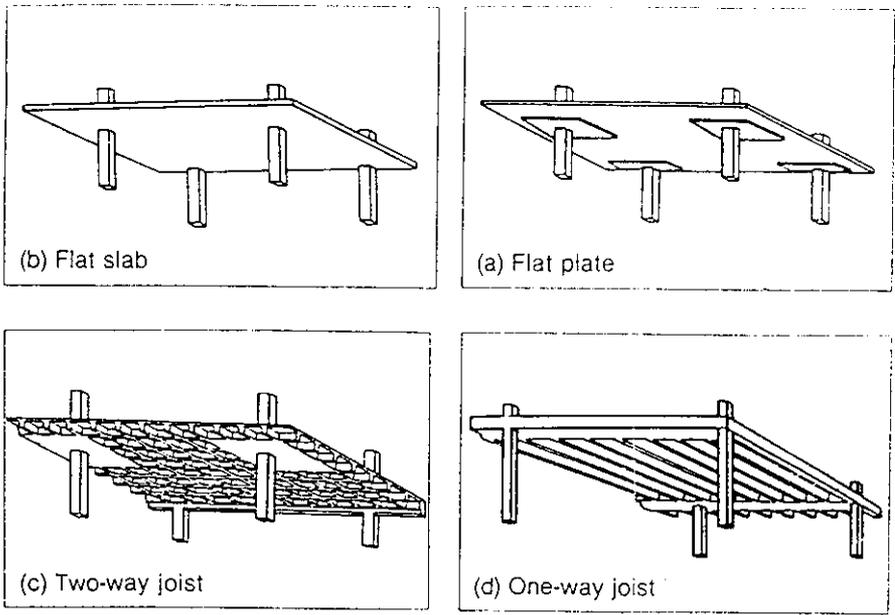
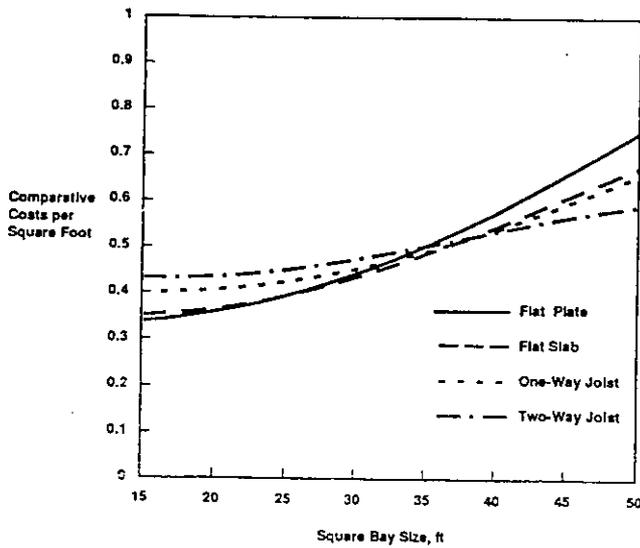


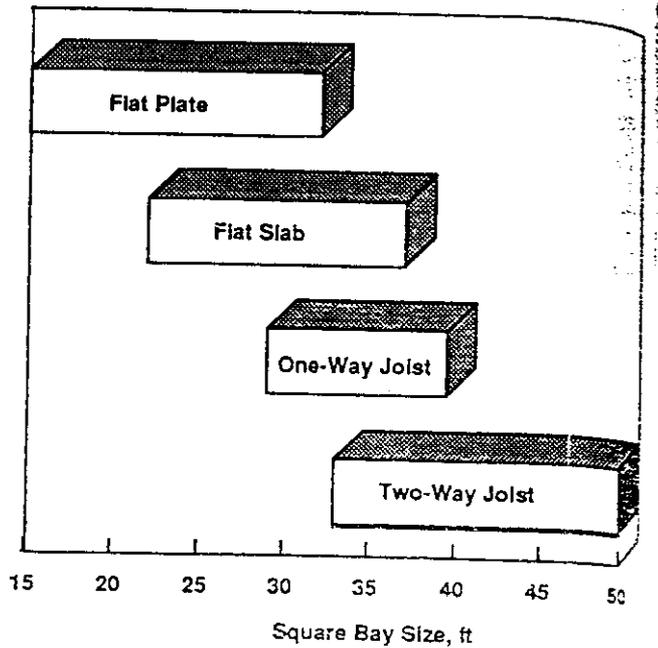
Fig. 5.5 TYPES OF FRAMED CONSTRUCTION



—Cast-in-place concrete slab system.



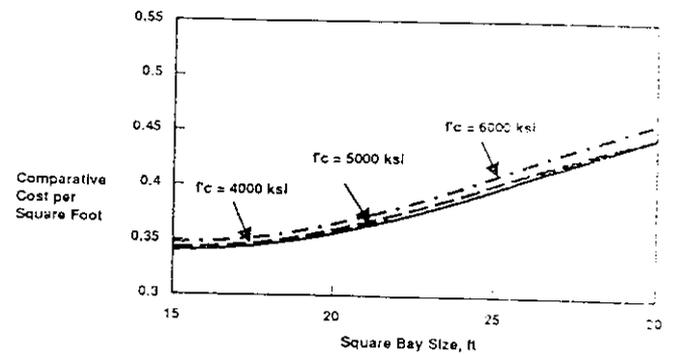
—Relative costs of different slab systems.



—Economical slab systems for different square bay sizes.

Table 1 — Material quantities for flat plate systems with varying slab thicknesses and column sizes

Bay size (ft)	Slab depth (in.)	Column size (in.)	Quantities		
			Concrete (ft ³ /ft ²)	Steel (psf)	Forms (ft ² /ft ²)
15 × 15	6	14	0.50	2.20	1.0
15 × 20	7.5	18	0.63	1.95	1.0
15 × 25	9.5	20	0.79	2.51	1.0
15 × 30	11.5	22	0.96	3.00	1.0
20 × 20	7.5	20	0.63	2.12	1.0
20 × 25	9.5	22	0.79	2.55	1.0
20 × 30	12	24	1.00	3.18	1.0
25 × 25	9.5	26	0.79	2.76	1.0
25 × 30	12	30	1.00	3.22	1.0
30 × 30	12	32	1.00	3.50	1.0



—Relative costs of flat plates for various concrete strengths.

Fig. 5.6 ECONOMICAL FLOOR SYSTEM

CHAPTER-6

BUILDING ECONOMICS, MANAGEMENT AND COST ANALYSIS TO MULTI STOREYED FLATS

6.1. BUILDING ECONOMICS AND MANAGEMENT

6.1.1. Cost Control and Cost Planning

Adequate control of expenditure is a pre-requisite for the successful completion of any project. Although in some cases, cost may be secondary in importance compared to quality or speed of construction, usually it is more important than other factors. The cost limit may be imposed for various reasons, e.g. the building owner may have only a limited sum to spend or he may fix a cost limit on the basis of previous experience of similar buildings, or the outlay may be governed by possible return from the building by way of rent or sale. Hence there is a need for an effective method of controlling the cost.

A satisfactory cost control procedure enables the designer to observe and control the interaction of design and cost, while planning the project. By this means, it is possible to ensure that the resulting scheme gives value for money and, where necessary, is accurately related to an agreed cost limit. The architect/designer aims to distribute available resources in a balanced way throughout

the building, so that the amount spent on various elements such as walls, floors, finishes, services etc. are related appropriately to the type of building and to each other.

Basic to all estimating and cost control is what can be called, 'Building economics', i.e. a study of the factors which influence the cost of building developments. They can be grouped as (a) design factors-shape of building, circulation space, structural form, prefabrication, site utilisation, coverage, density of development, effect of contours, maintenance considerations etc. (b) contract - types of contract and basis of tender (c) administrative factors.

Major factors which influence the cost are discussed below:-

1. Shape of Building

The plan shape of the building is mostly governed by the functional and aesthetic requirements. However for a given plinth area, the cost will be minimum, when the perimeter is least. Thus for a given plinth area, the cost of a building with square shape will be less than that of buildings which are rectangular or irregular in shape or having a number of offsets. Cost of services and site development work tends to become more as shape of building change from simple to complex. With simple shapes, the

construction can be completed faster and hence the overall cost will be less.

2. Size of Building

Generally cost does not rise proportionately with increase in plan size. The greater the plan size of the building, the less will be the cost per unit of plinth area. This is due to increased wall length in smaller plans.

3. Circulation Space

Circulation space though necessary for movement, is not effectively used unlike spaces for working, living, sleeping etc. Hence, the ratio of circulation space to overall plinth area should be kept minimum. This is perhaps most obvious in the case of buildings meant for letting out, where the rent return is based on useful floor area.

4. Height

The storey height of the building should be kept minimum, as per functional requirements specially for thermal comfort and provision of fans. Any increase in height over this will lead to increased loads, thicker walls, larger foundations, use of additional quantities of materials and extra time for the construction.

5. Number of Storeys

The number of storeys also influences the cost of buildings. As a general rule, average cost per square metre

increases with the number of storeys except for double storey construction, where a marginal saving can be achieved as compared to single storey construction. But the number of storeys must be decided in relation to costs of land and development which also influence the overall cost of buildings.

6. Area of openings

The area of openings for joinery increases the cost of building, because the cost of joinery is much more than the cost of masonry. The opening area should be optimum from considerations of light and ventilation and tendency to give unnecessary openings should be discouraged.

7. Structural Design

Structural design influence the overall cost of a building considerably. By using latest theories of analysis and design like limit state method, the cost of structure can be brought down. Computer aided methods of analysis and design will go a long way in achieving efficiency and economy. Instead of using thumb rule methods, a building should be designed strictly as per codal provisions. For example, instead of providing two brick thick walls in the ground floor of a four storeyed load bearing wall as per thumb rule, a single brick thick wall could be designed as per codal provisions in areas where good quality bricks are

available. Similarly, by rational design of foundations, significant economy can be achieved.

Use of structurally efficient sections, will result in considerable saving in steel, concrete and cost. CBRI has developed several economical flooring/roofing schemes, where the concrete below the neutral axis is eliminated to a great extent. For larger spans and heavier loads, use of prestressing reduces the cost. In Northern India, where good quality bricks are available, load bearing brick wall scheme is found economical for 4 to 5 storey height, beyond which R.C. frames with infill walls are preferred.

8. Selection of Materials

Materials account for about two-third of the total cost of a building. Hence, use of efficient and economical alternate materials will go a long way in reducing the construction cost. Use of high strength deformed bars in place of mild steel in reinforced concrete members will result in about 30 per cent saving in steel and substantial saving in cost. Similarly, by designing concrete mixes, instead of using nominal mixes, substantial saving in cement can be achieved. Use of lime mortars and composite mortars will also result in saving of cement and better performance of masonry/plaster. Studies carried out has shown that high magnesium and dolomitic lime (20 to 40 per cent MgO content) available in large quantities at a low price can find

greater use as building lime. Part (upto 20 percent) replacement of portland cement with suitable quality of fly ash will also conserve cement, which is in short supply. Activated lime pozzolana mixture developed at CBRI is another economical alternative to cement mortar.

9. Construction Technology

Another method of reducing the cost of construction is by the application of appropriate construction technology. Obsolete construction technology is costly and time-consuming. It is generally seen that new techniques save scarce materials like cement and steel and hence should be encouraged. Indigenous techniques should be preferred to foreign technology, as most of them will not be suiting to the conditions in the country.

10. Prefabrication

Prefabricated construction is found economical for mass construction of buildings, where standardised plan are used. In India, where bricks and construction labour are generally cheap, partial prefabrication with insitu stone/brick walls and precast flooring/roofing schemes are found economical.

11. Modular Coordination and Standardisation

If buildings are designed according to the principles of modular coordination and the sizes and types of

components are standardised, there will be considerable saving in the overall cost of buildings.

12. Site Consideration

The cost of building will vary depending upon the place, where it is to be located and the specific site conditions. For example, the cost of construction in towns is likely to be more than that in rural areas, due to high labour costs in town and other factors. If a building is to be erected on a restricted site with difficult access, where material storage and handling is a problem the overall cost of building may go up. Similarly in a sloping site, the construction cost will be more. In a sloping ground, it is usually economical to fix the ground level such that there is a greater volume of excavation at one end than filling at the other end. As far as possible, a long narrow building should be sited along the contour line than across it. In case a new building is to be constructed adjacent to an existing building, considerable extra expenditure will be involved in shoring the foundation of existing building. In ground with filled up, loose or expansive soils and water logged areas, the cost of foundation will be high. In areas affected with termites or saltpeter, the cost of construction will be high due to the special precautions to be taken.

13. Maintenance and Repairs

While Planning a building, the 'all-in-cost' of the building consisting of initial cost, maintenance cost, replacement cost, running and operational cost over its life should be considered and the design which is economical in 'all-in-cost' should be adopted. A design which costs the least in initial cost may work out to be very uneconomical in the long run, if the maintenance cost is high. the magnitude of maintenance cost may be gauged from the fact that a considerable percentage of the labour in building industry is engaged in maintenance work. The annual cost of maintaining the main structure of a building is usually only a fraction of the cost of maintaining its fittings, finishes and services. Hence, special attention should be given in the design/procurement of fittings and fixtures and design/construction of services.

14. Basis of Contract

Some variation in cost may be expected, according to the basis on which a contract is placed, and this must be taken into account when estimating and deciding upon the form of contract. Studies carried out at CBRI has shown that lump sum type of contract performs the best in respect of completion time, completion cost and time and cost over runs for repetitive type of construction. Comparison of different types of contracts is discussed. Competitive

tenders based on bill of quantities is also likely to produce keen competition, resulting in reduced cost. Negotiated contract on a bill of quantities will normally be not as low as the lowest tender obtained in a competition. In cases of cost plus contract, where actual cost plus an agreed percentage is paid to the contractor, a higher cost of work will give a higher amount to the contractor. Hence the cost of construction is likely to be higher in this type of contract.

15. Time Factor

The cost of a project depends on the completion time also. As the overhead costs of a contractor per unit time is almost constant, any delay in the completion of the project will result in increased cost to him and to the owner, as returns on his investment is delayed. Depending upon the quantum of work, the infrastructural facilities and availability of materials and labour, there is an optimum completion time for a project. In case the project is to be completed before the optimum completion time, overtime working at enhanced overtime rates will have to be done, leading to increase in the cost of projects.

16. Construction Management

The construction process throws many difficult and complex management problems. To overcome them and to ensure

judicious allocation and efficient use of resources, improved management techniques should be used. Management aims at making the best use of all resources. One of the most serious problems faced by construction industry is regarding time and cost over runs. Modern management techniques like CPM and PERT are vital tools for timely and economical completion of projects. The network management system uses logical and simple procedures for reducing large volumes of complex information into a graphical or tabular form which can be readily employed in decision making. These techniques highlight critical activities involved in a project and enable around co-ordination among various project agencies to complete the project in time. However, these aids need regular review and updating along with the progress of work. A system for efficient management of building projects called 'Integrated Management System' is developed.

6.1.2. Material and Labour Requirements for Buildings

An estimate of manpower and material requirements is generally required for buildings prior to the start of construction for various purposes such as budgeting and procurement of materials, computation of cost indices, justification of tenders etc. Rough calculations for the quantities of important materials are usually based on certain percentages of the total cost of building. This may

not project the true computation as these percentages remain constant only when there is uniform increase or decrease in prices of materials and labour - a phenomenon which rarely occurs. An alternative method of computation as these percentages remain constant only when there is uniform increase or decrease in prices of materials and labour - a phenomenon which rarely occurs. An alternative method of computation of requirements of material/labour is to prepare detailed estimates/bills of quantities and then calculate the requirements with the aid of material and labour constants, usually derived from the analysis of rates. This method, though ideal, is very time-consuming and requires complete set of final drawings, designs, specifications and detailing in advance which are normally not available in most of the organisations due to many procedural difficulties. Studies carried out at the CBRI project a quick method of estimation of materials and labour for various types of buildings. Simple statistical equations have been worked out for building portion, which relate the consumption of each material/labour to the plinth area of the building. For services portion, the norms/requirements have been given in tabular form. The study covers office as well as residential buildings both load bearing and framed construction.

Basis of Study

The study has been based on the past performance of completed buildings in terms of actual quantities of materials and labour consumed for completion of work. The actual quantities of materials and labour were computed from the final bills of contractors with the help of average material and labour constants. This exercise was done for a number of buildings with different plinth areas for each category of construction. Thus, bills of quantities of 45 single storeyed load bearing wall residential buildings, 35 double storeyed load bearing wall residential buildings, 60 four storeyed residential buildings with framed construction and 14 office buildings were studied. The data on internal services are based on the study of 63 residential and 10 office buildings. All the buildings are conventional, designed as per the normal practice of Central/State P.W.Ds and public sector undertakings. The analysis has been based on particular sets of reference specification being commonly adopted for various types of construction work. Quantities thus computed reveal the comparative consumption of each material and labour in buildings with different plingth areas for the same type of construction. In the tables, labour and material constants have been given per unit plinth area. For different buildings with the same plinth area, the arrangement of internal spaces, walls etc. can vary. Hence an error of upto plus/minus 10 per cent can

be expected in the values of materials and labour computed as per the equations given in the tables. Statistical relationships have been established between each type of material/labour and plinth area for the following types of buildings.

Residential Buildings

- i. Load Bearing Construction
 - a. Single Storey dwellings
 - b. Double storey dwellings
- ii. Framed Construction
 - Four Storey dwellings

6.1.3. Residential Buildings

In case of residential buildings, the relationships have been worked out for load bearing as well as for framed construction. In load bearing construction, single and double storeyed buildings with normal depth and width of foundation have been considered. The relationships are applicable for plinth areas varying from 30 to 300 m². In case of four storeyed framed construction, the analysis has been done considering column foundation of two metre depth and the relationships are applicable for a range of 30 to 100m² plinth area only. The storey height of the buildings taken is 3.10m and specifications adopted for the analysis - both for load bearing and framed construction are shown in

Table 6.1. The equations of materials and labour are listed in Table 6.2 and 6.3. It may be noted that in case of load bearing construction, relationships for both sub-structure and super-structure are given in consolidated form. However, for framed construction separate relationships are worked out for superstructure and sub-structure and the latter part is shown in Table 6.1.

Certain types of housing units are built in a row or are semi-detached. The quantities, for such construction are expressed as a function of the plinth area of an individual unit. For computing the quantities for a row of single storey houses, the requirements should be calculated first for an individual tenement and the quantities required for a row are obtained by multiplying with the number of tenements in the row. In case of double or four storeyed construction, the requirements of any individual material or labour is calculated by putting the plinth area of a single tenement in the relevant equation and the quantities thus arrived at are multiplied with the number of quarters whether these are semi-detached or one above the other.

6.1.4. Internal services

In the normal practice, to account for the cost of internal services in the estimate, a certain percentage of building cost is added to the cost of building portion. But this percentage may not remain constant due to non-

uniform escalation of prices of different materials/labour. In order to give a ready-to-use information for computation of cost of services and material and labour requirements, data have been worked out and given in tabular form for residential buildings.

6.1.5. Services for Residential Buildings

The requirements are not given in the form of statistical realtions because there are certain prefixed norms for providing services according to type of tenements. So the data have been presented in the tabular form only for various types of tenements ranging from type I to type IV and Janta to MIG type.

Number of storeys in a building has a sizeable impact on the inputs in case of water supply and sanitary services whereas it will not make much difference in case of electrical services. So separate norms have been provided for buildings with different number of storeys for internal water supply and sanitary services. These are worked out for double and four storeyed construction and only one set of norms has been prepared for electrical services. The reference specifications and the system of services on which the analysis has been based are shown in Table 6.6. The average storey-height of residential building considered is 3.10 m and the distance of watermains from the residences

has been taken between 5 and 8 m. The information regarding water supply/sanitary services worked out for type I to type V dwellings is produced in Table 6.7 and 6.8 for double and four storeyed construction respectively.. Similar data on electrical services is given in Table 6.9.

6.1.6. ELEMENTAL COST ANALYSIS OF RESIDENTIAL BUILDINGS

Elemental cost analysis (ECA) is a systematic breakdown of cost data among various elements of a buildings. Its primary function is to provide a method of comparing the cost of one building with another. It attempts to isolate points of differences so that variation in specifications, construction and functions can be properly evaluated. In other words, it presents in a systematic manner a set of facts about cost pertaining to a particular building with different specifications. For carrying out the analysis, the building is split into different elements such as foundation, walls, floors, roofs, finishes, doors and windows, water supply and sanitary service, internal electrification etc.

The normal practice of projecting the elemental cost analysis of building is either in terms of percentage of the total cost for each element or absolute cost of each element or cost of items of plinth area rate for each element. But the cost varies from time to time and place to place, depending upon the market rates which will also affect the

changes in cost analysis. To eliminate the limitations of the present practice, it has been developed a method of elemental cost analysis in terms of consumption of basic materials and labour per unit plinth area of building. With this data, elemental cost analysis for any place at any time can be worked out from the prevailing rates of materials and labour. The data have been computed from final bills of completed projects collected from various construction agencies. The data from the final bills were adjusted according to a set of common specifications as given for residential buildings earlier in the chapter. After making adjustments in the final bills, the consumption of materials and labour was worked out with the help of average material and labour constants for each element and subelement. The consumption of material/labour for 10m^2 of plinth area for two and four storeyed residential buildings (load bearing construction) are given in Table 6.11.

Uses

The data can be used to find out the percentage distribution of cost among various elements and sub elements of buildings at any time and place from the prevailing rates of materials and labour. The percentage of cost for each sub-element can also be split into labour and material cost. The percentage to the contractor in case of lump sum contracts. It identifies the parts of a building which

consume major portion of building cost. The possible to consider whether a different distribution would produce a cheaper building. It provides information for adopting rational approach towards the provision of escalation of cost during the progress of work. It is also helpful in budgeting, in planning of procurement of materials at different stages and is useful for cost planning purposes.

6.1.7. Comparative Performance of Different Building Contract Systems

In the country, building construction projects are executed through contractors. There are different types of contracts such as lump sum contract, item rate contract, percentage rate contract etc. The system of contract affects the completion time and cost of the project to a great extent. Hence it is necessary to study the comparative performance of various contracting systems. Work has been done in this direction and the results of the study are discussed here.

Lump sum contracts are based on a fixed price agreed upon in advance and the contractor has to complete the work in accordance with the plans, specifications, construction details and other contract documents which are supplied to him in advance. The profit of the contractor is also included in the lump sum contract. In item rate contract and percentage rate contract, bills of quantities contract,

items are priced by the contractor and payments are made for the amount of work actually carried out. In percentage rate contract, the contractor quotes on a percentage basis on the standard schedule of rates and payment is made item-wise on the basis of amount of work actually carried out.

Comparative Merits/Demerits of Different Contract Systems

Lump sum contract is preferred for traditional and repetitive type of construction. The nature and extent of work is indicated on drawings and specifications, with or without bills of quantities. The significant features of this type of contract system are:

- i. Commitments are known in advance;
- ii. Quick interim and final payments;
- iii. Better and easier cost control;
- iv. Reduction in administrative work during construction period resulting in better supervision;
- v. Higher efficiency and speed in construction leading to increased profit for the contractor;
- vi. Preparation of plans, construction details and specification possible in advance;
- vii. Contractors can quote higher rates to cover unforeseen risks.

For work which entails large estimate using relatively few methods of construction and where the volume of work

cannot be exactly determined in advance, item rate of percentage rate contracts are used. The significant features of these systems are:

- i. A reasonably accurate estimate is a prerequisite for good results.
- ii. Provides for more variation
- iii. Complete drawings and specifications not required in advance.
- iv. Possibility of over-payment to contractor due to computation and book keeping reduced;
- v. Proper planning in advancing not possible.
- vi. Over running of time and cost due to delayed decision on drawings, details and specifications.

6.1.8. Performance of Different Contract Systems

Performance of different contracting systems were compared by studying a large number of residential buildings executed by different departments using different contracting systems. For comparing the performance with regard to time and cost, statistical relationships between each of these variables and the total plinth area of buildings in the project, were established. Comparison of the systems was done with respect to the following parameters.

i. Completion time

The completion time for projects using lump sum contract is the least compared to those with item rate and percentage rate contracts. Item rate contract takes 45 to 75 per cent additional time and the percentage rate contract takes 45 to 55 per cent additional time over lump sum contract, depending upon the size of the project.

ii. Completion Cost

For comparing the completion cost of different types of contracts, the data collected was adjusted due to variations caused by specifications, number of storeys, execution of work at different places, design features, execution of work in different years and degree of competition in bidding. The analysis indicates that upto a plinth area of 1870 m², percentage rate contract performs comparatively better as far as completion cost is concerned, while for plinth areas beyond 1870m², it can be said that the performance of lump sum contract is better than percentage rate contract.

iii. Variation in Time

The performance of contracts were compared by studying the extent of time variation between stipulated and actual completion time as a percentage of stipulated time. 79 percent of lump sum contracts, 36 per cent of percentage

rate contract and 30 per cent of item rate contracts were completed within a time variation of 50 per cent while for the rest of the projects the time variation was more than 50 per cent. Hence, it can be concluded that the performance of lump sum contract is comparatively better.

iv. Variation in cost

In case of 85 per cent of lump sum contracts, 46 per cent of percentage rate contract and 45 per cent of item rate contracts, the variation in completion cost was within 5 per cent of tendered cost. Thus, variation in cost is least in case of lump sum contract.

v. disputes

Study of incidence of disputes which went to arbitration shows that it is minimum in case of lump sum contracts, namely, 10 per cent compared to corresponding figures of 47 and 19 for percentage rate and item rate contracts respectively.

Thus, it can be seen that the performance of lump sum rate contract is better than percentage rate and item rate contracts for projects like housing. there is not much difference in the performance of percentage rate and item rate contracts.

6.2. COST ANALYSIS RELATED TO SOME OF THE TAMIL NADU HOUSING BOARD FLATS

The Tamil Nadu Housing Board Coimbatore unit proposed to construct 54 flats at Ganapathy under Tamil Nadu Government Rental housing scheme during the year 1992-93 and 1993-94 at an estimated cost of Rs.85,85,900/-. The details to the flats to be constructed are given below with the corresponding estimated cost.

1.	1 Block	Construction of 'A' Type (6 flats) flats	14,95,100.00
2.	2 Block	Construction of 'B' Type (12 flats) flats	26,65,000.00
3.	2 Block	Construction of 'C' Type	18,11,800.00
4.	2 Block	Construction 'D ₂ ' type	26,14,000.00
		Total Rs.	85,85,900.00

The above proposed type of flats are to be allotted on rental basis for Tamil Nadu government employees. From the proposed flats, two types are chosen for cost analysis ('C' type and 'D₂ Type flats) and the break up details for various construction materials used are arrived at to form a general construction opinion on flats.

'C' type plinth Area = 49.06sq.m. (1unit)

'D₂ type plinth Area = 37.25sq.m. (1unit)

S.No.	Construction Materials	'C' Type		'D' Type	
		Total	Require ment/sq.m	Total	Require ment/sq.m
1.	40mm metal for foundation	30m ³	0.611m ³	40m ³	1.143m ³
2.	R.R.masonry foundation & basement	73m ³	1.488m ³	103m ³	2.943m ³
3.	Bricks 23x11x7cm for foundtion and basement	65000	1325 Nos	1,00,000	2860 Nos
4.	20mm metal for roof slab and other	46m ³	46m ³	0.938m ³	1.914m ³
5.	10mm metal for	-	-	-	-
6.	Cement	60M.T	1.223M.T	80M.T	2.286M.T
7.	Steel	5.30M.T	0.108M.T	7.70M.T	0.220M.T

The Total estimate amount per unit plinth area is furnished below.

S.No.	Type of flate	Total Cost	Rate/Sq.m
1.	Construction of 'C' Type flats for 1 unit	Rs.1,44,783/-	Rs.2951/-
2.	Construction of 'D ₂ ' Type flats for 1 unit	Rs.1,06,426/-	Rs.2857/-

The rates are adopted vide P.W.D. standard schedule of rates for the year 1992-93 with an escalation charges @ 5% for 1993-94.

6.3. Materials requirement per unit floor area

The requirement of the following materials were worked out for different types of floors (single storey, two storey three storeys and four storeys) and the same is given in the form of graph.

TABLE

REQUIREMENT OF VARIOUS MATERIALS PER UNIT FLOOR AREA					
S.No.	Requirement Materials	Single Storey	2 Storeyed Flat	3 Storeyed Flat	4 storeyed Flat
1.	Brick	275 Nos	265 Nos	255 Nos	249 Nos
2.	20mm HBS	0.1766m ³	0.1743m ³	0.173m ³	0.172m ³
3.	Cement	224 Kg	214 Kg	203Kg	178Kg
4.	Steel	16.60Kg	15.32Kg	14.29Kg	13.88Kg
5.	Sand	0.0905m ³	0.0872m ³	0.0865m ³	0.0862m ³

6.4. PLINTH AREA RATE FOR DIFFERENT STOREYS

The estimate amount and plinth area rate for the different storeys were worked out as detailed blow.

No. of Storey	No of Units	Estimate Amount	Plinth ₂ area rate/m ²
1. Single Storey	One unit	Rs.1,13,500	Rs.3046/-
2. Two storeys	8 units	Rs.8,07,000	Rs.2920/-
3. Three storeys	12 units	Rs.12,77,000	Rs.2857/-
4. Four storeys	16 units	Rs.15,50,000	Rs.2784/-

Based on graph, it is clear that there is a reduction of cost per unit floor area if the floors are more than two.

6.5. PERCENTAGE COST OF DIFFERENT ITEMS OF WORK IN RELATION TO THE TOTAL COST OF CONSTRUCTION AS ON DECEMBER 1992.

The following Table gives the percentage cost of various items of work in relation total cost of buildings in the case of four types of residential buildings.

Table

S.No.	Item of work	Single Storey residence	Two Storey flats	Three Storey flats	Four Storey flats
1.	E.W. Excavation	0.40	0.29	0.19	0.15
2.	C.C.1:5:10 for foundation	2.44	2.32	1.46	1.20
3.	R.R Masonry	6.76	6.56	4.14	3.40
4.	B.W. in CM 1:5 for basement	1.55	0.67	0.42	0.35
5.	Sand Filling	2.87	0.92	0.58	0.48
6.	Plinth beam in RCC 1:2:4	0.73	0.77	0.49	0.40
7.	B.W. for superstructure	10.39	11.81	12.35	12.93
8.	Brick Partition walls 10.5 cm Tk.	1.20	1.21	1.56	1.60
9.	Brick Partition walls 7.5cm Tk	0.17	0.26	0.25	0.27
10.	RCC 1;2:4 for slab	3.74	5.96	6.01	6.59
11.	PC Cup board slabs	0.68	0.65	0.61	6.68
12.	RC Jalli 40mm Tk	0.10	0.10	0.10	0.11
13.	Form works	4.80	6.10	6.29	6.45

S.No.	Item of work	Single Storey residence	Two Storey flats	Three Storey flats	Four Storey flats
14.	C.W. Wrought and putup	5.21	5.72	5.85	5.94
15.	T.W. Shutters	7.53	9.46	9.58	9.82
16.	M.S. hold fasts	0.12	0.17	0.16	0.17
17.	M.S. window grills	0.69	0.55	0.52	0.57
18.	Flooring concrete	0.66	0.45	0.28	0.23
19.	Floor finish	0.91	0.47	0.43	0.47
20.	Weathering course	0.67	0.45	0.28	0.23
21.	Roofing Tiles	2.69	2.30	1.46	1.20
22.	Mosaic tiles	-	0.60	0.57	0.62
23.	Dadooing walls	-	0.31	2.98	3.26
24.	Fabrication of steel	4.36	5.95	6.60	6.93
25.	Plastering of walls	3.78	4.48	4.16	4.65
26.	Stucco Plastering	-	0.05	0.05	0.06
27.	Painting walls with snocem	0.32	0.70	0.72	0.76
28.	White wahing 3 coats	0.24	0.35	0.32	0.35

S.No.	Item of work	Single Storey residence	Two Storey flats	Three Storey flats	Four Storey flats
29.	Painting wood work	1.39	1.10	1.03	1.12
30.	A.C. Down fall pipes	0.40	0.16	0.15	0.17
31.	B.W. for stair case	-	0.09	0.08	0.09
32.	B.W. for parapet	-	0.20	0.18	0.22
33.	Plastering for steps	-	0.09	0.08	0.09
34.	G.I. Pipes and special	0.54	1.61	2.53	2.67
35.	Stone ware pipes	0.26	0.13	0.11	0.09
36.	I.W.C. for floors labour charges	-	0.15	0.19	0.24
37.	I.W.C. for G.F. labour charges	-	0.11	0.07	0.06
38.	S.W. bend	0.02	0.01	-	-
39.	Nahini trap	-	0.04	0.04	0.04
40.	S.W. Gully	0.10	0.07	0.04	0.03
41.	Gratings	0.02	0.07	0.02	0.03
42.	Inspection chambers	0.67	0.43	0.27	0.22
43.	A.C./C.I. soil pipes and special	1.76	0.84	0.80	1.07
44.	Ferro cement tank	-	1.35	1.86	1.81

S.No.	Item of work	Single Storey residence	Two Storey flats	Three Storey flats	Four Storey flats
45.	'U' shape drains and septic tank	2.55	0.23	0.14	0.12
46.	Electrical arrangements	3.11	2.35	3.17	2.47
47.	Cost of IWC/EWC, W. basins	0.67	0.25	0.23	0.26
48.	Ext. service connection	3.89	0.62	0.39	0.33
49.	Pavement around building	2.33	0.47	0.39	0.32
50.	Escalation charges	5	5	5	5
51.	Contingencies charges	2.50	2.50	2.50	2.50
52.	Supervision charges	12.50	12.50	12.50	12.50

TABLE 6.1

SPECIFICATIONS ADOPTED IN RESIDENTIAL BUILDINGS

Element	Single and Double Storey Construction	Four Storey (RCC Frammed Building)
(1)	(2)	(3)
Foundation	Excavation in ordinary soil cement concrete (5 cm thick) 1:5:10 with stone ballast in beds, brick work in cement mortar 1:6, 38 mm thick DPC consisting of cement concrete 1:2:4 with bitumen coating on top @ 1.7 kg/cm ² and sand filling (10 cm thick in plinth)	Excavation in ordinary soil 2m deep, RCC 1:2:4 column footings with cement concrete 1:4:8 with stone blast in beds, RCC 1:2:4 plinth beams finished smooth with 6 mm cement mortar 1:3, brick work in cement mortar 1:6, sand filling (10 cm) in plinth.
Frame		RCC 1:2:4 columns and beams finished smooth with 6mm thick cement mortar 1:3 including neeru finish.
Walling	Brick work in cement mortar 1:6 (23 cm thick load bearing and 11 cm thick partitions), RCC work 1:2:4 in lintels, beams and chajjas finished smooth with 6mm thick cement mortar 1:3	Brick work in cement mortar 1:6, RCC work 1:2:4 in lintel beams and chajjas finished smooth with 6 mm thick cement mortar 1:3.

Floor	38mm thick cement concrete 1:2:4 laid over cement concrete (11.5 cm thick) 1:5:10 with stone ballast.	8mm thick cement concrete 1:2:4 laid over 11.5cm thick C.C.1:5:10 with stone blast in ground floor and over RCC slab for upper floors.
Roof	R.C.C. slab with lime concrete terrace (Average 11 cm thick) with bitumen coating under-neath @ 1.7 Kg/sqm.	R.C.C. slab with lime concrete (Average 10 cm thick) with bitumen coating underneath @ 1.7 Kg/sqm and top finished with 40mm C.C. 1:2:4. Brick work in cement mortar 1:6 in parapet finished with C.C. 1:2:4 coping.
Joinery	Timber frames 100x75mm, 38 mm thick panelled shutters for doors and fully glazed shutters for windows.	Timber frames 100x75mm, 38 mm thick timber panelled shutters for doors and fully glazed shutters for windows.
Finishes	Levelling top of wall surfaces with cement mortar 1:3, 12 mm thick cement plaster 1:6 on smooth sides of walls 20 mm thick cement plaster (1:3) shirting and dado, internally white washed and externally colour washed, painting woodwork with an oil paint.	12mm thick cement plaster 1:4 on internal faces on the walls and 20 mm thick cement plaster 1:3 on external faces of walls including neeru finish internally white washed and externally colour washed, painting wood work with an oil paint.
Stairs	R.C.C. stairs in double storey	R.C.C. stairs
Fittings & fixtures	Precast R.C.C. shelves, M.S.roundbars in windows, raised cooking platform.	Precase R.C.C. 1:2:4 shelves, M.S. round bars in windows timber cupboards, raised cooking platforms.

Table - 6.2

Equations for materials requirement (A is the plinth area in M²)
in residential buildings

Equations

	Single Storey	Double Storey	Four storey* (RCC Framed)
Bricks (% Nos.)	2.26A + 66.8	2.15A + 63	-26.2+2.56A - 0.0096A ²
Cement (tonne)	0.153A + 0.57	0.145A + 0.54	0.182A - 0.35
Steel (kg)	21.3A - 314	21.97A - 305	-1491 + 92.0A - 0.36A ²
Sand (m ³)	0.47A - 7	0.376A - 5.6	0.361A - 0.38
Coarse aggregate			
i. 20mm and down (m ³)	0.176A - 0.21	0.178A - 0.21	0.295A - 0.75
ii. 40mm & down (m ³)	0.145A + 1.5	0.075A + 0.78	0.45 + 0.0027A + 0.0001A ²
Brick Aggregate (m ³)	0.113A - 0.83	0.056A - 0.42	0.021A + 0.01
Timber fraiges and shutters(m ³)	0.019A + 0.23	0.01A + 0.23	0.020A + 0.11
Timber shuttering (m ³)	0.0042A	0.0042A	0.009A - 0.03
Ballies (m)	0.504A	0.504A	0.009A + 0.14
Lime (Quigdal)	0.145A - 0.35	0.073A - 0.17	0.063A - 0.08
Surkhi (m ³)	0.052A - 0.37	0.026A - 0.18	0.01A
Bitumen $\frac{1}{2}$ K8)	1.836A - 9	0.918A - 4	0.90A - 2.41
Glass (m ²)	0.064A - 0.73	0.064A - 0.73	0.056A - 0.06
Primer (Lt)	0.068A	0.068A	0.061A + 0.56
Paint (Lt)	0.108A + 0.27	0.108A + 0.27	0.085A + 1.93

* Equations for superstructure only.

Table - 6.3
Equations for Labour Requirement
(A is the plinth area in m²)
in residential buildings

Labour	Equations		
	Single storey	Double storey	four storey* (R.C.C. Frames)
Mason (Days)	$1.335A+28$	$1.335A+26$	$1.67A-2$
Carpenter (Days)	$1.184A-9$	$1.194A-9$	$1.61A$
Painter (Days)	$0.089a$	$0.089A$	$0.09A$
Blacksmith(Days)	$0.269A-4$	$0.274A-4$	$-16+1.01A-0.004A^2$
Mazdoor (Days)	$4.769A+32$	$4.91A+33$	$5.49A-9.2$

* Equation for super-structure only.

Table - 6.4

**Equations for materials and labour requirement of
substructure in Four-storeyed (RCC Framed)
Residential Building**

Materials/Labour	Equations
Materials	
Cement (tonne)	$0.0204A - 0.014$
Sand (m ³)	$0.036A$
Coarse Aggregate 20mm and down (m ³)	$0.071a - 0.01$
Steel (kg)	$-171 + 10.46a - 0.041A^2$
Timber-shuttering (m ³)	$0.0007A$
Ballies (m)	$0.036A + 0.06$
Labour	
Mason (days)	$0.023A$
Carpenter (days)	$0.05A$
Blacksmith (days)	$-1.6 + 0.1A - 0.0003A^2$
Mazdoor (days)	$0.343A$

Table 6.5

Specifications and Systems of Services for Residential Buildings

S.No.	Element/Item of work	Specifications/system
WATER SUPPLY AND SANITARY SERVICES		
A. SPECIFICATIONS:		
1.	Water Closet	<p>i. For smaller tenements-one Indian type W.c. Complete with all accessories.</p> <p>ii. For bigger tenements (where two WCs are provided) - one Indian type W.c. and one European type W.C; complete with all accessories.</p>
2.	Soil pipe/waste	Sand cast iron pipe with lead pipe/vent pipe caulked joined with paint of any colour over a coat of primer
3.	Wash Basin	White vitreous china wash basin 630 x 450 mm with single C.P. brass pillar tap complete with all other accessories.
4.	Kitchen sink	white glazed fire clay kitchen sink 600 x 450 x 250 mm complete with all accessories.
5.	Mirror	600 x 450 mm bevelled edge mirror of superior glass with 6 mm thick asbestos sheet.
6.	Towel Rail	C.P. brass towel rail 750 x 20 mm.
7.	Water Pipe	G.I. pipe work with all fittings and finished with decorative paint.
8.	Bibcock/Stopcock	Brass bibcock/stop cock.
9.	connection Pipe	Lead connection pipe with brass unions.

S.No.	Element/Item of work	Specifications/system
10.	Shower Rose	C.P. brass shower rose of 100 mm diameter with 15 or 20mm inlet.
11.	Storage tank	R.C.C. storage tank

B. SYSTEM OF SERVICES:

1. Drainage system:

For four storeyed construction

i. 100 mm dia soil pipe vented with 50mm dia vent pipe.

ii. 75 mm dia waste pipe without any vent pipe

For double storeyed construction

100 mm dia soil pipe without any vent pipe and 50mm dia waste pipe without any vent pipe.

2. Overhead storage Tank:

For four storeyed construction

Single tank-270 Ltrs. capacity for each tenement.

For double storeyed construction

One tank-270 Ltrscapacity for two tenements in case of type I to type IV quarters and single tank for each tenement in case of type V quarter.

ELECTRICAL SERVICES

SPECIFICATIONS

1. Wiring
 2. Fittings
- PVC insulated Aluminium conductor in recessed conduit.
Quality and type of fittings are not selected, however, material and labour have been included in the data

Table 6.6
Material/Labour Requirements for Internal Water Supply and Sanitary Services
(Double Storeyed Residential Construction)

S.No.	Material/ Labour	Unit	Type-I Janta	Type-II	Type-III	Type-IV	Type-V
			25 M ²	37 M ²	56 M ²	84 M ²	122 M ²
Average Plinth Area							
1.	W.C. Seat*	Nos	1	1	1	2	2
2.	Wash Basin*	Nos	Nil	Nil	1	1	2
3.	Sin*	Nos	Nil	Nil	Nil	1	1
4.	Sand Cast Iron Pipe:						
	a) 100 mm dia	M	3.2	4.7	5.8	7.2	8.9
	b) 50 mm dia	M	2.40	3.9	8.2	8.6	18.00
5.	Cement	Tonne	0.21	0.28	0.37	0.37	0.51
6.	Sand	Cu.M.	0.61	0.84	1.08	1.08	1.41
7.	C. Agg.	Cu.M.	1.03	1.41	1.78	1.78	2.24
8.	Paint	Ltr.	2.00	2.70	3.70	4.90	6.90
9.	Primer	Ltr.	0.08	0.14	0.21	0.25	0.43
10.	Bricks	Nos.	100	135	215	215	350
11.	M.S.Holder Bat Clamp	Nos.	3.5	5.0	8.5	9.5	16.5
12.	Floor Trap	Nos.	1.0	2.0	3.0	4.0	5.0
13.	GI Pipe 15 mm	M	11.44	10.70	14.00	18.65	38.50
14.	GI Pipe 20 mm & above	M	Nil	10.43	18.65	21.53	40.00
15.	Bibcock 15 mm	Nos.	2	3	3	5	6

S.No.	Material/ Labour	Unit	Type-I Janta	Type-II	Type-III	Type-IV	Type-V
16.	Stopcock 15 mm	Nos. Nil	3	3	5	6	
17.	Pig Lead	Kg.	8.70	13.79	23.70	26.17	47.00
18.	Spun Yarn	Kg.	1.7	2.3	3.4	3.7	4.99
19.	Lead Connector 30 cm.	Nos.	Nil	Nil	Nil	1	1
20.	Shower Rose 100x100 mm	Nos.	1	1	1	2	2
21.	Tank (RCC) 270 Ltrs.	Nos.	0.5	0.4	0.5	0.5	1
22.	S.W.Pipe 100 mm - 50 mm dia	M	6.71	8.95	9.57	9.68	10.45
23.	Gully Trap 100x100mm	Nos.	1	1	1.5	1.5	2
24.	Mirror 600x450mm	Nos.	Nil	Nil	Nil	1	2
25.	Towel Rail 750x20 mm	Nos.	Nil	Nil	Nil	1	2
26.	Fitter	Days	3.71	5.68	8.63	11.51	18.85
27.	Mason	Days	2.29	3.27	4.87	6.45	8.83
28.	Painter	Days	0.44	0.62	0.79	1.15	1.7
29.	Beldar	Days	8.11	11.38	16.34	20.63	30.35

* Complete with all accessories and fittings.

Table 6.7
Material/Labour Requirements for Internal Water Supply and Sanitary Services
(Four Storeyed Residential Construction)

S.No.	Material/ Labour	Unit	Type-I Janta	42 M ²	Type-II	60 M ²	Type-III	70 M ²	Type-IV	112 M ²
Average Plinth Area										
1.	W.C. Seat*	Nos	1		1		1		2	
2.	Wash Basin*	Nos	Nil		Nil		1		2	
3.	Sink*	Nos	Nil		Nil		1		2	
4.	Sand Cast Iron Pipe:	M	8.10		8.30		8.90		10.40	
	a) 100 mm dia	M	3.90		4.30		4.40		3.90	
	b) 75 mm dia	M	2.80		3.10		3.50		3.90	
	b) 50 mm dia	Tonnes	0.19		0.24		0.25		0.33	
5.	Cement	Cu.M.	0.55		0.67		0.74		0.95	
6.	Sand	Cu.M.	0.79		1.12		1.13		1.16	
7.	C. Aggregate	Litres	4.17		4.36		4.94		5.96	
8.	Paint	Litres	0.30		0.30		0.32		0.44	
9.	Primer	Nos.	130		135		150		180	
10.	Bricks	Nos.	9.0		10.0		11.0		12.0	
11.	M.S.Holder Bat Clamp (100 to 50 mm)	Nos.	2		2		3		5	
12.	Trap 100 mm	Nos.	3.0		4.0		4.0		5.0	
13.	Bands (of various sizes)	Nos.	3.0		2.5		2.5		2.0	
14.	Junctions (of various sizes)	M	22.4		26.20		30.00		37.00	
15.	GI Pipe 15 mm	M	17.60		23.40		25.00		41.00	
16.	GI Pipe 20 mm & above	Nos.	3		3		4		5	
17.	Bibcock 15 mm	Nos.	3		3		4		5	

S.No.	Material/ Labour	Unit	Type-I Janta	Type-II	Type-III	Type-IV
18.	Stopcock 15 mm	Nos.	3	3	4	5
19.	Stopcock 20 mm	Nos.	1	1	1	1
20.	Pig Lead	Kg.	22.3	23.30	25.00	29.60
21.	Spun Yarn	Kg.	2.5	2.5	3.0	3.0
22.	Lead Connector 30 cm.	Nos.	1.0	1.0	1.0	2.0
23.	Shower Rose 100 mm	Nos.	1	1	1	2
24.	Tank (RCC) 270 Ltrs.	Nos.	1.0	1.0	1.0	1.0
25.	S.W.Pipe 100 mm - 150 mm dia	M	4.10	6.60	6.60	10.20
26.	Gully Trap 100x100mm	Nos.	0.50	0.50	1.0	1.0
27.	Mirror 600x450mm	Nos.	Nil	Nil	1.0	2.0
28.	Towel Rail 750x20 mm	Nos.	Nil	Nil	1.0	2.0
29.	Fitter	Days	9.90	11.50	13.8	20.60
30.	Mason	Days	3.60	4.20	6.0	7.8
31.	Painter	Days	1.00	1.00	1.00	1.80
32.	Beldar	Days	17.60	22.00	24.00	34.60

* Complete with all accessories and fittings.

Table - 6.8

Material and Labour Requirements for Electrical Services (Internal) for Various Categories of Residences

S.No.	Item/Material/ Labour	Unit	MIG	LIG	Janata	Type	Type	Type	Type
Average Plinth Area Sub Head-Wiring		m ²	100.0	58.0	25.0	112.0	70.0	60.0	42.0
1.	5 Amp. Tumbler Switch (Single Pole).	Nos	28.8	17.4	9.7	23.0	17.0	14.7	10.9
2.	5 Amp. Tumbler Switch (Double Pole).	"	1.5	1.5	1.1	1.0	Nil	0.4	0.7
3.	15 Amp. tumbler Switch	"	4.0	2.0	Nil	3.0	1.3	1.0	Nil
4.	5 Amp. Socket	"	6.8	4.0	2.0	5.0	3.3	3.0	2.0
5.	15 Amp. Socket	"	4.0	2.0	Nil	3.0	1.3	1.0	Nil
6.	1.5 Sq.mm PVC Insulated Al.conductor Single core cable	M	300.0	174.6	124.4	260.9	184.3	146.4	121.7
7.	2.5 Sq.mm PVC Insulated Al.Conductor Single Core cable	M	Nil	12.4	2.8	8.4	18.1	17.8	18.6
8.	4-6 Sq.mm PVC Insulated Al. Conductor single Core Cable	M	116.0	62.4	11.6	100.5	35.0	35.0	Nil
9.	Conduit Heavy Gauge 19mm	M	145.0	93.0	49.0	125.0	77.0	68.0	53.0
10.	Conduct (H.G.) 25mm	M	12.6	Nil	Nil	16.2	9.3	7.1	Nil
11.	Socket for 19 mm Conduit	Nos	15.0	33.0	20.0	46.0	30.0	28.0	19.0
12.	Inspection Bend 19 mm	"	38.0	24.0	12.0	32.0	20.0	17.0	13.0
13.	Socket for 25 mm Conduit	"	4.0	Nil	Nil	1.0	1.0	1.0	Nil
14.	Inspection Bend 25 mm	"	1.0	Nil	Nil	1.0	1.0	1.0	Nil
15.	Saddles	Nos	375.0	226.0	116.0	365.0	212.0	192.0	132.0
16.	I.C.Box 75x75x60mm	"	41.0	25.0	12.0	31.0	20.0	17.0	12.0
17.	I.C.Box 200x150x100mm	"	5.1	3.0	1.3	4.7	3.6	3.0	2.0
18.	Phenolic Laminated/Bakelite sheet	M2	0.46	0.28	0.13	0.38	0.26	0.22	0.15
19.	Junction Box 1 way	Nos	23.1	14.4	7.6	19.0	14.7	11.4	8.9

S.No.	Item/Material/ Labour	Unit	MIG	LIG	Janata	Type	Type	Type	Type
20.	Junction Box w ways	Nos	1.5	1.5	1.1	1.0	0.4	0.4	0.7
21.	Ceiling rose 2 plate	"	24.6	15.0	8.8	20.0	14.8	12.0	9.6
22.	Iron Screws 35 mm	"	739.0	436.0	231.10	656.0	401.0	352.0	249.0
23.	Iron Screws 20mm	"	387.0	214.0	93.0	279.0	161.0	153.0	101.0
24.	Washers	"	184.0	110.0	51.0	145.0	92.0	80.0	55.0
	LABOUR								
25.	Wireman	Day	18.8	11.2	6.0	16.5	10.4	9.3	6.3
26.	Mason	"	26.4	17.3	8.9	24.8	15.7	13.7	9.6
27.	Khalasi	"	47.4	28.5	14.9	41.4	26.0	22.7	15.9
28.	Painter	"	0.3	0.2	0.1	0.2	0.2	0.1	0.1
	SUB HEAD-FITTINGS								
29.	L.Type Cast Al.anodized wall Bracket and Brass Holder (Complete)	Nos	13.5	8.5	6.2	8.0	8.0	5.8	5.3
30.	Circular Ceiling Fitting Complete	"	1.7	1.9	Nil	3.0	1.7	1.0	Nil
31.	Bulk head fitting (complete)	"	1.2	1.8	1.3	1.7	1.3	1.8	1.8
32.	Iron Screws 20mm	"	49.0	33.0	20.0	38.0	34.0	25.0	24.0
	LABOUR								
33.	Wireman	Day	0.8	0.6	0.3	0.7	0.5	0.4	0.4
34.	Khalasi	"	0.8	0.6	0.3	0.7	0.5	0.4	0.4
	SUB-HEAD-I.C. BOARDS, SWITCHES & DISTRIBUTION BOARDS								
35.	15 Amp.SP.and N Switch Fuse unit	Nos	4.2	3.7	1.6	5.3	3.3	3.0	1.9
36.	2 Way MC DB 15 Amp/Way	Nos	1.0	1.0	Nil	Nil	1.7	1.5	1.0
37.	4 Way MC DB 15 Amp/Way	Nos	1.0	Nil	Nil	1.4	Nil	Nil	Nil
38.	Bolts & Nuts 25x3 mm	Nos	24.0	18.0	6.0	19.0	12.0	12.0	11.0
39.	Wireman	Day	0.5	0.4	0.1	0.4	0.3	0.3	0.2
40.	Khalasi	Day	0.5	0.4	0.1	0.4	0.3	0.3	0.2

Table - 6.9

Material and labour inputs for various elements and sub-elements for two and four-storeyed residential buildings (load bearing (walls))

For 10M² Plinth Area

Figs. in lines a_m are for four storeyed dwellings. Figs. in line b_m are for two storeyed dwellings.

S.No.	Material or Labour	Element (i) Foundation and Plinth										(ii) Walling			(iii) Structural floor		
		Excavation	Sand filling	Bed Con-crete	Brick Work	Damp Proof course	Brick Work	RCC in lintels beams and chajjas	Rein force-ment	RCC (Con-crete Work)	Form Work	Slabs rein-force					
1.	Cement	(a) ton	-	-	0.09	0.08	0.005	0.3	0.133	-	-	0.44	-	-	-	-	
		(b)	-	-	0.13	0.09	0.01	0.3	0.122	-	-	0.44	-	-	-	-	
2.	Sand	(a)M ³	-	0.2	0.32	0.34	0.007	1.3	0.19	-	-	0.64	-	-	-	-	
		(b)	-	0.4	0.46	0.39	0.013	1.3	0.18	-	-	0.64	-	-	-	-	
3.	Coarse Aggregate	(a)M ³	-	-	0.61	-	0.013	-	0.34	-	-	1.113	-	-	-	-	
		(b)	-	-	0.87	-	0.03	-	0.31	-	-	1.113	-	-	-	-	
4.	Steel	Kg	-	-	-	-	-	-	-	-	51.0	-	-	100.0	-		
		(b)	-	-	-	-	-	-	-	-	46.0	-	-	100.0	-		
5.	Timber	(a)m ³	-	-	-	-	-	-	0.0144	-	-	-	-	0.0304	-		
		(b)	-	-	-	-	-	-	0.0137	-	-	-	-	0.0304	-		

6.	Ballies	(a)m (b)	-	-	-	-	-	-	-	1.20	-	-	-	3.71	-
			-	-	-	-	-	-	-	1.13	-	-	-	3.71	-
7.	Bricks	(a) No. (b)	-	-	627	-	-	2371	-	-	-	-	-	-	-
			-	-	716	-	-	2371	-	-	-	-	-	-	-
8.	Bitumen	(a)Kg (b)	-	-	-	-	0.66	-	-	-	-	-	-	-	-
			-	-	-	-	1.33	-	-	-	-	-	-	-	-
9.	Mason	(a)Day (b)	-	0.07	0.9	0.035	5.6	0.24	-	0.093	-	-	-	-	-
			-	0.1	0.01	0.07	5.1	0.22	-	0.93	-	-	-	-	-
10.	Carpenter	(a)Day (b)	-	-	-	-	-	0.72	-	-	-	-	4.18	-	-
			-	-	-	-	-	0.68	-	-	-	-	4.18	-	-
11.	Blacksmith	(a)Day (b)	-	-	-	-	-	-	0.50	-	-	-	-	0.95	-
			-	-	-	-	-	-	0.45	-	-	-	-	0.95	-
12.	Painter	(a)Day (b)	-	-	-	0.008	-	-	-	-	-	-	-	-	-
			-	-	-	0.016	-	-	-	-	-	-	-	-	-
13.	Belder	(a)Day (b)	1.10	0.51	1.20	1.9	0.035	10.62	2.19	0.50	5.85	4.2	0.95	4.2	0.95
			0.99	0.94	0.09	1.73	0.07	10.08	1.87	0.45	5.25	4.2	0.95	4.2	0.95

Table 6.9 (Continued)

Material and labour inputs for various elements and sub-elements for two and four-storied residential buildings (load bearing (walls))

S.No.	Material or labour	Element (iv) Staircase		(v) Doors			(vi) Windows			
		Sub Ele- ment Unit	RCC (Conc- rete)	Reinforce ment	Frame	Shuter	Holdfast	Frame	Shutter	Holdfast
1. Cement	(a)ton	0.019	-	-	-	0.007	-	-	0.006	-
	(b)	0.019	-	-	-	0.007	-	-	0.006	-
2. Sand	(a)m ³	0.028	-	-	-	0.014	-	-	0.013	-
	(b)	0.028	-	-	-	0.014	-	-	0.013	-
3. Coarse Aggregate	(a)m ³	0.049	-	-	-	0.027	-	-	0.025	-
	(b)	0.049	-	-	-	0.027	-	-	0.025	-
4. Steel	(a)Kg	-	-	7.5	-	2.4	-	-	2.3	22.4
	(b)	-	-	7.5	-	2.4	-	-	2.3	22.4
5. Timber	(a)m ³	-	0.0012	-	0.38	0.052	-	0.04	0.021	-
	(b)	-	0.0012	-	0.38	0.052	-	0.04	0.021	-
6. Ballies	(a)m	-	0.03	-	-	-	-	-	-	-
	(b)	-	0.03	-	-	-	-	-	-	-
7. Glass	(a)M ²	-	-	-	-	-	-	-	0.47	-
	(b)	-	-	-	-	-	-	-	0.47	-

8. Mason	(a)Day	0.11	-	-	-	-	0.19	-	-	0.17	-
	(b)	0.11	-	-	-	-	0.19	-	-	0.17	-
9. Carpenter	(a)Day	-	0.12	-	0.4	2.5	-	0.42	1.23	-	0.13
	(b)	-	0.12	-	0.4	2.5	-	0.42	1.23	-	0.13
10. Blacksmith	(a)Day	-	-	0.07	-	-	0.18	-	-	0.17	0.65
	(b)	-	-	0.07	-	-	0.18	-	-	0.17	0.65
11. Beldar	(a)Day	0.27	0.07	0.07	0.2	0.68	0.23	0.21	0.37	0.22	0.20
	(b)	0.27	0.07	0.07	0.2	0.68	0.23	0.21	0.37	0.22	0.20

Table 6.9 (Continued)

Material and labour inputs for various elements and sub-elements for two and four-storeyed residential buildings (load bearing (walls))

S.No.	Material or labour	Element (vii) Flooring		(viii) Roofing		(ix) Finishes			
		Sub Ele- ment Unit	40mm (Conc- rete) Layer	Skirt -ing	Lime concrete	Bitumen painting	15mm plaster	12mm plaster	White/ Colour Wash
1.	Cement	(a)ton	0.13	0.025	0.014	-	0.086	0.072	-
		(b)	0.13	0.025	0.028	-	0.092	0.077	-
2.	Sand	(a)m ³	0.155	0.049	0.029	0.013	0.366	0.306	-
		(b)	0.155	0.049	0.058	0.026	0.394	0.33	-
3.	Coarse Aggregate	(a)m ³	0.31	-	-	-	-	-	-
		(b)	0.31	-	-	-	-	-	-
4.	Brick Aggregate	(a)m ³	-	-	0.21	-	-	-	-
		(b)	-	-	0.42	-	-	-	-
5.	Lime	(a)Qt1	-	-	0.33	-	-	-	0.153
		(b)	-	-	0.66	-	-	-	0.176
6.	Surki	(a)m ³	-	-	0.10	-	-	-	-
		(b)	-	-	0.20	-	-	-	-

7. Brick tiles	(a)No. (b)	- -	- -	75.00 150.00	- -	- -	- -	- -	- -
8. Glass	(a)m ² (b)	0.46 0.46	- -	- -	- -	- -	- -	- -	- -
9. Bitumen	(a)Kg (b)	- -	- -	- -	3.55 7.10	- -	- -	- -	- -
10. Primer	(a)Ltr (b)	- -	- -	- -	- -	- -	- -	- -	0.51 0.51
11. Paint	(a)Ltr (b)	- -	- -	- -	- -	- -	- -	- -	0.85 0.85
12. Mason	(a)Day (b)	1.45 1.45	0.33 0.33	0.40 0.80	- -	1.81 2.01	1.61 1.73	- -	- -
13. Painter	(a)Day (b)	- -	- -	- -	0.03 0.06	- -	- -	- -	0.53 0.53
14. White washer	(a)Day (b)	- -	- -	- -	- -	- -	- -	0.92 1.06	- -
15. Beldar	(a)Day (b)	2.15 2.15	0.47 0.47	2.22 4.44	0.08 0.16	2.86 3.07	2.41 2.59	0.92 1.06	0.53 0.53

Table 6.9 (Continued)

Material and labour inputs for various elements and sub-elements for two and four-storeyed residential buildings (load bearing (walls))

S.No.	Material/Labour	Element (x)	Water Supply & Sanitary Services	Soil/waste vent/drain-age pipes	Fittings	Water supply
		Sub-element Unit				
1.	W.C. Seat (complete with all accessories & fittings)	No.	0.18	-	-	-
2.	Wash Basin	NO.	0.18	-	-	-
3.	Sand Cast Iron Pipe: (a) 100mm (b) 50mm	M	-	1.04	-	-
		M	-	1.46	-	-
4.	Cement	Tgne	-	0.065	Nil	Nil
5.	Sand	m ³	-	0.19	Nil	Nil
6.	Coarse Aggregate	m	-	0.32	Nil	Nil
7.	Paint	Litr	-	0.47	0.04	0.04
8.	Primer	Litr	-	0.020	0.02	0.02
9.	Bricks	No.	-	38	-	-
10.	M.S. Holder Bat clamp	No.	-	38.00	-	-
11.	Floor Trap	No.	-	0.54	-	-
12.	G.I. pipe 15mm	M	-	-	-	2.5
13.	G.I. Pipe 20mm and above	M	-	-	-	3.3
14.	Bibcock 15mm	No.	-	-	-	0.54
15.	Stopcock 15mm	No.	-	-	-	0.54
16.	Pig lead	Kg	-	4.2	-	-
17.	Spun Yarn	Kg	-	0.61	-	-
18.	Lead Connector 30 cm	No.	-	-	-	0.18

19. Shower rose 100m	No.	0.18	-	-
20. Tank (RCC)270 Ltrs	No.	-	-	0.1
21. S.W. Pipe 100mm - 150 mm	M	-	1.7	-
22. Gully Trap 100 mm x 100 mm	No.	-	0.7	-
23. Fitter	Day	0.28	0.57	0.69
24. Mason	Day	0.15	0.73	Nil
25. Painter	Day	0.045	0.30	0.07
26. Beldar	Day	0.39	2.00	0.56

* computation has been based on medium size tenement
(Plinth area 56m²) double storeyed construction.

Table 6.9 (Continued)

Material and labour inputs for various elements and sub-elements for two and four-storeyed residential buildings (load bearing (walls))

S.No.	Material/Labour	Element (xi)	Internal Fittings	Electrification
		Sub-Element Unit		I.C. Boards Switches and Distribution Boards
1.	5Amp. tumbler switch (single pole)	No.	2.4	-
2.	5Amp. tumbler switch (double pole)	No.	0.1	-
3.	15 Amp. tumbler switch (double pole)	No.	0.19	-
4.	5 Amp. Socket	No.	0.47	-
5.	15 Amp. Socket	No.	0.19	-
6.	PVC insulated Al.conductor single	M		
	Core Cable:			
	a. 1.5 Sq.mm.		26.3	-
	b. 2.5 Sq.mm.		2.6	-
	c. 4.6 Sq.mm.		5.0	-
7.	Conduit 15mm (H.G.)	M	11.0	-
8.	Conduit 25mm (H.G.)	M	1.33	-
9.	Socket 19mm & 25 mm	No.	4.7	-
10.	Inspection bends 19mm & 25 mm	No.	3.1	-
11.	Saddles or staples	No.	30.00	-
12.	I.C.Box 75 x 75 x 60 mm	No.	2.9	-
13.	I.C.Box 200 x 150 x 100 mm	Ng	5.4	-
14.	Phenolic laminated sheet	M ²	0.04	-
15.	Junction Boz	No.	2.2	-
16.	Ceiling rose(2 plate)	No.	2.1	-

S.No.	Material/Labour	Element (xi)	Internal	Electrification
		Sub- Element Unit	Wiring Fittings	I.C. Boards Switches and Dis- tribution Boards
17.	"L" type cast Al.anodized wall bracket brass socket (Complete)	No.	1.14	-
18.	Circular ceiling fitting (complete)	No.	0.24	-
19.	Bulk Head Fitting (complete)	No.	0.19	-
20.	15Amp. S.P. & N. Switch Fuse Unit	No.	-	0.47
21.	2 Way M.C.D.B. 15 Amp./Way	No.	-	0.24
22.	Wireman	Day	0.07	0.04
23.	Mason	Day	-	-
24.	Painter	Day	-	-
25.	Khalasi	Day	0.07	0.04

* Computation has been based on tenement with 70m² plinth area.

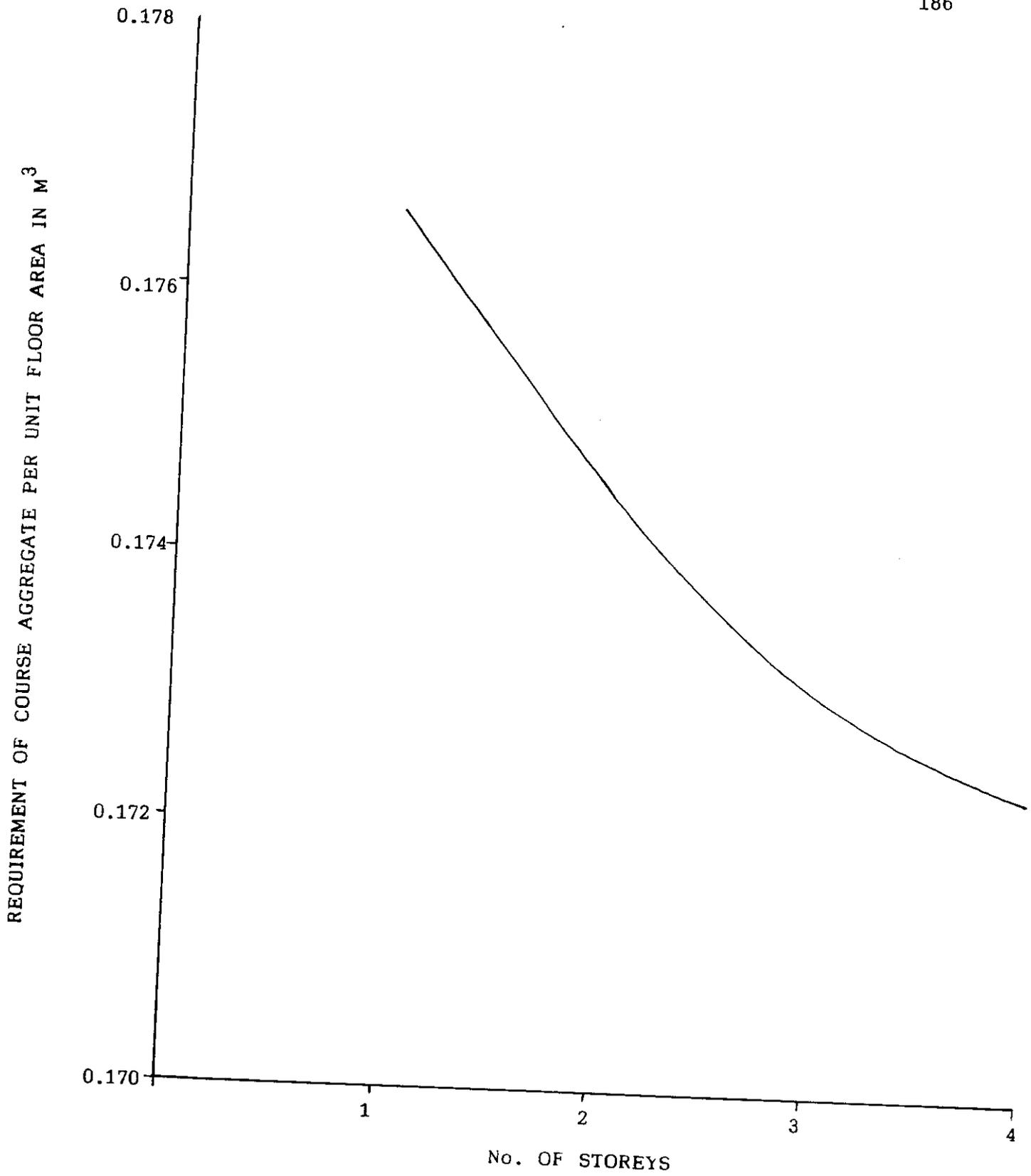


Fig. 6.1. VARIATION OF COARSE AGGREGATE REQUIREMENT WITH No. OF STOREYS

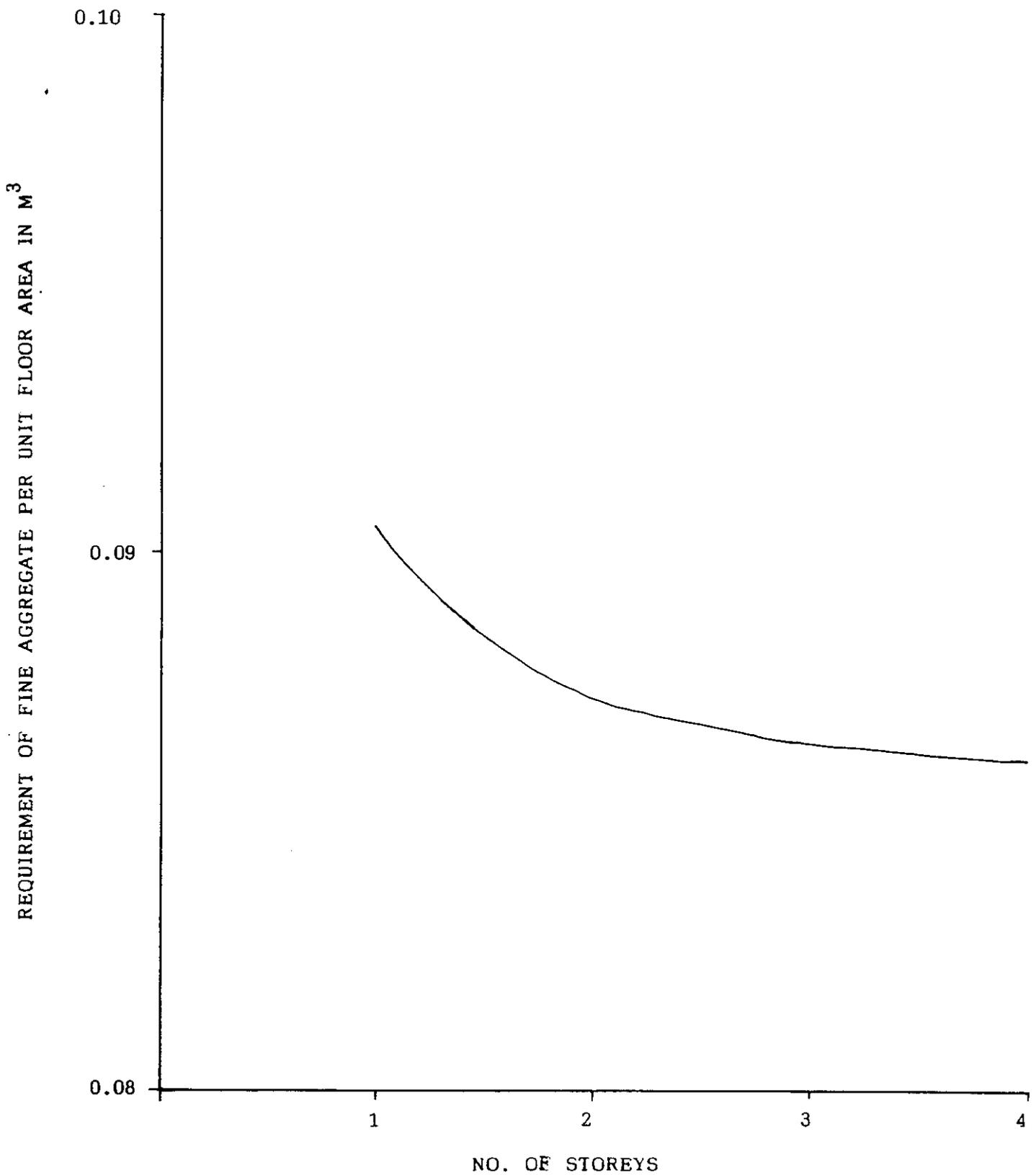


Fig. 6.2 VARIATION OF FINE AGGREGATE REQUIREMENT WITH UNIT No. OF STOREYS

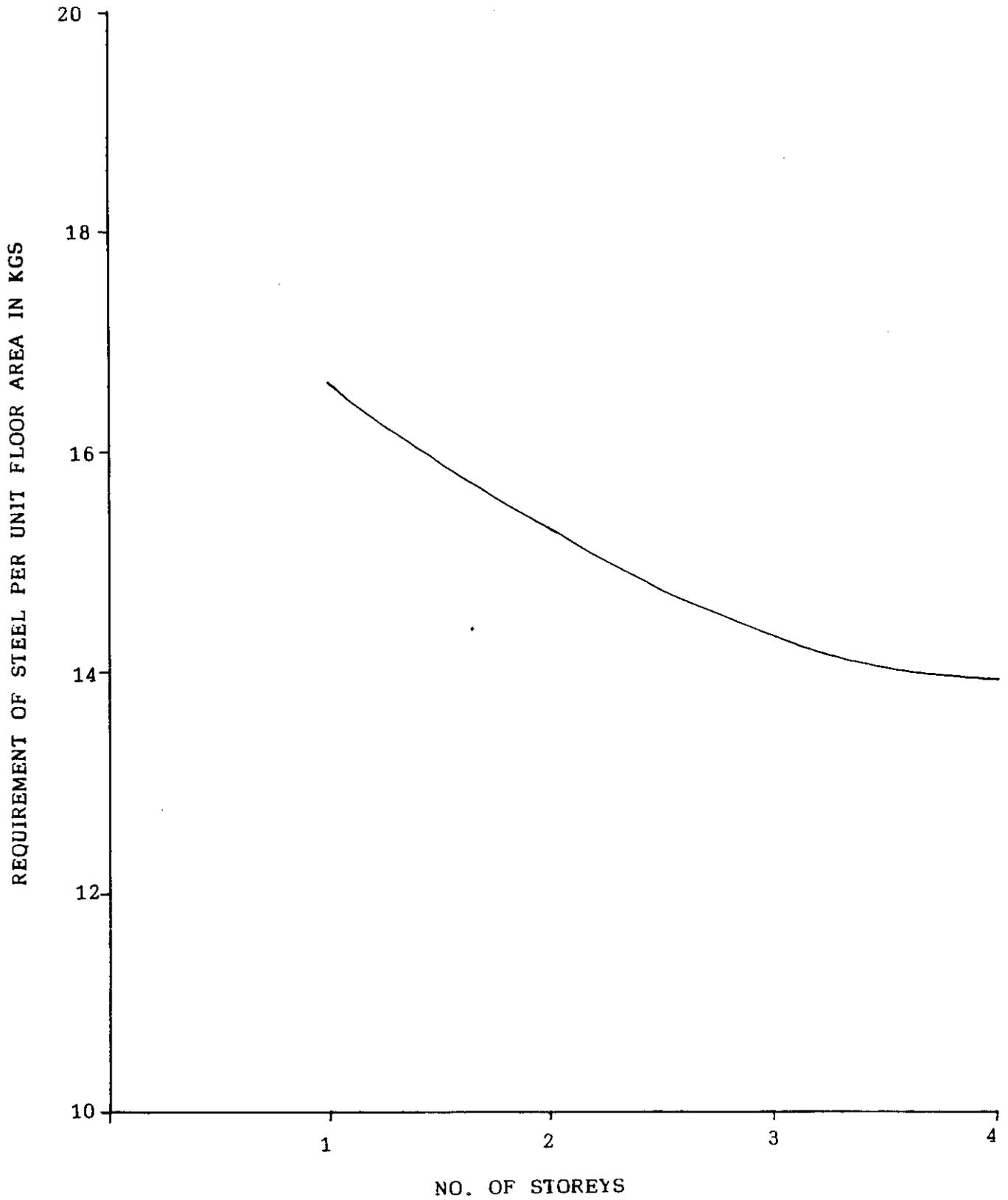


Fig. 6.3 VARIATION OF STEEL REQUIREMENT WITH UNIT
No. OF FLOORS

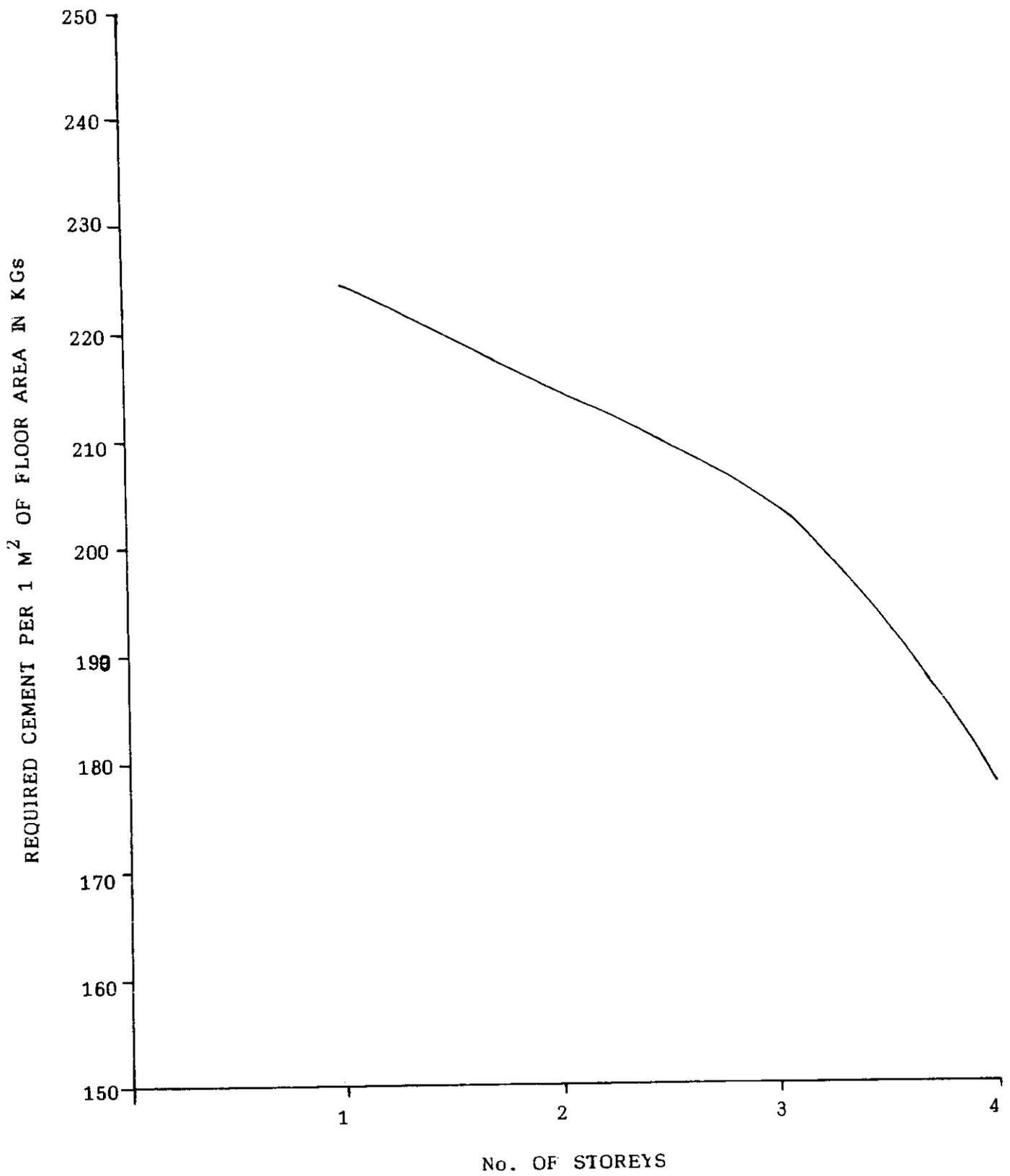


Fig. 6.4 VARIATION OF CEMENT REQUIREMENT WITH UNIT NO. OF FLOORS

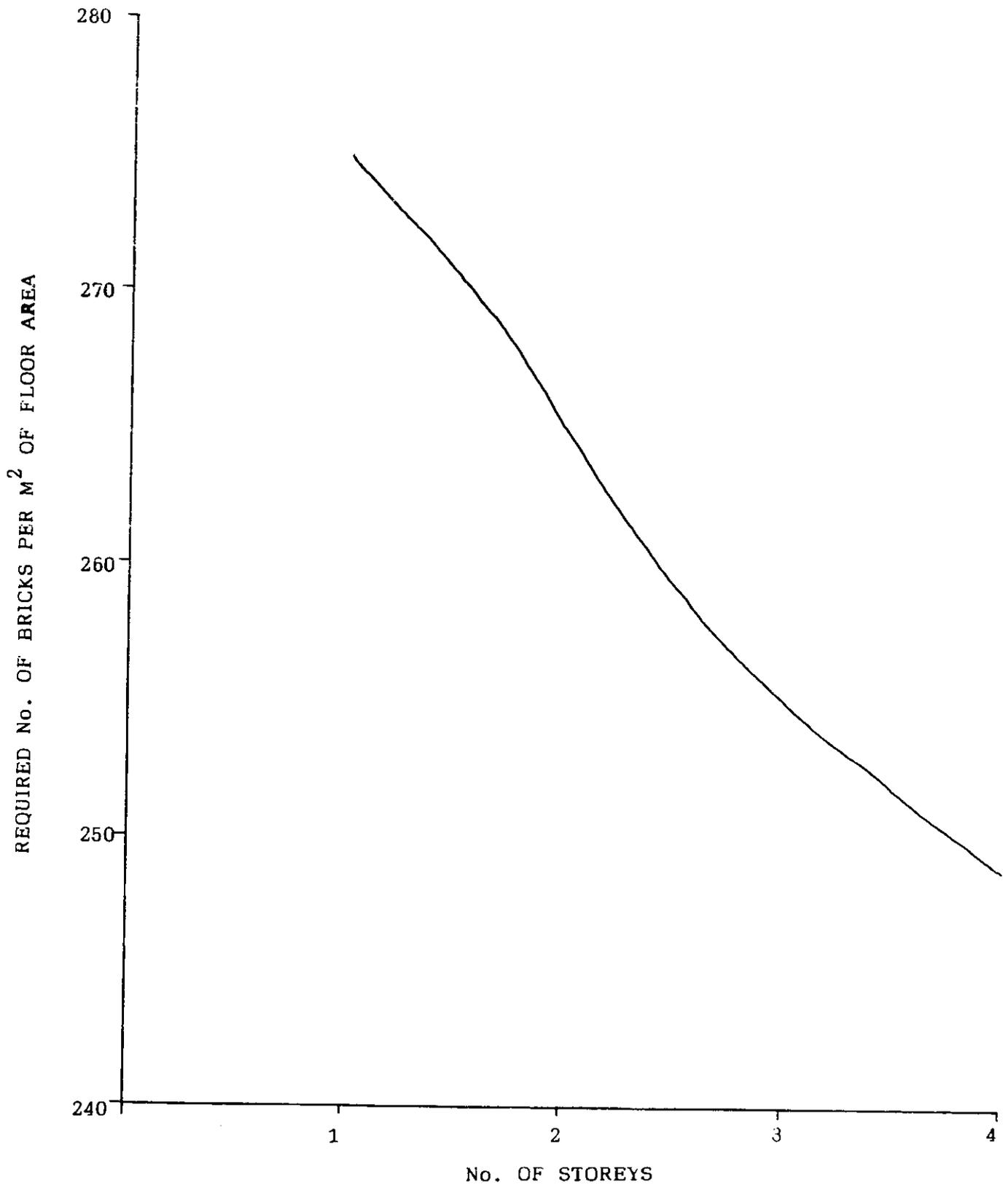


Fig. 6.5 VARIATION OF BRICKS REQUIREMENTS WITH UNIT No. OF FLOORS

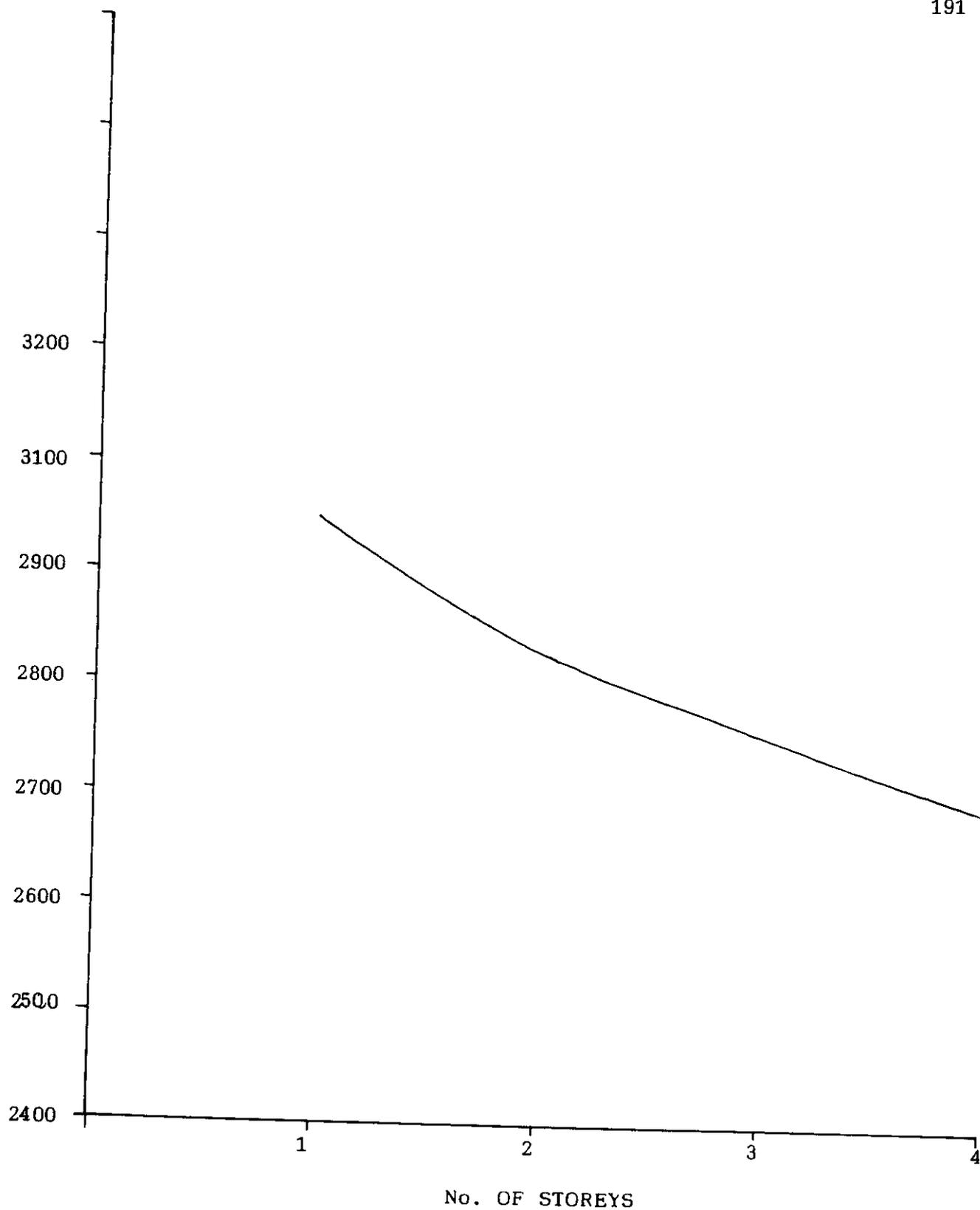


Fig. 6.6 VARIATION OF PLINTH AREA RATE WITH UNIT
No. OF FLOORS

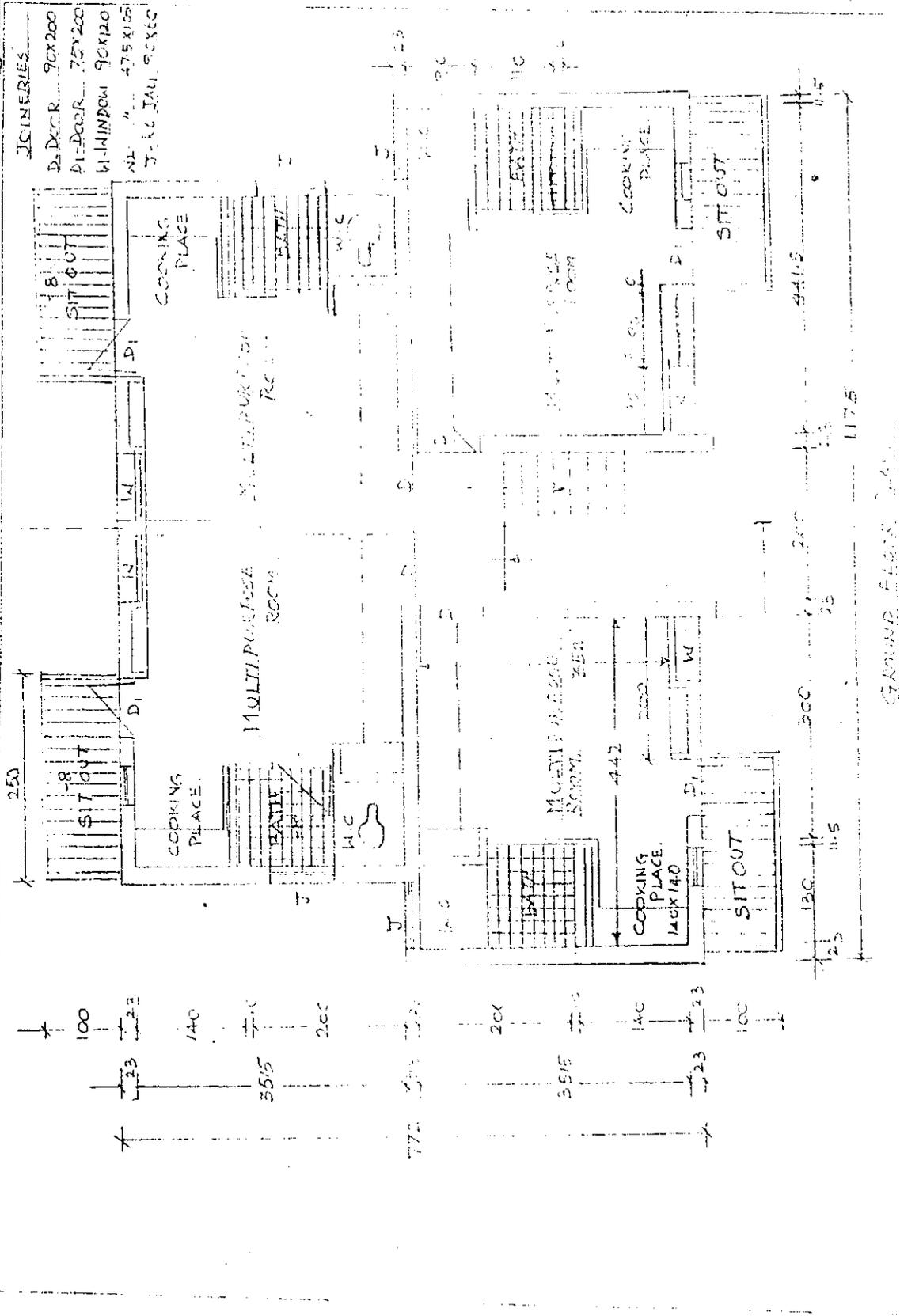
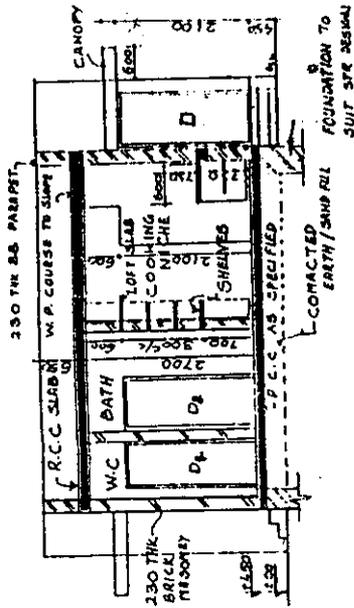
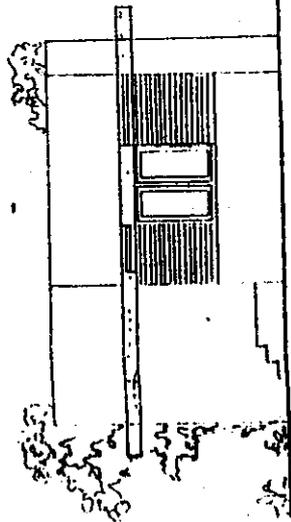


Fig. 6.9 TAMILNADU HOUSING BOARD FLAT TYPE [E] FOR L.I.G. GROUP

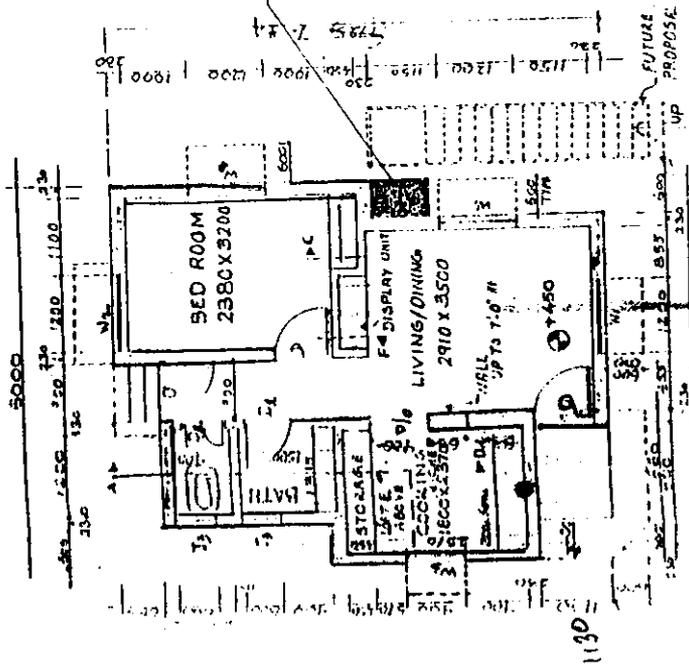
PLINTH AREA OF UNIT = 21.98M² SCALE 1:50



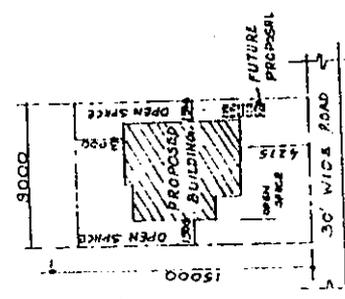
SECTION AA



ELEVATION



ROOF SLAB PROTECTION ABOVE FOR FUTURE STAIRCASE



PLAN SITE PLAN 200

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23/9/91
2000

D. Sivaraj, B.E., M.E.
Assistant Executive Engineer
Coimbatore Housing Unit
COMBATORE-641012

Fig. 6.10 Single Storey Residential Flat

CHAPTER - 7

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

7.1. CONCLUSIONS

The following conclusions are drawn from this studies:

- i. The economical construction of residential flats can be programmed keeping in mind the previous experience and with precautionary measures using the rules and regulations stipulated by the government and National Building code.
- ii. The Tables and graph prepared in this study will be useful for the future residential flat promoters
- iii. From the analysis made in this investigation it is found that the required quantities of building materials and the cost of construction per unit floor area decrease as the number of storeys increases.

7.2. SUGGESTIONS FOR FUTURE WORK

- i. Multistoreyed residential flats using RCC frame work shall be designed and the cost compared with load bearing structure for a given floor area.
- ii. The residential flats may be analysed using flat plate and flat slab system of roof slab and cost compared with convential RCC slab.

iii. The low cost building materials like prefabricated structure and slab may be used for residential flats and cost compared with conventional types of construction.

APPENDIX - A

Construction of D2 Type flat Item wise quantity of work

S.No.	Description	For 2 storey	For 3 storey	For 4 storey	Remarks
1.	Earth work excavation	170m ³	170m ³	170m ³	
2.	Cement concrete 1:5:10 using 40mm metal	34.00m ³	34.00m ³	34.00m ³	
3.	R.R masonry in CM 1:5	93.00m ³	93.00m ³	93.00m ³	
4.	B.W. in CM 1:5 for basement	6.00m ³	6.00m ³	6.00m ³	
5.	Sand filling	66.00m ³	66.00m ³	66.00m ³	
6.	Plinth beam in RCC 1:2:4	4.50m ³	4.50m ³	4.50m ³	
7.	B.W. in CM 1:6 for superstructure	117.50m ³	178.50m ³	247.00m ³	
8.	Brick Partition wall 115 mm thick	126.00m ²	189.00m ²	317.00m ²	
9.	Brick Partition wall 75 mm thick	38.00m ²	57.00m ²	76.00m ²	
10.	R.C.C. 1:2:4 for slab	43.00m ³	64.50m ³	90.00m ³	
11.	Precast cupboard slab 1:2:4 using 10mm chips.				
a.	20mm thick	40m ²	60m ²	80m ²	
b.	40mm thick	10m ²	15m ²	20m ²	
c.	50mm thick	4m ²	6m ²	8m ²	
12.	Precast RC jally 40mm thick	4.80m ²	7.20m ²	9.60m ²	
13.	Providing form work for concrete				
a.	For plinth beam	30m ²	30m ²	30m ²	
b.	For Slabs and beams etc	400m ²	600m ²	830m ²	
c.	For Sunshade, facia etc	16m ²	24m ²	32m ²	
14.	T.W. wrought and putup	2m ³	3m ³	4m ³	

15. S & F T.W. Shutters

i. Panelled shutters

a. 90 x 200 cm	26.00m ²	38.90m ²	51.80m ²
b. 75x 200 cm	42.10m ²	65.00m ²	86.00m ²

ii. Glazed shutters

a. Overall height 120cm	21.60m ²	32.40m ²	43.20m ²
b. Overall height 105cm	6.30m ²	9.40m ²	12.50m ²

16. S & F M.S. hold fasks	454 Nos	678 Nos	892 Nos
17. S & F 12mm M.S. window bars	34 m ²	51m ²	68m ²
18. Flooring concrete 1:8:16	9m ³	9m ³	9m ³
19. Floor finish with CM 1:4, 20mm	90m ²	130m ²	173m ²
20. Weathering course	10.50m ³	10.50m ³	10.50m ³
21. Hyd.pressed Tiler over roof in in CM 1:3, 20mm	172m ²	172m ²	172m ²
22. Mosaic tiles	20m ²	30m ²	40m ²
23. Dwelling walls	100m ²	150m ²	200m ²
24. Supply & fabrication of steel			
a. MS rods	1.50M.T.	2.10M.T.	2.75M.T.
b. RTS rods	2.50M.T.	3.50M.T.	4.50M.T.
25. Plastering in CM 1:5, 12mm Tk.	1600m ²	2350m ²	3200m ²
26. Stucco plastering for elevation	12 m ²	17 m ²	22 m ²
27. Painting walls with snocem	530 m ²	850 m ²	1100 m ²
28. White washing 3 coats	1500 m ²	2200 m ²	2900 m ²
29. Painting nnew wood work	250 m ²	370 m ²	490 m ²
30. SF 100mm dia AC rain fall pipe	26 m	40 m	54 m
31. Brick work in cm 1:4 for S/C steps	0.70 m ³	1 m ³	1.40 m ³

32. Parapet BW for hand rail in cm 1:4	12 m ²	17 m ²	25 m ²
33. Plastering in cm 1:4 20 mm thick	17 m ²	25 m ²	33 m ²
34. S&F G.I. Pipes and special	13,000	19,500	26,000
35. S&F S.W. Pipe	35 m	50 m	70 m
36. L&C for fixing I.W.C. in floor slab	4 Nos.	8 Nos.	12 Nos.
37. L/C for fixing IWC in G.F.	4 Nos.	4 Nos.	4 Nos.
38. S&F S.W. bend 100 mm dia	4 Nos.	4 Nos.	4 Nos.
39. S&F 63 mm dia Nahini trap	8 Nos.	12 Nos.	16 Nos.
40. S&F 150x100 mm S.W. Gully	4 Nos.	4 Nos.	4 Nos.
41. S&F 75mm C.I. grating	8 Nos.	12 Nos.	16 Nos.
42. Construction of inspection chamber	4 Nos.	4 Nos.	4 Nos.
43. S&F AC/C.I. Soil pipe and special	6800/-	10200/-	16600/-
44. Ferro cement tank	8 Nos.	12 Nos.	16 Nos.
45. Construction of "U" shape drain	20 M	20 M	20 M
46. Providing electrical arrangements	27000/-	40500/-	54000/-
47. Cost of IWC, EWC, wash basin etc.	2000/-	3000/-	4000/-
48. Extl house service connection	5000/-	5000/-	5000/-
49. Providing pavement	5000/-	5000/-	5000/-
50. Escalation charges	10%	10%	10%
51. Contingencies charges	2.5%	2.5%	2.5%
52. Supervision charges	12.5%	12.5%	12.5%
Floor area	261.20 m ²	391.80 m ²	522.40 m ²

APPENDIX - B

Tamil Nadu Housing Board (Residential Unit)

ABSTRACT ESTIMATE (Single Floor)

S.No.	Quantity	Description of work	Rate	Per	Amount
1.	36.50 m ³	E.W. excavation for foundation	13.92	m ³	508.08
2.	5.70 m ³	C.C. 1:5:10 for foundation	550.18	"	3136.03
3.	15.3 m ³	R.R. in cm 1:5 for foundation	568.01	"	8690.55
4.	3.50 m ³	B.W. in cm 1:5 for basement	902.63	"	1988.04
5.	33.00 m ³	Filling with sand	111.90	"	3692.70
6.	18.70 m ³	B.W. in cm 1:6 for super structure	713.83	"	13348.62
7.	20.00 m ²	Brick partition wall in cm 1:6 for 115mm thick	77.01	m ²	1540.20
8.	4.0 m ²	Brick partition wall in cm 1:6 for 75 mm thick	54.36	m ²	217.44
9.		R.C.C. 1:2:4 using 20 mm Jelly			
	1.00 m ³	a) Foundation of basement	1109.76	m ³	1109.76
	1.00 m ³	b) Ground floor	1118.76	"	1118.76
10.		Precast C/B slabs in C.C. 1:2:4			
	8.40 m ²	a) 20 mm thick slabs	90.04	m ²	756.34
	1.05 m ²	b) 40 mm thick slabs	113.06	m ²	118.71
11.	0.75 m ²	Precast R.C. jally 1:2:4 50mm thick	176.88	m ²	132.66
12.	3.8m ²	Casting pre-cast chanel units	153.14	m ²	581.93
13.		Providing Form work			
	11.00m ²	a. Large quantity	113.75	m ²	1251.25
	6.70m ²	b. Small quantity	129.23	m ²	865.84
	3.40m ²	c. Plinth beam	56.87	m ²	193.36

14.	0.29m ³	Best Indian Wood wrought and putup for Door and Windows	23,100.00	m ³	6699.00
15.		S&F of C.W. shutters Door			
		1. Single Leaf fully paneled Door shutters			
	4.68m ²	a. 90cm x 200cm	904.94	m ²	4235.12
	2.54m ²	b. 75cm x 200cm	093.67	m ²	4235.12
		2. Glazed window shutter			
	4.61m ²	a. Overall height of 120cm	590.44	m ²	2,721.93
	0.72m ²	b. Overall height of 105cm	583.00	m ²	419.76
16.	6.80m ²	S & F of 12mm dia MS rods	129.91	m ²	883.39
17.	50 Nos	S & F of MS hold fast	3.00	each	150.00
18.	2.10m ³	Flooring concrete 1:8:16	402.76	m ³	845.80
19.	28m ²	Finishing the top of flooring in 20mm thick	41.81	m ²	1170.68
20.		Supplying, fabricating and placing in position of steel grills			
	0.10 MT	a. MS rods	14685/-	MT	1468.50
	0.16 MT	b. RTS rods	14835/-	MT	2373.60
	0.12 MT	c. 3mm wires	14,685/-	MT	1762.20
21.	2.50m ³	Weathering course	345.10	m ³	862.75
22.	32m ²	Hydraulic pressed tiles in CM.1:3	108.03	m ²	3456.96
23.	215m ²	Plastering in CM.1:5 12mm thick	22.58	m ²	4854.70
24.	165m ²	White washing 3 coat	1087	m ²	308.55
25.	112m ²	Colour washing two coats over one coat of white washing	3.67	m ²	411.04
26.	5.00m ²	Painting the Iron bars	22.70	m ²	113.50
27.	47.00m ²	Painting new wood work	35.52	m ²	1,669.44

28.	10.50m	S&F of 100mm A.C. rain water pipe	49.00	Rmt	514.50	
29.		S&F of G.I. pipes and specials	2.5	Rmt	700.00	
30.	3m	S&F of 100 mm S.W. pipe	29.25	Rmt	87.75	
31.	1 No.	S&F of 100mm S.W. Bend	22.00	each	22.00	
32.	1 No.	S&F of 20" IWC	311.80	each	311.80	
33.	1 No.	S&F of 75mm C.I. gratings	21.00	each	21.00	
34.	1 No.	S&F of 150x100 size gully trap	133.50	each	133.50	
35.	1 No.	Constn. of Inspection chamber 60x45x90cm	867.00	each	867.00	
36.	1 No.	Constn. of Septic Tank	2256	each	2256.00	
37.	L.S.	Providing Electrical arrangement	L.S.	each	4000.00	
38.	L.S.	Provision for external electrical service connection and E.B.deposit	L.S.	each	2000.00	
39.	15 Rmt	Provision for U shape drain	-	-	1666.00	
40.	L.S.	Providing Plat form allround the building	L.S.	-	3000.00	
		Price escalation @ 5%	...	L.S	...	3616.14
		Tender excess @ 5%	...	L.S	...	2797.00
		Contigencies @ 2 1/2%	...	L.S	...	1993.00
		Petty supervision charge a 2 1/2%	...	L.S	...	2043.00
		Supervision charges @ 12 1/2%	...	L.S	...	10508.00

		Total	Rs.			113500.00

Plinth Area 38,495 Sq.m
Plinth Area rate Rs.3046/m²

APPENDIX - C

Tamil Nadu Housing Board Flat (D2 Type)

ABSTRACT ESTIMATE (3 STOREY)

S.No.	Quantity	Description of work	Rate	Per	Amount
1.	170 m ³	Earth work excavation for	13.92	m ³	2366.40
2.	34m ³	C.C. 1:5:10 for foundation	550.18	m ³	18706.12
3.	93m ³	R.R. in CM 1:5 for foundation and basement	568.01	m ³	52824.93
4.	6.00m ³	B.W. in CM 1:5 for foundation and basement	902.63	m ³	5415.78
5.	66.0m ³	Filling in foundation with River sand	111.90	m ³	7385.40
6.	58.50m ³	B.W. in CM 1:5 for Ground floor	909.63	m ³	53213.36
7.		B.W. in CM 1:6 for			
	59.00 m ³	a. First floor	713.83	m ³	42115.97
	61.0m ³	b. Second floor	723.83	m ³	44153.63
	7.5m ³	c. Third floor	733.83	m ³	5503.73
8.		Brick partition wall 115mm thick			
	63.00m ²	a. In Ground floor	77.01	m ²	4851.63
	63.00m ²	b. In First Floor	78.11	m ²	4920.93
	128.00m ²	c. In Second Floor	79.21	m ²	10138.88
He		Brick partition wall 75mm thick			
	19.00m ²	a. In Ground floor	54.36	m ²	1032.84
	19.00m ²	b. In first Floor	55.11	m ²	1047.09
	19.00m ²	c. In second floor	55.81	m ²	1060.39

10.		RCC 1:2:4 using 20mm H.B.S. Jelly			
	5.60m ³	a. Foundation and basement	1109.76	m ³	6214.66
	21.50m ³	b. In ground floor	1118.76	m ³	24053.34
	21.50m ³	c. In first floor	1128.76	m ³	23139.58
	21.50m ³	d. In second floor	1138.76	m ³	24483.34
	4.00m ³	c. In third floor	1148.76	m ³	4595.04
11.		Pre-cast cubboard slabs 1;2:4 using 10mm chips			
	60.00m ²	a. 20mm thick	90.04	m ²	5402.40
	15.00m ²	b. 40mm thick	113.06	m ²	1695.90
	6.00m ²	c. 50mm thick	123.82	m ²	742.92
12.	7.50m ²	Precast RCC Jally 40mm thick	176.88	m ²	1326.60
13.		Providing formwork for concrete			
	630m ²	a. Large quantity	113.75	m ²	71662.50
	24m ²	b. Small quantity	129.23	m ²	3101.52
	30m ²	c. Plinth beam	56.87	m ²	1706.10
14.	2.90m ²	Best Indian Teak Wood wrought and putup	23100.00	m ³	66990.00
15.		S&F of T.W. shuttes			
		i. Panelled shetters			
	38.90m ²	a. 90 x 200 cm	904.94	m ²	35202.17
	65 m ²	b. 75 x 200 cm	903.67	m ²	58738.55
		ii. Glazed shutters			
	32.40m ²	a. Overall height of 120cm	590.44	m ²	19130.26
	9.40m ²	b. Overall height of 105 cm	583.00	m ²	5480.20
16.	678 Nos	S&F of MS hold fasts	3.00	each	2034.00

17.	51 m ²	S&F of 12mm M.S. bars	129.91	m ²	6625.41
18.	9.00m ³	Flooring concrete 1:8:16	402.76	m ³	3624.84
19.	130m ²	Floor finishing with CM 1:4 20mm Tk.	41.81	m ²	5435.30
20.	220.0m ²	Ellis pattern flooring (1:3)	47.62	m ²	10857.36
21.	10.50m ³	Weathering course	345.10	m ³	3623.55
22.	172 m ²	Hyd. pressed tiles over roof in CM 1:3	108.03	m ²	18581.16
23.	30m ²	Mosaic tiles	242.11	m ²	7263.30
24.	150m ²	Dadoing	253.61	m ²	38041.50
25.		Supplying fabrication of steel			
	2.15 M.T.	a. M.S. rods	14685.00	M.T.	31572.75
	3.55 M.T	b. R.T.S. rods	14,835.00	M.T.	52664.25
26.	2350m ²	Plastering in CM 1:5 12mm thick	22.58	m ²	53063.00
27.	17m ²	Stucco plastering	35.79	m ²	608.43
28.	850m ²	Painting walls with Snowcem	10.80	m ²	9180.00
29.	2200m ²	WB !KZ MX.B !=) KB #ZZ -WXX.	e>qn	\$ ²	sees>ff
30.	370m ²	Painting new wood work	35.52	m ²	13142.40
31.	40 RMT	S & F of 100mm A.c. rainwater pipe	49.00	Rmt	1960.00
32.	1m ³	B.W. in CM 1:4 for S/c steps	999.60	m ³	999.60
33.	17m ²	Parapet B.W. for handrail in	138.08	m ²	2346.17
34.	25m ²	Plastering in CM 1:4 20mm TK	41.81	m ²	1045.25
35.	L.S.	S&F of GI pipe & special	... L.S ...		19500.00
36.	50 RMT	S&f S.W. Pipe	29.25	Rmt	1462.50
37.	8 NOS.	L/c for fixing I.W.C. in F.F & S.F.	311.80	each	2494.80
38.	4 Nos.	L/c for fixing I.W.C. in G.F.	215.20	each	860.80

39.	4 Nos	S & F of S.W. Bend 100mm	22.00	each	88.00
40.	12 Nos	S & F of 63 mm Najiani trap	43.00	each	516.00
41.	4 Nos	S & F of 150 x 100mm S.W. gully trap	133.50	each	534.00
42.	12 Nos	S & F of 75 mm C.I. gratings	21.00	each	252.00
43.	4 Nos	Const. of Inspection chamber	867.00	each	3468.00
44.	L.S.	S & F A.C/C.I. Soil pipes & Specials	...	L.S ...	10300.00
45.	12 Nos	Casting and erection of ferro-cement tank	911.10	each	10993.20
46.	20 Rmt	Const. of U shape drain	92.15	Rmt	1843.00
47.	L.S.	Providing Electrical arrangement	...	L.S ...	40500.00
48.	L.S.	Cost of IWE, EWC wash basin etc	...	L.S ...	3000.00
49.	L.S.	House service connection	...	L.S ...	5000.00
50.	L.S.	Providing platform allround	...	L.S ...	5000.00
51.	L.S.	Price escalation @ 5%	...	L.S ...	49046.27
52.	L.S.	Tender excess @ 5%	...	L.S ...	51500.00
53.	L.S.	Contingencies @ 2 1/2%	...	L.S ...	27000.00
54.	L.S.	Petty supervision charges @ 2 1/2%	...	L.S ...	27700.00
55.	L.S.	Supervision charges @ 12 1/2%	...	L.S ...	141817.00

Total for 12 Nos. Rs. 1277000.00

Rate for One flat Rs.1,06,420.00

Plinth area - 37.25m²

Plinth area Rate = 2,856.82/m² or Rs.2857/-

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