GOVERNMENT OF TAMILNADU

GUIDELINES FOR RECONSTRUCTION OF HOUSES AFFECTED BY TSUNAMI

GENERAL AND PUBLIC BUILDINGS (RCC)

DESIGN FOR SAFETY...

UNDP India

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FOREWORD

The Government of Tamil Nadu initiated a number of steps in consultation with experts, research institutions, technical universities and civil society organizations for formulating comprehensive guidelines for the reconstruction programme of houses damaged by the tsunami of 2004. More than 35,000 houses are being constructed in the first phase by various organizations including Tamil Nadu Slum Clearance Board for providing disaster resistant house to the tsunami affected families. Government also announced a comprehensive housing reconstruction policy to provide safe structures resistant to different disasters like floods, cyclones, earthquakes, tsunami, etc in areas which are vulnerable to such disasters.

A number of training programmes were organized for the Engineers and Building Supervisors of various Government and Non-Governmental Organizations to sensitize them to follow good construction practices while building the structures. The study undertaken as a follow up on the supervision of the quality of such structures, indicated areas of concern with respect to quality of construction. The findings of this study were also discussed with the District Collectors concerned. One of the major findings of this study was the need for comprehensive guidelines for General and Public Buildings built with Reinforced Cement Concrete. The State Government with the advice and guidance of Prof. A R Santhakumar has prepared the guidelines based on various practices in the districts and national codes. The guidelines were circulated to the following team of experts for comments, suggestions and modifications:-

1. Dr. N Lakshmanan, Director, Structural Engineering Research Centre.
2. Thiru R Jayaram, Chief Engineer, Tamil Nadu Slum Clearance Board.
3. Thiru S Nagarajan, Deputy Chief Engineer (Buildings), Public Works Department.
4. Dr. K.P. Jaya, Assistant Professor, Structural Engineering Division, Anna University.
5. Thiru M Syed Mohamed Abuthalib, Executive Engineer (Tsunami), O/C SC & CRA.
6. Thiru Hariharasubramanian, Engineering Specialist, Tsunami PIU, RD & PR Department.
7. Thiru Alok Patnaik, Shelter Specialist, UNDP, Chennai.

These guidelines will be of use to the tsunami reconstruction programme for RCC structures throughout the various districts of Tamil Nadu. These guidelines have been specifically framed for the reconstruction of general residential and public buildings considering multi hazard perspective, for the communities which have been affected by the tsunami of 26 December 2004 in the coastal districts of Tamil Nadu. These guidelines should also be strictly followed for the construction of houses and public utilities in other districts apart from the coastal districts, which are prone to cyclones and earthquakes.

Public buildings such as schools, hospitals etc. should be suitably planned and designed with disaster resistant features. For such buildings, analysis and design should be carried out as per this guideline.

I am sure that this measure would help in reducing the loss of precious lives in future disasters.

I compliment the team of experts who have brought out these guidelines for dissemination to all the stakeholders. I thank UNDP, particularly Prof. A R Santhakumar and Er. Alok Patnaik for taking the responsibility of bringing out this document at an appropriate time. All the organizations concerned including UNDP are requested to organize IEC campaigns as well as training programmes for communicating these guidelines to the widest audience possible.

(C.V. SANKAR)

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PUBLIC BUILDING GUIDELINES

1. INTRODUCTION

A very severe earthquake measuring magnitude of 8.9 on Richter Scale struck northern Sumatra, Indonesia at 00:58:50 UTC or 06:28 AM IST. The earthquake driven tsunami was felt widely along the east coast of India. The calamity which struck the Tamil Nadu coast was unprecedented in its suddenness and ferocity. It was also widespread in scale affecting villages and towns all along the coastline. A calamity of this nature has never been known.

1.1 Cyclones:

Tamil Nadu being located in a highly vulnerable part of Peninsular India - the Deccan Plateau and flanked by the Bay of Bengal and the Arabian Sea, is frequently subjected to overwhelming devastation by natural calamities due to cyclonic storms and flooding in its coastal districts. Records of the past occurrences of cyclonic storms highlight the alarming fact that severe cyclonic storms are more frequent in the Bay of Bengal than in the Arabian Sea and records indicate that from the beginning of this century about 400 cyclonic storms formed in the Bay of Bengal as compared to just 80 in the Arabian Sea. Almost every year on an average, one severe cyclone in the pre-monsoon period and one or two in the post-monsoon period are expected during the Northeast monsoon period in the Bay of Bengal. The area normally affected by cyclones is the entire first line coastal taluks right from Chennai district to Ramanathapuram district. Tamil Nadu is one of the most vulnerable States in the country affected by cyclones.

As per the Wind & Cyclone zoning map as given in IS 875(Part-3) - 1987, and Vulnerability Atlas of India, brought out by BMTPC, there are six basic wind speeds considered for zoning, i.e. 55, 50, 47, 44, 39 and 33 m/sec. These peak wind speeds represent the peak gust velocity averaged over a short duration of 3 sec., at a height of 10 m above the ground level in an open terrain with a return period of 50 years. From wind damage point of view, these are categorized as follows:

55 m/sec- Very high damage risk zone- A

50 m/sec- Very high damage risk zone- B

47 m/sec- High damage risk zone

44 m/sec- Moderate damage risk zone- A

39 m/sec- Moderate damage risk zone- B

33 m/sec-Low damage risk zone

The wind speed zoning map of Tamil Nadu as per the Vulnerability Atlas of India is shown on inside back wrapper, Tamil Nadu falls in three categories of the wind zones :

50 m/sec- Very high damage risk zone -B

47 m/sec- High damage risk zone

44 m/sec- Moderate damage risk zone –A

Importance factor (f) to be considered for the following types of buildings is:

Special Buildings including Societal buildings, Schools, Hospitals

involving post-cyclone importance	f = 1.3	
Industrial structures	f = 1.15	
Normal buildings	f = 1.0	(1)

Wind Induced Loads

Wind force is basically random and dynamic in nature, and it is treated as stationary for simplicity in the analysis and design of structures. As per IS 875 (Part 3) Code, the wind load on a building/ structure shall be calculated for (i) the building as a whole and (ii) the individual elements/ members. Wind loads on individual elements/ members are calculated as given below:

$$F = \left(C_{pe} - C_{pi}\right) A \left(\frac{1}{2} \rho V_z^2\right) \quad (2)$$

where C_{pe} and C_{pi} = external and internal pressure coefficients, respectively; A = surface area of structural element/ member; ρ = air density; and V_z = design wind speed at height z.

The total wind load on the building/ structure is calculated as given below:

$$F = C_f A_e \left(\frac{1}{2} \rho V_z^2\right) \quad (3)$$

where C_f = force coefficient for the building; A_e = effective frontal area of the building or structure.

When the fundamental frequency of the structure is less than 1Hz or the aspect ratio (height/ width) of the structure is very high (>5), the structure is considered as dynamically sensitive to wind. The equivalent steady state wind load on such building/ structure based on gust effectiveness factor approach is given as,

$$F = G C_f \left(\frac{1}{2} \rho \bar{V}_z^2\right) A_e \quad (4)$$

where, $\bar{V}_z$ = hourly mean wind speed at height z;

G = Gust Effectiveness Factor (GEF)

IS 875 (Part 3) code suggests the following expression for the estimation of the gust effectiveness factor,

$$G = 1 + g_f r \sqrt{B(1+\phi)^2 + \left(\frac{SE}{\beta}\right)} \quad (5)$$

where, g_f = peak factor; r = roughness factor (twice the value of intensity of turbulence, $\sigma_V / \bar{V}$); B = background factor; S = size reduction factor; E = measure of available energy in the wind stream at the natural frequency of the structure; β = damping coefficient of the structure, σ_V = r.m.s value of along wind fluctuations.

The parameters g_f, r, B, S, E and β can be obtained from the IS 875 (Part 3) code using different graphs. The parameter ϕ in Eq.(5) can be calculated as $(g_f r\sqrt{B})/4.$ The parameter ϕ is to be accounted only for buildings less than 75m high in terrain category 4 and for buildings less than 25m high in terrain category 3 and is to be taken as zero in all other cases.

Even though the Indian code specifies that the cyclonic wind speeds have been included in estimating the basic wind speed, the extreme value analysis carried out at SERC, Chennai, clearly reveals that the cyclonic wind speeds are far in excess of the wind speeds recommended in IS 875 (Part 3). The possible reason may be the use of non-cyclonic and cyclonic winds as belonging to one parent distribution. Based on the evaluated characteristic cyclonic wind speeds for different coastal regions a common basic cyclonic wind speed of 65 m/s has been recommended for adoption in cyclone-prone regions. To obtain the corresponding risk coefficient, k_1, the values of the parameters A and B defined in IS:875 (Part 3) code were suggested as 95 and 35 kmph, respectively.IS 15498 code has slightly modified the above mentioned basic cyclonic wind speed by including an enhancement factor for cyclonic risk as given below,

$$V_z = f\,k_1\ k_2\ k_3\ V_b \qquad (6)$$

where $k_1, k_2,$ *and* k_3 are defined as per IS 875 (Part 3) code

f = enhancement factor for cyclonic risk (same as importance factor Eq(1))

1.2 Earthquakes:

Though not as seismically active as States in the northern and western parts of the country, small to moderate earthquakes have occurred in the state of Tamil Nadu. Earthquakes in the state of Tamil Nadu are mid-plate in nature and the frequency of earthquakes is low i.e. the gap between moderate sized events is fairly long. Tremors have been felt in almost every corner of the state, mostly from distant earthquakes in adjoining States or from the Indian Ocean. Historically however, most earthquakes have originated in western and northeastern regions. Seismic activity in the recent past has occurred in clusters along the borders with Andhra Pradesh, Karnataka and Kerala. Several faults have been identified in this region out of which many show evidence of movement during the Holocene period. The east-west trending Cauvery Fault, Tirukkovilur - Pondicherry Fault and Vaigai River Fault and the north-south trending Comorin-Point Calimere Fault and Rajapatnam-Devipatnam Fault are some of them and run close to major urban centres like Coimbatore, Madurai, Nagapattinam, Thanjavur and Pondicherry.

Latest Seismic zoning map of Bureau of Indian Standards classifies Tamil Nadu into two categories - Zone II and Zone III which are under low risk and Moderate risk respectively (as shown on map on back wrapper).

Determination of lateral loads due to earthquake

The procedure recommended is either equivalent static approach or based on dynamic analysis. The main difference between the equivalent lateral load procedure and dynamic analysis procedure lies in the magnitude and distribution of the forces along the height of the building. In the dynamic analysis procedure the lateral forces are based on properties of natural modes of vibration which depend on distribution of mass and stiffness along the height. In the equivalent lateral force procedure, the magnitude of forces is based on fundamental period and the distribution of forces is given based on simple formula applicable for regular buildings.

Regular and Irregular Configuration

To perform well in an earthquake, a building should possess four main attributes, namely simple and regular configuration, and adequate lateral strength, stiffness and ductility. Buildings having simple regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation, suffer much less damage than buildings with irregular configurations.

Equivalent lateral force procedure

The design base shear is first computed for the whole structure and then distributed along the height of the building based on simple formula. The design lateral load obtained at each floor level is then distributed to individual lateral load resisting elements based on floor diaphragm action. In RCC buildings with rigid floors the shear in that floor is distributed based on the relative rigidity of the frames.

Design Seismic Base Shear

The total design lateral force or design seismic base shear (V_B)along any principal direction shall be determined by the following expression:

Where

$$V_B = A_h W \qquad (7)$$

The design horizontal seismic coefficient A_h for a structure shall be determined by the following expression:

$$A_h = \frac{ZIS_a}{2Rg} \qquad (8)$$

Z=Zone factor given in Table 2 of IS 1893: 2002, is for the Maximum Considered.

Earthquake (MCE) for the service life of structure in a zone. The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) to the Design Basis Earthquake (DBE).

I=Importance factor, depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance (Table 6 of IS 1893:2002). This table is reproduced below as Table 1

R=Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0 (Table 7 of IS1893:2002). The values of R for buildings are given in Table 7 of IS 1893:2002.

S_a/g = Average response acceleration coefficient

Table 1 Importance Factors, I

(Clause 6.4.2)

SI No.	Structure	Importance Factor
(1)	(2)	(3)
i)	Important service and community builidings, such as hospitals; schools; monumental structures; emergency buildings like telephone exchange, television stations, radio stations, railway stations, fire station buildings; large community halls like cinema halls, assembly halls and subway stations, power stations etc.	1.5
ii)	All other buildings	1.0
	NOTES 1. The design engineer may choose values of importance factor / greater than those mentioned above. 2. Buildings not covered in SI No. (i) and (ii) above may be designed for higher value of I, depending on economy, strategy considerations like multi-storey buildings having several residential units. 3. This does not apply to temporary structures like excavations, scaffolding etc of short duration.	

1.3 Tsunamis and Tidal waves

A sudden movement of the ocean floor generally produces tsunamis or seismic sea waves. As the water waves approach land, their velocity decreases and their height increases from 5 to 8m, or even more. Obviously, tsunamis can be devastating for buildings built in coastal areas. Tidal waves are caused by the effect of planets on the sea level. Tidal waves can cause flooding and damage buildings in the coastal zone.

This special guidelines deals with the design of structures located on coastal sites to resist the forces induced due to tsunami impact and is applicable to concrete and masonry buildings, earth dams, embankments, dykes, retaining walls, tsunami shelters and engineered multistory buildings that may be used for vertical evacuation.

Lateral Loads due to Tsunami impact

Hydrodynamic Loads

The hydrodynamic loads due to tsunami and storm surge on coastal structures include hydrostatic pressure, buoyancy force, fluid flow drag and surge impingement.

Hydrostatic Force (F_h)

Hydrostatic force occurs when standing or slow moving water encounters a building or building component. The lateral hydrostatic force is given by:

$$F_h = ½ \rho g (h + u_p^2 / 2g)^2 \quad (9)$$

Where,

F_h : Hydrostatic force

ρ : Density of water

g: accleration due to gravity

h: water depth

u_p : Water velocity normal to the wall (as obtained from simulation)

The resultant force will act horizontally at a distance of h_R above the base of the wall where:

$$h_R = 1/3(h+ u_p^2 / 2g)$$

Hydrostatic force is usually important for 2-D structures such as seawalls and dikes or for evaluation of an individual wall panel where the water level outsides differ substantially from the level inside.

Buoyant Force (F_b)

The buoyant or vertical hydrostatic forces on a structure or structural member subjected to partial or total submergence will act vertically through the center of mass of the displaced volume. Buoyant forces are a concern for basement, empty above ground and below ground tanks, and for swimming pools. The buoyant force is given by:

$$F_b = \rho g V \quad (10)$$

Where, V is the volume of water displaced by the structure considered. This force is significant in tsunami and storm surge situation.

Hydrodynamic Drag Force (F_d)

The hydrodynamic drag force on a structure component in the direction of a steady flow can be expressed as:

$$F_d = ½ \rho C_D A u_p^2 \quad (11)$$

Where,

C_D : Drag coefficient, the value is taken as 1.0 for circular piles, 2.0 for square piles and 1.5 for wall sections. A : Projected Area normal to the direction of the flow.

Surge Impingement (F_s)

Surge forces are caused by the leading edge of a surge of water impinging on a structure. The hydrodynamic force of the leading edge of the fluid flow acting per unit area of a structure due to tsunami surge is given by:

$$F_s = 4.5 \rho g h^2 \quad (12)$$

Where, h is the height of surging flow. The resultant acts at a distance of approximately h above the base of the wall. This equation is applicable for walls within heights equal to or greater than 3h. Walls whose heights are less than 3h require surge force to be calculated based on appropriate combination of hydrostatic and hydrodynamic force equation for the given situation.

Impact Force (F_i)

During the tsunami or storm surge, water-borne objects (e.g. boats, oil rigs, vehicles, drift wood etc.) may hit a coastal structure with tremendous impact force.. The generalized expression for impact force F_I is give by following equation:

$$F_i = m\,(u_I / \Delta t) \qquad (13)$$

Where, u_I is the approach velocity that is assumed equal to the flow velocity, m is the mass of the body, Δt is the impact duration that is equal to the time between the initial contact of the body with the building and the maximum impact force.

Breaking Wave Force(F_{brkw})

Following expression for wave breaking force may be used:

$$F_{brkw} = \tfrac{1}{2}\,\rho\, C_{db}\, H_{\mathbf{b}} \qquad (14)$$

Where, C_{db} is a shape coefficient (value = 2.25 for square or rectangular piles and 1.75 for round piles), D is the pile diameter, and H_b is the wave breaking height ($H_b = 0.78\, d_s$, where d_s is the design still water depth).

Tsunami and Storm Surge Scour

The behavior of tsunami and storm surge scour is very complex and dependent on the geometric properties of the bridge columns as well and the material properties of the surrounding soil at the base. Currently, no simple formula exists for scour prediction. In the absence of site specific data a footing depth

$$d_s = (wh+1)^{0.65} \qquad (15)$$

is suggested for a length of 'd_s' from the corners of buildings or structures, with a minimum depth of 1m in any case. w is the footing width in 'metres' and 'h' the innundation depth in metres of Tsunami run-up on land.

Summary:

These guidelines have been specifically framed for the reconstruction of public buildings considering multi hazard perspective, for the communities which have been affected by the tsunami of 26th December 2004 in coastal districts of Tamil Nadu. These guidelines will also be helpful for the construction of houses in other districts apart from the coastal districts, which are prone to cyclones and earthquakes.

Public buildings such as schools, hospitals etc. should be suitably planned and designed. For such buildings, analysis and design can be carried out as per this guidelines.

2. DESIGN PHILOSOPHY

2.1. R.C.C design of buildings can be carried out mainly by three methods. They are namely: (1) Working stress method, (2) Ultimate load method and (3) Limit state method.

2.2. The Limit state method is now in vogue in all government design offices and premier private consulting firms. The Bureau of Indian Standards have published I.S.:456-2000 incorporating the use of Limit state Method of design. The designer should therefore get well versed with the theory of Limit State Method of design.

Working Stress Method: Used over decades, this method is now practically outdated because of its inherent limitations.

The I.S:456-2000 code gives emphasis on Limit State Method.

Limit State Method is a judicious amalgamation of Working Stress Method and Ultimate Load Method, removing the drawbacks of both the methods but retaining their good points. It is also based on sound scientific principles and backed by years of research. The Limit State Method has proved to have an edge over the Working Stress Method from the economic point of view and is more rational. Consequently we need not stick to Working Stress Method any more.

Accordingly, all designs of R.C.C. structures are to be made as per Limit State Method.

2.3. Codes: In carrying out the design calculations, one has to comply with the provisions of various I.S. Codes. Use of special publications of the Bureau of Indian Standards and Hand Books which contain readymade design tables can be made.

2.4. General Technical Guidelines

The designer is advised to study these and I.S. codes carefully and all their provisions are to be satisfied. Appendix 2 gives Building categories for various multi hazard resisting features.

2.5. Special Provisions

Besides analytical part of structural design, following factors should also be kept in mind while designing the structure.

(a) Strength of structure.

(b) Durability of structure.

(c) Serviceability of structure, during construction as well as during design life time.

(d) Economy in the use of building materials and ease of construction.

(e) Economy in the construction process such as in centering and form work.

(f) Aesthetics of the completed structure.

(g) Appendix 3 gives designs for making the structure friendly to physically challenged.

3. COMPUTER AIDED DESIGN

Personal computers of sufficiently high speed and large memory capacity are now available to Design structures. Software such as STAAD or SAP are available for design office use. Designer should get conversant with the User Manuals of these programs so that they can work out economical and safe designs.

4. STEPS INVOLVED IN RCC DESIGN

The R.C.C. design of a building is carried out in following steps.

(i) Study the architectural drawings.

(ii) Study the field data.

(iii) Prepare R.C.C. layouts at various floor levels.

(iv) Decide the imposed live load and other loads such as wind, seismic and other miscellaneous loads, (where applicable), as per I.S. 875, considering the contemplated use of space, and seismic zone of the site of proposed building as per IS 1893.

(v) Fix the tentative slab and beam sizes and then prepare preliminary beam design. Using values of support reactions from preliminary beam design, prepare preliminary column design and based on these load calculations, fix tentative column section and it's concrete mix. As far as possible, for multistoried buildings, the same column size and concrete grade should be used for at least two stories so as to avoid frequent changes in column size and concrete mix to facilitate easy and quick construction. Minimum grade of Concrete to be adopted for structural members at all floors is M 20 for Non Coastal Region and M 30 for Coastal Region.

(vi) Group the members such as columns, beams, slabs, footings etc. wherever possible, on the basis of the similarity of loading pattern, spans, end conditions etc. It reduces the quantum of calculation work and facilitate in ease of construction.

(vii) Prepare R.C.C. Layouts and get concurrence of the Architect for tentative sizes of beams and columns and other structural members if any. In the layout, show the structural arrangement and orientation of columns, layout of beams, type of slab (with its design live load) at different floor levels. Also indicate how the different structural members transfer the load of each floor successively to the foundation level.

For a building, generally the following R.C.C. layouts are prepared:

(a) R.C.C. layout at pile cap/ plinth level.

(b) R.C.C. layout at various floor levels or at typical floor level (depending on similarity of Architectural plans.)

(c) R.C.C. layout at terrace level.

(d) R.C.C. layout at staircase roof level and where lifts are provided.

(e) R.C.C. layout at lift machine room floor level.

(f) R.C.C. layout showing water tank at roof level.

It is required to provide continuous plinth beam and lintel beam in disaster prone areas.

(viii) Finalize various structural frames in X-direction and Y- direction followed by preparation of frame sketches and filling in, data of the frames on coding sheets, for computer aided frame analysis. A typical layout for analysis is shown in Fig.1

(ix) Feed the data of frames in to the computer and recheck the data stored, by getting a hard copy print out.

(x) Analyze the frames using approved software based on stiffness matrix method and obtain the analysis printout. The computer program STAAD pro incorporates the beam design program (as per Limit State Method) However, it is necessary to manually check the design especially for ductile detailing and for adopting capacity design procedures as per IS 13920.

(xi) Calculations of Horizontal forces: Whenever the structure is to be designed for horizontal forces (due to seismic or wind forces) refer I.S. : 1893 for seismic forces and I.S. :875 Part-III for wind forces.

All design parameters for seismic /wind analysis shall be carefully chosen. The proper selection of the various parameters is a critical stage in design process.

(xii) For getting design forces on the column, assemble the design data, using results obtained in analysis of respective X and Y direction frames, which include the column under consideration.

(xiii) Design individual footings manually using Hand Book of R.C.C. members or a software For design of other types of footing refer standard text books.

(xiv) Design slabs manually by using Hand Book for R.C. members.

(xv) Design beams by using the frame analysis output. Some programs give area of reinforcement at various locations and diameter and spacing of shear reinforcement. However, it is necessary to check the reinforcement provided, manually to ensure that specific detailing rules for ductile detailing are adopted.

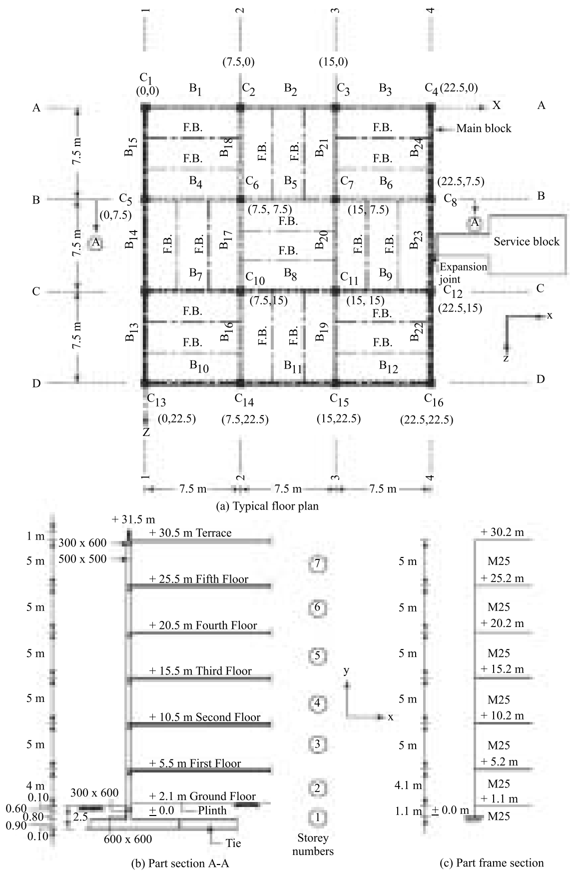


Fig.1 Typical layout and frames in X and Y directions

Designer's work now involves the following:

(a) Fix the bar diameter and number of bars (at top and bottom) at various locations along the beam span, as per codal provisions and practice.

(b) Finalize the diameter and spacing of shear reinforcement as per analysis results and as per codal provisions of detailing where ever applicable.

(c) The drawings for intersection of beams and beam column junctions have to be carefully prepared as per ductile detailing procedures given in IS 13920.

Design of secondary beams are done manually on similar lines.

(xvi) Prepare R.C.C. schedules for footings, slabs, beams and columns at various levels, on completion of respective design. As these R.C.C. schedules are to be used during the execution, designer should take maximum care in preparing them. Schedules should be prepared by one Engineer, and thoroughly cross checked by another Engineer. In schedules, special instructions to the field engineers should be highlighted and sketches should be drawn wherever necessary.

5. STUDY OF ARCHITECTURAL DRAWINGS

5.1 As the building is to be constructed as per the drawings prepared by the Architect, it is very much necessary for the Designer to Correctly visualize the structural arrangement satisfying the Architect. A Designer, after studying Architect's plans, can suggest necessary change like additions/deletions and orientations of columns and beams as required from structural point of view.

5.2 For this, the designer should have a complete set of prints of original approved architectural drawings of the buildings namely i) Plans at all the floor levels, ii) Elevations, (front, back and sides), iii) Salient cross sections where change in elevation occurs and any other sections that will aid to visualize the structure more easily. The cross sections should show the internal details like locations of windows, doors, toilets staircases lift machine room, staircase rooms, and any other special features like gutter at roof level, projections proposed to give special elevation treatment, etc.

5.3 During the study following points should be noted. The drawings should be examined to find out,

(i) Whether the plan shows all the required dimensions and levels so that the designer can arrive at the lengths and sizes of different members. Wherever necessary, obligatory member size as required by Architect (on architectural grounds) are given.

(ii) Whether the plans and schedules of doors and windows etc. are supplied so as to enable designer to decide beam size at these locations.

(iii) Whether thickness of various walls and their height (in case of partition walls) is given.

(iv) Whether functional requirements and utility of various spaces are specified in the plans. These details will help in deciding the imposed load on these spaces.

(v) Whether material for walls is specified.

(vi) The structural arrangement and sizes proposed by the Architect should not generally be changed except where structural design requirements can not be fulfilled by using other alternatives like using higher grade of concrete mix or by using higher percentage of steel or by using any other suitable alternate structural arrangement. Any change so necessitated should be made in consultation with the Architect. Further design should be carried out accordingly.

(vii) Note the false ceiling, lighting arrangement, lift/s along with their individual carrying capacity (either passenger or goods), Air Conditioning ducts, acoustical treatment, R.C.C. cladding, finishing items, fixtures, service openings proposed by the Architect.

(viii) Note the position/s of expansion joints, future expansion (horizontal and/ vertical) contemplated in the Architect's plan and check up with the present scope of work (indicated in the "Field Data" submitted by the field engineers). The design of the present phase will account for future expansion provision such as loads to be considered for column and footing design (combined /expansion joint footing) if any.

If this aspect is neglected it will create design as well as execution problems in the next phase of work. In case of vertical expansion in future, the design load for the present terrace shall be maximum of the future floor level design load or present terrace level design load.

(ix) Whether equipment layout has been given, particularly in the areas where heavy machinery is proposed to be located.

(x) Special features like sun breakers, fins, built- in cupboards with their sections so as to enable designer to take proper account of the same.

(xi) Whether the location/s of the over head water tanks specified by the Architect and whether "Field Data" submitted by field engineer furnishes the required capacity of each over head water tank.

(xii) What type of water proofing treatment is proposed in toilet blocks and on terrace?

The findings of the above scrutiny should be brought to the notice of the Architect and his clear opinion on this matter should be obtained before proceeding ahead with R.C.C. design.

6. FIELD DATA

6.1 As such the designer must also have through information of the site where the structure is proposed to be constructed.

6.2 The "Field Data" is a must before starting design work. However, it is generally noticed, that the "Field Data" lacks vital information such as bearing capacity of the founding strata, proposed location and capacity of over head water tank/s, electrical lift loads, future horizontal and/or vertical expansion etc. So, on receipt of "Field Data", it should be checked thoroughly and if any data is found to be missing, the same should be obtained from field engineer, to avoid delay in starting the design work.

6.3 Besides information on the points mentioned above, information on special points also is to be supplied where applicable by the field officers, like :

(i) Machinery and/or equipment layout.

(ii) Air cooling /air conditioning ducting layouts including exhaust arrangements.

(iii) False ceiling arrangements, proposed acoustical treatment, electrical lighting and audio system fixtures.

(iv) Fire fighting pipeline/s or any other special ducting layouts.

(v) Sub-soil and sub-soil water properties particularly Sulfide and Chloride contents where the building is located in coastal and or highly polluted industrial area.

(vi) Importance factors (I) and the soil foundation system as per I.S. 1893, to be considered for the proposed building when the building is being constructed in seismic zone. It may be noted that the importance factor more than 1.0 leads to increased seismic forces consequently the reinforcement requirement increases. Also improper value of foundation soil factor will lead to erroneous higher value of seismic forces and lead ultimately to unnecessary uneconomical design. Therefore before starting Seismic Analysis, Importance factor (I) and the soil data should be assessed.

(vii) In case foundations, other than open type of foundation, safe bearing capacity of the founding strata and its depth from the general ground level along with trial bore log details and test results on samples, should be analysed. Based on these, proper type of foundation should be adopted.

7. LIST OF I.S. CODES GENERALLY REQUIRED TO BE REFERRED FOR BUILDING DESIGN

7.1 The important I.S. Codes (with their latest editions/ amendments) to be referred to, for design of building are as follows :

(i) I.S. 456-2000: Code of practice for plain and reinforced concrete.

(ii) I.S. 800-Draft: Code of practice for use of structural steel in general building constriction.

(iii) I.S. 875-1987 (Part I to V): Designs loads other than earthquake for the Building Design.

Part-I: Dead loads.

Part-II: Imposed loads.

Part-III: Wind loads.

Part IV: Snow loads.

Part V: Special loads and load combinations.

(iv) I.S. 1080-1965: Code of practice for design and construction of shallow foundation in soils (other than Raft, Ring and shell)

(v) I.S:1642-1988: Fire safety of Buildings (General) Details of construction.

(vi) I.S.: 1643-1988: Code of practice for Fire safety of Buildings (General) Exposure Hazard.

(vii) I.S. 1644-1988: Code of practice for Fire safety of Buildings (General) Exit requirements and personal Hazards.

(viii) I.S. 1888-1972: Methods of load test on soils.

(ix) I.S:1893-2002: Criteria for earthquake resistant design of structures.

(x) I.S: 1904-1986: Code of practice for design & construction of pile foundation in soil structural safety of building foundation.

(xi) I.S. 2911-1990: Code of practice for design and construction of pile (Part I to IV) foundation.

(xii) I.S. 2950-1981: Code of practice for design and construction of raft foundation.

(xiii) I.S. 3370-1965: Code of Practice for water retaining structures.

(xiv) I.S. 3414-1987: Code of Practice for Design and Installation of joints in buildings.

(xv) I.S. 4326-1993: Code of practice for earthquake resistant design of structure.

(xvi) I.S. 6403-1981: Code of practice for Determination of bearing pressure of shallow foundation.

(xvii) I.S. 13920-1993: Code of practice for ductility detailing of reinforced concrete structures subjected to seismic forces.

I.S. Codes are also available for design of special types of structures like folded plate, shell structures etc. Refer publication list of BIS for the same.

Similarly there are a number of special publications of I.S. which are useful for design of buildings such as:

(i) SP-16: Design Aids to I.S: 456-1978

(ii) SP-22: Explanation to I.S. : 1893 & I.S. :4326.

(iii) SP-23: Concrete Mix.

(iv) SP-24: Explanation of I.S. 456-1978.

(v) SP-25: Cracks in buildings and their repairs.

(vi) SP- 34: Detailing in R.C.C. structures.

(vii) SP-38: Design of steel trusses.

7.2 While designing R.C.C. structures, important provisions of I.S. codes must be followed.

8. GENERAL PRACTICE FOLLOWED IN DESIGN

(i) The loading to be considered for design of different parts of the structure including wind loads shall be as per I.S. 875-1987 (Part I to V) and I.S. 1893-2002 (seismic loads).

(ii) Live load for sanitary block shall be 200 kg/m2. Temperature load and the relevant load combination as per IS 875 Part V should be considered.

(iii) Lift machine room slab shall be designed for a minimum live load of 1000 kg/m^2.

(iv) Lift load shall be considered as per relevant I.S. codes and as per capacity of lift and the same shall be increased by 100% for impact while designing.

(v) Loading due to electrical installation e.g. AC. ducting, exhaust fans etc.shall be got confirmed from the Engineer from the electrical wing.

(vi) Seismic loads shall be as per I.S. 1893-2002 and I.S. 4326-1993. The method of analysis and values of various parameters shall be taken as per relevant provisions of codes.

(vii) Ductility provisions specified in I.S. 4326-1993 and I.S. 13920-1993 shall be adopted in design, for Zone III and above. Tsunami prone area should be treated as Zone III or above.

(viii) Any other loads which may be required to be considered in the designs due to special type or nature of the structure shall be documented and included.

(ix) Deduction in dead loads for opening in walls need not be considered.

(x) Unless otherwise specified, the weight of various materials shall be considered as given below.

   (a) Brick masonry: 1920 kg/m^3

   (b) Reinforced cement concrete: 2500 kg/m^3

   (c) Floor finish: 100 kg/m^3

   (d) Brick Bat Coba of 112mm thickness laid on terrace for water proofing treatment : 200 kg/m^2

   (e) Brick Bat Coba in bath & W.C. depending on thickness of water proofing treatment : 1920 kg/m^3

(xi) The analysis shall be carried out separately for dead loads, live loads, temperature loads, seismic loads, and wind loads. Temperature loads cannot be neglected especially if the buildings are long. All the structural components shall be designed for the worst combination of the above loads as per IS 875 Part V.

(xii) In case of tall building, if required Model analysis shall be done for horizontal forces, as per I.S: 1893 and I.S. 875 (Part III).

(xiii) Minimum reinforcement in all structural members shall be as per relevant clause I.S. 456-2000 and IS 13920: 1993.

(xiv) The R.C.C. detailing in general shall be as per SP: 34. and as per ductile detailing code IS 13920:1993.

(xv) High Yield Stress deformed bars Fe415 shall be used for main reinforcement. Mild Steel bars may be used only as distribution steel.

(xvi) Diameter of bars in footings shall be not less than 12 mm.

(xvii) Spacing of stirrups in beams shall not exceed 300mm.

(xviii) Thickness of slab shall not be less than 10cm and in toilet and staircase blocks not less than 150mm.

(xix) Depth of beam shall not be less than 230mm.

(xx) Spacing of ties in columns shall not exceed 30cm or 0.75 times width minus effective cover used which ever is more stringent.

(xxi) The longitudinal bars in columns shall not be less than 12mm in diameter.

9. GUIDELINES FOR PREPARATION OF R.C.C. LAYOUTS

9.1 The preparation of R.C.C. layouts involves fixing of locations of columns and beams, denoting slabs with respect to design live load, type of slab and numbering these structural elements. (Fig.1 shows a typical layout)

9.2 There are two types of joints which need to be considered in the layouts. They are (a) Movements joints, (b) Expansion joints.

9.3 If the length of building exceeds 45m, expansion joints shall be provided to split into suitable parts which are individually less than 45m. in length. Building having wings in different directions shall be provided with expansion joints at the connection of the wings to the central core to avoid torsion effects. Expansion joints may also be provided when there is a sudden change in plan dimensions. For details of the joints refer to I.S.3414-1968, I.S. 4326-1976 and I.S. 3370-1965 (Part-I). The gap should satisfy provisions of IS: 1893:2002.

9.4 In case of the building is having different number of stories for different parts of the building, thus having different dynamic characteristics, then such parts shall be kept separated by a movement joint to avoid unequal loading, unequal settlement and collusion during an earthquake. Movement joints may also to be provided if the different parts of building are located on different stratas and of different safe bearing capacities. Such movement joints, however shall be provided right to the bottom of the foundation, unlike the expansion joints which are provided only up to the top of the foundation. In this regard refer to SP-34 (explanatory Hand Book of I.S. 456-1978) Clause 26.1 and also refer Clause 5.1.1 of I.S. 4326-1993. As per this clause the minimum total gap between these joints shall be 25mm. In addition the gap should satisfy the provisions of IS 1893:2002.

9.5 Separate R.C.C. layouts are to be prepared for different levels i.e. plinth, typical or at each floor level (if the plans are not identical at all floor levels) terrace floor level, staircase block roof level and where applicable lift machine room roof level.

10. GUIDELINE FOR FIXING THE POSITION AND ORIENTATION OF COLUMNS IN THE LAYOUT

This is an important stage. It is a skillful job and economy in design is achieved by locating columns at proper and / ideal locations.

(i) Normally the positions of the columns are shown by Architect in his plans.

(ii) Columns should generally and preferably be located at or near corners and intersection / junction of walls.

(iii) If the site restrictions make it obligatory to locate column footings within the property line the column may be shifted inside along a cross wall to accommodate footings within the property line. However, such shifting will call for special design and detailing as per IS 13920:1993. Alternatively trapezoidal footing, eccentric footing can also be adopted. In residential buildings; generally columns should be located at 3 to 4m. c/c to avoid large span for beams. This will control deflection and cracking.

(iv) While fixing the columns orientation care should be taken that it does not change architectural elevation. This can be achieved by keeping the column orientations and side restrictions as proposed in plans by the Architect but will increase the reinforcements to satisfy IS 13920:1993.

(v) As far as possible, column projection/s outside the walls should be avoided, unless Architect's plans show contrary or same is required as structural requirement.

(vi) Columns should not obstruct door and window position/s shown in the Architect's plans.

(vii) Column should be so positioned, that continuous frames from one end to the other end of building in both X and Y directions are available. This will increase the global stiffness of the building against horizontal forces.

(viii) When the locations of two columns are near to each other (for e.g. the corner of the building and intersection of the walls) then as for as possible only one large column should be provided.

(ix) As far as possible, column should not be closer than 2m.c/c to avoid stripped /combined /continuous footings. Generally the maximum distance between two columns should not be more than 8m ctoc. In such cases; vertical acceleration for the beams will have to be considered.

(x) Columns should be provided around staircases and lift wells.

(xi) Preferably overhead water tank should rest on the columns. The height of water tank should be restricted to 2.0m. Otherwise special design of water tank should be made accounting for earthquake effects.

(xii) Twin columns of equal size are desirable at expansion joints.

(xiii) Every column must be connected (tied) in both directions with beams at each floor level, so as to avoid buckling due to slenderness effects.

(xiv) Column supported on a beam (floating column) should be avoided.

(xv) When columns along with connecting beams form a frame, the columns should be so orientated that as far as possible the larger dimension of the column is perpendicular to the major axis of bending. By this arrangement column section and the reinforcements are utilized to the best structural advantage.

11. GUIDELINES FOR FINALIZING THE BEAM POSITIONS

(i) Normally beams shall be provided below all the walls.

(ii) Beams shall be provided for supporting staircase fights at floor levels and at mid landing levels.

(iii) Beams should be positioned so as to restrict the slab thickness, to 15 cm, satisfying the deflection criteria. To achieve this, secondary beams shall be provided where necessary.

(iv) Generally we come across with the situation that there is a gap between the floor level beam and beam supporting the chajja. Here the depth of floor beam shall be so chosen that it can support chajja also. However if depth so required is large (distance between floor beam bottom and lintel top, greater than 30cm) provide separate beam.

However, if beams are close, the column in between should be designed for appropriate enhanced shear.

(v) If two slabs are at different levels, provisions of a separate beam as above shall be followed.

(vi) As far as possible, cantilever beams should not be projected from Columns, to avoid torsion.

(vii) Beams of equal depths shall be provided on both sides of the expansion joint.

(viii) To get the required minimum head room, following alternatives can be tried.

(a) Reduce the beam depth without violating deflection criteria and maximum percentage of steel criteria for beams.

(b) In case there is a wall, over the beam without any opening, inverted beam may be provided in consultation with Architect.

(ix) Where secondary beam are proposed to reduce the slab thickness and to form a grid of beams, the secondary beams shall preferably be provided of lesser depth than the depth of supporting beams so that main reinforcement of secondary beams shall always pass above the main beam reinforcement.

(x) In toilet block provide minimum number of secondary beams so that casting slabs and beam will be simple. ‘No secondary beam’ condition would be ideal.

(xi) Beams which are required to give a flat look from the underside shall be provided as Inverted Beams, e.g. canopies. Alternatively hidden beams inside the slab having the same depth as thickness of slab may be adopted. Such hidden beams can be provided in toilet blocks, under partition wall etc. where a cluster of beams can be avoided. Note that such concealed beams will not help in reducing the deflections.

12. GUIDELINES FOR FIXING THE SLAB DIRECTIONS

(i) Slab shall be designed as one way slab if ratio of Ly to Lx is more than 2 and two way slab, if the ratio is equal or less than 2.

Where Lx is shorter span and Ly is longer span of the slab.

(ii) However as per Designers choice slabs up to 2.5m spans may be designed as one way slabs. In such cases reinforcements in the other direction is necessary to take care of cracking and other secondary effects. The effect of in plane forces in the slab due to earthquake loading warrants provision of minimum percentage of steel in both directions.

(iii) Canopy, Chajja, balcony slabs are generally designed as cantilever slabs.

(iv) W.C. slab is generally made sloping or sunk by about 50cm.below general floor level for Indian type water closet. Slabs for toilet block and Nahani slab are generally sunk by 20cm. below general floor level.

(v) Staircase waist slab is generally designed as a one way slab.

(vi) Loft slabs over toilets are generally supported on partition walls of toilet which is not a good practice. In such cases at least W.C. Loft load should be considered while designing the beams supporting these walls and the partition wall should be designed with sufficient horizontal and vertical bands.

13. NUMBERING SYSTEM AND NOTATIONS TO BE ADOPTED IN LAYOUTS

13.1 Columns:

Columns are numbered serially with integer number suffixed to letter "C" i.e. C_1, C_2, and C_3 etc. The columns are numbered from lower most left corner of the R.C.C. layout. Numbering shall proceed from left to right in X direction and proceeding successively in positive Y direction.

13.2 Beams:

(i) Beam actually supported over a column is called main beam. Beam supported over other beam is called secondary beam.

(ii) A beam number is composed of two parts e.g. 5.1, 5.2 etc. The part to the left of decimal point denotes the left side reference column number. The part to the right represents serial number of the beam.

(iii) For numbering the secondary beams in "X" direction the first part of beam number shall be a reference column which shall be the nearest left side column of the beam. The second part shall be the beam number.

(iv) If the beams are at intermediate level above the floor under consideration then the beam number will be suffixed with a letter like A, B & M. e.g. If 5.1 is main beam at 1st floor level, 5.1 A is beam in X direction at 1st floor lintel level, and 5.2 M is a beam in Y direction at MIDLANDING LEVEL between the 1st floor and 2nd floor levels. "A" refers to floor level and "B" refers to lintel level and "M" refers mid- landing level.

13.3 Slabs:

13.3.1 The slab notation is composed of four parts. The first, second and third part are written on the left side of the decimal point and 4th is written on the right hand side of the decimal point e.g. 200SI.I, 500S2.2.

(i) The first part denotes the imposed live load intensity in kg/sqm. for which the particular slab is designed. This load is decided on basis of designated use of the particular space (the slab) as shown in the Architect's plans and as per provisions of I.S.875. This practice is useful and advantageous for maintaining a proper record especially when different slab panels are designed for different live loads. This record is also useful to avoid over loading of the slab in future change of usage.

(ii) The second part represents the type of the slab for e.g.

"S" denotes general floor slab,

"SF" denotes staircase flight slab,

"SR" denotes room roof level slab/ staircase room roof level slab,

"SM" denotes machine room floor slab,

"SC" denotes cantilever slab and

"ST" denotes terrace slab.

(iii) The third part is either "1"or"2", "1" denotes the slab is one way.The "2"denotes the slab is two way.

(iv) The forth part is the serial number of the slab is one way /two way category. Slabs having different end conditions shall be treated as different slabs for this notation.

What has been suggested is a method of notation for easy reference. Any other method which will convey all the information may also be used.

14. PREPARATION OF PRELIMINARY BEAM DESIGN (P.B.D.)

14.1 All beams of the same types having approximately equal span (+) or (-) 5% variation magnitude of loading, support conditions and geometric property are grouped together. The critical beam of the group is considered for the design. All secondary beams may be treated as simply supported beams.

14.2 Begin with fixing the dimensions of beam. The width of beam under a wall is preferably kept equal to the width of that wall to avoid offsets i.e. if the wall is of 23cm. then provided beam width of 230mm.

14.3 Minimum width of main and secondary beam shall be 230mm.However secondary beams can be less, satisfying IS 13920:1993. The width of beam should also satisfy architectural considerations.

14.4 The span to depth ratio for beam be adopted as follows:

For building in seismic zone above III between 10 to12 and for seismic zones I and II 12 to 15. The ratio "D/b" (depth divided by width) of beam should not generally exceed 4 if it is a shallow beam. The depth so calculated shall be as shown in the Architect's plan.

14.5 To limit deflection, of a beam (up to 10m span) within the permissible limit, under service load, the I.S. 456 provides the following span to depth ratios.

(i) For cantilever not more than 7.
(ii) For simply supported beam not more than 20.
(iii) For continuous beam not more than 26.

These ratios can be further modified according to Modification Factor depending upon percentage steel used in section as per I.S: 456.

14.6 The beams shall be designed as deep beam /shallow beam as the case may be.

14.7 The beam shall be treated as

(i) A rectangular beam if it does not support any slab on either side also if it is an inverted beam.
(ii) As Ell beam if it supports a slab on one side and
(iii) As Tee beam if it supports slab on both sides.

14.9.1 The following load combinations shall be considered:

(i) Design dead load on all spans with full design live load on two adjacent spans.
(ii) Design dead load on all spans with full design live load on alternate spans.

14.9.2 When design live load does not exceed 75% of the Design Dead load, the loading arrangement may be Design Dead load and Design live load, on all spans.

14.9.3 For beams and slabs continuous over supports, Load Combinations given in 14.9.1 may be assumed.

14.9.4 Find out reactions and fixed end moments, at supports of a beam by using standard beam formulae.

15. PRELIMINARY COLUMN DESIGN AND DETERMINATION OF PRELIMINARY COLUMN DESIGN AND DETERMINATION OF SIZE OF COLUMN SECTION (P.C.D.)

15.1 In P.C.D. of column section at particular floor, total load acting on the section is worked by adding.

(a) Load from upper column section.

(b) The support reactions (Calculated in PBD) of all relevant X and Y direction beams connected to the column at particular floor level.

(c) Self weight of the particular column.

The P.C.D. of a column is to be started from the top of the critical section and proceed to next lower section till you reach footing level.

15.2 The dimension of a particular column section is decided in the following way.

(i) A column shall have minimum section 23cm. X 23cm. if it is not an obligatory size column

(ii) The size of obligatory column/s shall be taken as shown on the architect's plan. For non obligatory columns as far as possible the smaller dimension shall equal to wall thickness as to avoid any projection inside the room. The longer dimension should be chosen such that it is a multiple of 5cm. and ratio $P_u/(f_{ck}bd)$ is restricted to, for non-seismic area 0.4 (for corner columns it may be 0.35) and for seismic region 0.35(for corner columns it may be 0.30)

Where Pu, F_{ck}, b, d, have the following meaning.

Pu is the factored load on the column. (in Newton)

Fck is characteristic compressive strength of concrete. (Newton/mm^2)

b is the breadth of the column. (mm)

d is the depth of the column. (mm)

15.3 The above ratios will ultimately help in keeping requirements of steel for columns within 0.8 to 2.5% which is economical and will avoid congestion of steel. Generally the concrete mix in R.C.C. work shall be of minimum M:20 grade. However for the structures in coastal area and highly polluted (Aggressive Atmosphere and/ or subsoil conditions) areas the minimum mix shall not be less than M30 grade.

15.4 If the size of column is obligatory or if size can not be increased to the desired size due to Architectural constraints and if the ratio of $P_u/(f_{ck}bd)$works out to be more than the limit specified above it will be necessary to upgrade the mix of concrete. For ease of construction frequent changes in column size should be avoided As far as possible in multistoried building at least two floors should have the same column section. Preferably least number of column sizes should be adopted in the entire building. And mix of all the columns on a particular floor should be same.

15.5 Effective length of column shall be calculated as per I.S: 456:2000.

15.6 Columns shall be designed for direct load and uniaxial or biaxial bending considering different load, combinations as given in I.S.456:2000.

In addition, all columns shall be designed for minimum eccentricity equal to [(unsupported length of column /500) + (lateral dimension /30] subject to minimum eccentricity of 20mm in each direction.

15.7 Grouping of columns can be done on the basis of size, orientation and forces acting on it.

16. ANALYSIS FOR BUILDING FRAMES

16.1.1 A building may be required to be designed for Non Seismic/Seismic Forces and/ wind forces (whichever is governing) depending on the location, plan dimensions and height of the building.

16.1.2 For buildings located in seismic zone II, only (Dead Load +Live Load) Analysis is sufficient and seismic analysis is not required to be carried out.

Building up to Ground +2 floors in Seismic Zone II are generally designed by following the provisions of IS 456:2000.

However for building having G+3 stories and above located in Seismic Zone III the seismic analysis of the building frames is required to carried out. The magnitude of seismic nodal horizontal forces are worked out as per IS 1893:2002.

Before starting the analysis of frames the forces for which the building is to be designed and the design parameters and particularly Importance Factor (I) and soil foundation system for Seismic Design to be adopted should be finalized.

16.2 SEISMIC ANALYSIS

16.2.1 For calculating seismic forces refer provisions of I.S.: 1893-2002.

16.2.2 It should be noted that provisions of I.S : 1893:2002 do not apply for.

(i) Buildings constructed in steps, in hilly area.

(ii) Plaza type buildings, where there is sudden change in stiffness (high rise building with the side flanks).

(iii) Building with flexible first storey including buildings like assembly halls and cinema theatres where the central auditorium (in one storey) covers up to three stories of the side flank and other irregular buildings.

16.2.2.1 In general, in all seismic zones the buildings having height upto40m, can be designed for seismic forces by static Approach. For building greater than 40m and up to 90m height, Model Analysis is recommended. However the static approach may also be used for design of structures in zone II and III.

For building greater in height than 40m, checking for drift and torsion is necessary.

For building taller than 40m detailed Dynamic Analysis shall be made based on expected ground motion and model analysis.

At present for most of the buildings we come across, use of static approach is adequate.

However for important buildings it is felt necessary to carry out Dynamic Analysis,

16.2.3 STATIC APPROACH FOR SEISMIC ANALYSIS

16.2.3.1 In this approach the structure is treated as a discrete system, having concentrated masses at the different floor levels which compose of mass that of columns and walls of half the floor above and half of the floor below.

16.2.3.2 Using details from P.C.D. the base shear can be worked out as follows.

(i) Find the total load i.e. (Dead load+ Live load) on each floor by summing up loads of all columns at that floor level.

(ii) Find the Total live load acting on every floor.

Total live load =Live load intensity X Area on which this live load intensity acts,

In case of areas having different live load intensities, work out separately for each case and sum up to get total live load.

(iii) Total Dead load at each floor = (i) - (ii).

(iv) Find out Total Appropriate Live Load to be taken for working out horizontal seismic force as per I.S : 1893.

(v) For calculating the earthquake forces on terrace (roofs) the live load is not be considered.

(vi) Total weight of building to be taken for Seismic Design W= (iii)+ (iv).

(vii) From the seismic map of India find the Zone of the location of a building. Using the 'Importance factor ' (I.S.: 1893) for the soil foundation system as per I.S. : 1893, calculate A_h.

(viii) Calculate base shear (V_b), using formulas given in I.S. 1893, that is (V_b) = A_h x W.

(ix) Distribute the base shear between all floors of building as per I.S: 1893. These are floor lateral shear forces for frame analysis.

16.2.4 Seismic Analysis is carried out based on the following assumptions

(i) The Seismic forces acts, at a time along one direction only, i.e. when seismic force along with dead and live load forces are acting on a frame along X direction then on Y direction, only dead and live load forces are acting and vice versa. Also, earthquake is not likely to occur simultaneously with wind.

(ii) The nature of seismic force action is reversible in direction (i.e. + and - forces can act on the frame.)

(iii) Horizontal deflection of all joints of a frame, at particular floor level is same. This is the consequence of rigid floor diaphragm normally provided by monolithic slab.

(iv) The individual frame shares the storey shear in proportion to its stiffness.

(v) The inverse of deflection of a frame is treated as a measure of its stiffness.

16.2.5 A judicious choice of beam sections (as explained in Para 13.2) and column sections (as explained in Para 14.2) will ensure that the deflection of the frames are within permissible limits.

16.2.6 In the first phase, the Analysis, gives only Dead Load and Live Load Results.

16.2.7 To find the deflection of each frame apply value of Total storey shear (i.e. 100% of the horizontal force calculated for entire building) at the appropriate nodes and analyze for 2nd

phase of Analysis which gives the displacement at a particular level for all the X and Y direction frames.

Generally the deflection of the frame at terrace level is maximum.

As stated earlier the total base shear is shared in all X/Y frames of the buildings in inverse proportion of their deflections. The inverse of deflection for each frame is calculated.Then using these values; ratio of (inverse of deflection of a particular frame (X/Y) Direction /sum of inverse of Deflection of frames) is worked out in percentage for each and every frame.

16.2.8 In the third phase the percentage value of total base shear acting on a particular frame is used as input (horizontal forces acting on the frame at appropriate floor levels) and detailed frame analysis done.

16.3 WIND ANALYSIS:

As per I.S. 875:1987(Part-III) wind analysis is generally not necessary except for Tall Buildings. Para 7.1 of the code stipulates that "flexible slender structure and structural elements shall be investigated to ascertain the importance of wind induced oscillations or excitations along and across the direction of wind.

In general the following guidelines may be used for examining the problem of wind introduced oscillations.

(a) Building and closed structures with height to minimum lateral dimension ratio more than 5, and

(b) Buildings and closed structures whose natural frequency in the first mode is less than 1 Hz.

Any structure or building which satisfy either of the two criteria shall be examined for dynamic effects of wind. For this modal analysis (on similar lines of modal seismic analysis) should be carried out. If the wind introduced oscillations are significant, analytical methods or use of wind tunnel modeling will have be carried out.

16.3.1 Wind analysis for structure which are not required to be examined by dynamic analysis, is carried out by static approach and based on the following assumptions.

(i) the wind force act at a time only along one direction.

(ii) Horizontal deflection of all joints of frame at particular floor level is same.

(iii) The individual frame share the storey horizontal force in proportion to its stiffness.

16.3.2 Analysis for wind forces by static approach is done in the same manner as described for Seismic Analysis above but here the horizontal wind forces acting at each floor level is calculated as per provisions of I.S: 875(Part-3)-1987.

16.3.3 The wind analysis is carried out using similar assumptions as stated in 16.2.5 above for seismic condition.

16.3.4 The designer should note that Seismic and wind forces can act in either direction i.e. they are reversible forces. The overall effect is that these forces induce moments and tension at supports depending on the direction of their action.

17. PREPARATION OF FRAME SKETCHES, FILLING CODING SHEETS AND CREATING DATA FILES

17.1 The data of frames shall be written on the frame sketches. Following steps shall be considered in preparing the frame sketch.

Name all the frames of the layout starting with X direction frames i/e. X_1, X_2, etc. from left to right and then Y direction frames i.e. Y_1, Y_2, etc. from bottom to top in the R.C.C. layout.

(i) Draw frame sketch indicating the number of stories (including the vertical expansion proposed), and number of columns forming the particular frame.

(ii) Write the relevant column and beam numbers involved in the frame.

(iii) Dimension the storey heights (including plinth to footing level) and spans of beams.

(iv) Draw a sketches of column as per orientation as applicable to the frame, just bellow the footing level joint.

(v) Show the type of joint at foundation assumed for analysis (i.e. fixed or hinged at bottom).

(vi) Show all the loads coming on the beams and nodal vertical and horizontal forces.

(vii) Number the joints. Start from lower left most joint and proceed left to right and then bottom to top giving joint number serially.

(viii) Number the members. Start with beams first and then number columns. For beam member number start from lower left most beam and proceed left to right and then bottom to top numbering serially. For column number give immediate next number of the last beam member from the left most bottom column section. Proceed serially bottom to top and then left to right.

(ix) Group beams and columns according to span and loading. Indicate for each member, the group number to which it belongs.

17.2 With the help of frame sketch, data of all frames shall be written on coding sheets in the manner & format, required by frame analysis Program used. The data on coding sheets is then stored on a floppy disk or CD as data files.

18. ANALYSIS OF PLANE FRAME USING COMPUTER PROGRAM

18.1 Checking of Input Data

Before execution of programme in the computer it is very essential to check the input data thoroughly so as to avoid any errors in design, wastage of computer time and stationery. Always bear in mind "Garbage In, Garbage Out" in case of Computer Aided Analysis.

18.2 Guidelines for checking the Data file:

(i) Check whether the format of the particular data is correct or otherwise. The program will not get executed if there is format error.

(ii) Check each and every data, particularly data regarding frame geometry (number of bays, number of joints) member properties (breadth, depth, mix) and loading details. Any error in this data may execute the program fully. However output will give misleading and wrong results.

(iii) Data given in line No.4 onwards should be compatible with the data given in lines up to line 3. Any non compatibility will abort the execution of program.

18.3 Running of the Frame Analysis program

The program such as STAAD Pro uses Stiffness Matrix method of Analysis.

18.3.1 This program can be run only after installing the software properly.

18.3.2 Program is designed to give results for various load combinations with the appropriate load factors as per I.S: 456-2000(when so specified in the input data of frame) namely

(i) 1.5 [Dead Load + Live Load] for non-seismic analysis.

(ii) 1.2 [Dead Load + Live Load + Seismic Load] for seismic analysis.

(iii) 1.2 [Dead Load + Live Load + Wind Load] for wind analysis.

The designer has to decide which of these load combinations are required and accordingly give the details of horizontal loads. Additional load cases are required to check the stability as per IS.1893.

18.4 Output results from Computer

Program output gives values of axial force, moment and deflections for each member and R.C.C. Design of beams. (i.e. values of area of reinforcement, required at supports, quarter span and center of span and details of shear reinforcement)

The results obtained by running program should be thoroughly checked before accepting the same. The following checks are essential:

(a) The checking of input data as already discussed.

(b) Checking of displacements.

(i) Displacement of joint are printed. For fixed support end of a frame the value of displacement and rotations must be zero.

(ii) At hinged end of a frame horizontal and vertical displacement must be zero.

(iii) The maximum horizontal displacement due to earthquake forces between successive floors shall not exceed 0.004 times the difference in level between these floors.

(iv) Displacement of all joints on a particular floor should be equal or nearly equal. Horizontal displacement at the roof level must be less than H/500 where H is the height of the building.

(v) While checking of forces, at every joint following 3 equilibrium equation must be satisfied.

   (a) Sum of all vertical forces must be zero.

   (b) Sum of all horizontal forces must be zero.

   (c) Sum of all moments at the joint must be zero.

   Designer should personally check these points and check some joints for his own satisfaction.

   For the whole structure, equilibrium equation should be satisfied at the foundation level.

19. DESIGN OF VARIOUS R.C.C. ELEMENTS OF BUILDING

After the analysis is over, the designer will undertake the detailed design of various members of the building in the following order of actual construction, to be in tune with construction program decided by the field Engineers.

(i) Design of piles and pile caps/ open footings (depending on the site and foundation conditions).

(ii) Design of columns.

(iii) Design of beams. (Plinth Level to Terrace Level).

(iv) Design of slabs. (Plinth Level to Terrace Level).

(v) Design of water tank/s.

19.1 Design of Pile and Pile Cap

Piles are required to be provided where the strata of adequate bearing capacity are not available at reasonable depth, and site conditions dictate that open foundation is not feasible and economical. This is generally the case in black cotton soils and reclaimed areas.

For very low bearing capacity strata, and where pile foundation is not economical, we may adopt raft foundation. For codal provisions refer I.S.:2911.

It is good design practice to provide minimum two piles or 3 piles in triangular pattern and generally not more than 4 piles (in square pattern) under a column.

For piles, where the subsoil water is polluted and presence of sulfides and/ chlorides is more than the safe limits, sacrificial cover shall have to be provided. However, the same shall be neglected while working out the area of concrete required for sustaining the load on pile. The diameter of pile and pattern of pile cap for twin or triple pile group shall be so chosen that the adjoining pile caps do not get overlapped and there is at least minimum distance between the two adjacent pile caps as stipulated in the code. The mix of the concrete for casting of pile shall be always stipulated as M-30 or richer.

19.2 Design of open Footings

Isolated footings:

(i) Write down the different load combination values for the section "plinth to footing" of the column footing in question from the relevant X and Y direction Frame Analysis output.

(ii) The working load for each load combination is then worked out by dividing each load by the appropriate load factor of the particular load combination.

(iii) The maximum value of all these working loads is taken as design working load on footing.

(iv) The isolated footings are designed manually.

(v) Normally square or trapezoidal footing is provided except where the site conditions demand otherwise.

(vi) Designer shall check that with the designed dimensions, the isolated footings are not getting overlapped, If they are getting overlapped, suitable combined footings shall be designed.

Combined footings:

These are provided

(i) At the expansion joint locations and

(ii) When it is noticed that when designed as isolated footings, the footings are getting over lapped or encroaching on adjoining property. The design working load for combined footing shall be sum of design working loads of columns constituting the combined footing.

Special types of footings:

For design of pedestal or any other special type of footing like strip footing etc. reference may be made to standard text books.

Design Checks for all types of footings:

The design shall be checked for following,

(i) Check single shear, double shear.

(ii) Check for negative moment.

(iii) Check for bearing pressure on top of footing.

(iv) Check for uplift and lateral pressure effects.

19.3 DESIGN OF COLUMN SECTION:

A column is subjected to direct load and moment across its axes. Find out design loads and design moments across appropriate axes from the output of relevant X direction and Y direction frame analysis, for the design section under consideration.

The data for column design by Limit State Method shall be as per load combinations in IS code.

The columns shall be designed as uniaxial or biaxial type depending upon whether the moments are acting across one or both axes of column and their relative magnitudes.

Effective length of column member shall be worked out considering end conditions and used in the calculations.

The column design is done manually using Limit State Method The design section and the reinforcement shall satisfy all the combinations stated above. After designing the reinforcement detailing should satisfy IS13920:1993.

Approach for Economic Design of Column

In the design of column, two factors are to be keenly watched namely $P_u/(f_{ck}bd)$ and interaction factor.

The $P_u/(f_{ck}bd)$ factor is a measure of compressive force in column and by keeping the value of this factor equal to or less than 0.4, it is seen that the concrete section provided is utilised to the maximum extent.

The interaction factor is a measure of degree of utilization of steel reinforcement provided in the column section.The value of this factor (calculated as per I.S.456) close to 1.00 ensures that the external loads and moments are resisted optimally by the proposed concrete section along with the (proposed) steel reinforcement pattern.

Always begin by designing the top most section of a column and then proceed successively to the lower section.

Begin the design by choosing "One bar at each corner " i.e. 4 bar pattern (giving total area of reinforcement required on the basis of minimum steel criteria) and if this first approximation is not safe then modify the diameter of bars and / or reinforcement pattern till you get the interaction Ratio close to 1.0.

As far as possible, for the next lower story column section, continue the same bar diameters and reinforcement pattern.

Choosing proper reinforcement pattern

While deciding the pattern, it should be noted that when the C.G. of the steel provided is away from the N.A., it gives higher moment of resistance to the section.

If the first approximation of steel reinforcement proves inadequate, try to increase the diameter and /number of bars. It shall ensured that the pattern selected, the bigger diameter bars are always placed near the corner /faces away from axis of bending. Each successive trial shall be taken by gradually changing reinforcement, and the final trail should provide just adequate steel reinforcement. The reinforcement pattern should fulfill the minimum spacing criteria. The reinforcement bars are required to be laterally tied by providing links of proper shape.

While choosing the reinforcement pattern, provide adequate number of bars so that it satisfies spacing criteria as per I.S. 456:2000.

A sketch giving the suitable link arrangements for column reinforcement which will create least congestion and aid easy flow of concrete in steel cage is necessary. This will be included when discussing about detailing of reinforcement.

The number of reinforcement bars shall be so chosen that for uniaxial column, equal area of steel on opposite faces is provided and for biaxial column, equal area of steel on all four faces is provided.

The column should be designed to satisfy capacity shear criteria. Capacity shear must be calculated manually and not taken from shear values of computer analysis. Plastic hinge should be detailed to behave in a ductile manner.

19.4 Design of Beams

(i) Based on analysis compute the area of required steel at supports, at quarter span (from each end) and at centre of span. The Designer has only to choose the diameter and numbers of top and bottom bars such that actual steel area is just over the design value and there is no congestion of steel. It is incorrect to provide excess steel than what is required. Excess flexural steel may make the beam fail in a brittle manner due to crushing of concrete.

Non congestion can be ensured by keeping horizontal distance between the bars as the largest of the following,

(a) The diameter of bar (in mm) if the diameters are equal.

(b) The maximum diameter (in mm) of bar if the diameters are unequal.

(c) 5 mm more than the nominal maximum size of coarse aggregate.

For ensuring better compaction of concrete with needle vibrator, it is desirable that this minimum clear distance be more than 50 mm. To achieve this, reinforcement may be spread or more number of layers of steel can be used.

(ii) The anchor bars (at top and bottom) shall be minimum 2 Nos. of 12 mm diameter.

(i) Where it is not possible to accommodate all the bars in one layer, provide them in layers. The vertical distance between these layers shall not be less than the largest of following:

(a) 15mm.

(b) 2/3 of the nominal maximum size (in mm) of coarse aggregate.

(c) Nominal size of bars (in mm).

(ii) It is a good practice that bars at the bottom of beam are taken straight without kinking.

(iii) When there are collinear beams over a support the extra steel over the support (at top and/ bottom as the case may be) shall be maximum required for the either of the two.

For collinear beams the extra steel over support shall be continued in the adjoining span for a length equal to effective depth plus anchorage length or 25% of the adjoining span whichever is more.

For non collinear beams the extra steel over support shall be anchored in supporting column for full anchorage length plus width of column.

(iv) The stirrups of shear reinforcement shall be provided with appropriate diameter of mild steel or H.Y.S.D. bars so that there is no congestion of reinforcement in beam and it shall be seen than the ductility criteria where applicable is also fulfilled.

For requirements of ductility detailing refer IS 13920:1993

19.5 Design of Slabs

(i) The slabs may be one way or two way depending on the panel dimensions.The design moment coefficients of a particular slab shall be taken in accordance with its boundary conditions.

(ii) Design of slabs is done manually by referring to design Hand Book for R.C.C such as SP 16

(iii) Minimum diameter of bars for slabs shall be 8 mm.

(iv) In case of future vertical expansion, the R.C.C. layout of the top floor shall be as per Architect’s plan. However the slab reinforcement shall be maximum of that required for future floor or for present terrace loading including weathering course.

19.6 Design of overhead water tanks and other fixtures on roof.

The design of water tank is carried out as per procedure given in the “Reinforced Concrete Designer’s Hand Book” by Reynolds, and conforming to I.S.3370.

The seismic effects have to be taken into account as per IS 1893:1984.

Other fixtures on roof such as Chimney, Solar heating devices etc. have to be secured on the roof against seismic shear as per IS 1893:2002.

19.0 Drawings to accompany the design

The following drawings are required for successful execution of the project.

1. Foundation details.
2. Column and Plinth beam details- Cross section and longitudinal section.
3. Floor beam layout- Cross section and longitudinal sections.
4. Slab layout and reinforcement details.
5. Stair case room details with bottom dimensions for shuttering.
6. Roof slab details & Toilet Slab details- sunken-slab.
7. Lift head room and water tank details.
8. Miscellaneous details – Expansion Joint, Architectural features affecting structural performance, drain covers, ramps on ground, etc.

20. DETAILING ASPECTS OF REINFORCED CEMENT CONCRETE FRAMED BUILDINGS

With the spread of reinforced concrete construction to semi-urban and rural area in Tamil Nadu, often buildings are constructed using reinforced concrete columns and beams, without proper engineering design, based on the experience of local masons and petty contractors. Use of isolated columns together with load bearing walls for supporting long internal beams or those in verandahs and porches is becoming quite common. In most cases, such constructions suffer from deficiencies from the disaster resistance viewpoint since no consideration is given for the effect of lateral loads and the connection details are usually such that no moment carrying capacity due to lateral forces can be relied upon. Beams simply rest on top of columns and mostly held in position by friction. The friction can be overcome by buoyancy or upward movements due to either wind or earthquake or water uplift pressure due to Tidal waves or Tsunami.

The other serious deficiency is in concrete quality in respect of mixing, placing, compacting and curing. The aim of this section is to provide working guidelines for such buildings in R.C. frame constructions in which columns are supposed to resist vertical loads as well as horizontal forces and the filler walls are assumed to be neither load bearing nor taking part in the lateral resistance of the building. Large halls for gymnasia, assembly halls, etc., having a floor area more than 60m^2 or beam spans more than 7m must be designed and proof checked for adequacy.

Detailing of Beams

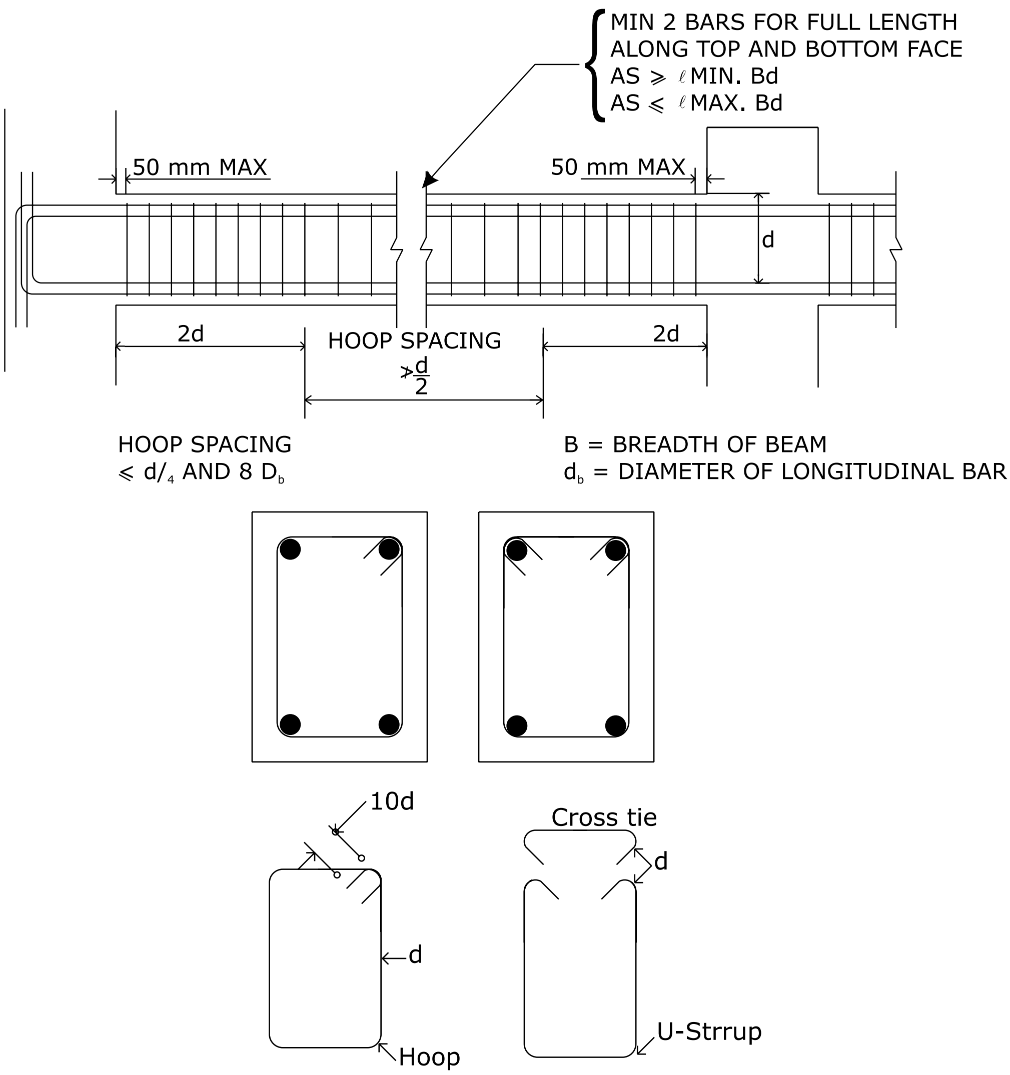
a) Longitudinal Steel

Beams should be reinforced on both top and bottom face throughout. Where reinforcement is required by calculation, the percentage should correspond to that required for ductile behavior. The recommended limits on steel area are shown in Table.2. Minimum steel should consist of two bars of 12mm diameter in case of mild steel (MS) and 10mm diameter when high strength deformed bars (HYSD) are used. Detailing of beam reinforcement is shown in Fig.2.

Table8: Recommended Limits on Steel Area Ratio in Beam

Concrete	Steel	p_{max}	p_{min}
M20	M.S (f_{y-}=250 Mpa)	0.011	0.0035
	HSD (f_y=415Mpa)	0.007	0.0022
M30	M.S (f_{y-}=250 Mpa)	0.015	0.0048
	HSD (f_y=415Mpa)	0.009	0.0029

Notes: f_{ck} = 28 days crushing strength of 150mm cubes,
f_{y} = Yield strength of reinforcement,
MS = Mild Steel, HSD = High-strength deformed bars,
$p = A_s/bh$,
$A_{smax} = p_{max}bh$,
$A_{smin} = p_{min}\,bh$



Beam Web Reinforcement

Fig.2. Detailing of beam reinforcement

b) Splicing of Steel

All longitudinal bars should be anchored or spliced for full strength development. All splices should be contained within at least three stirrups at each end and one in the middle of the splice so as to avoid spalling of cover concrete (fig.3).

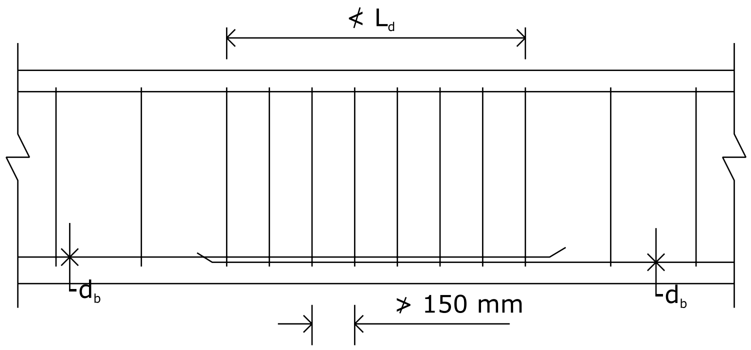


Fig.3.Splicing of reinforcement in a Beam

c) Transverse Stirrups

The ultimate shear strength of the beam should be designed to be more than its ultimate flexural strength. Vertical shear stirrups should be closely spaced at not more than one-fourth of effective depth in end 2d-length of spans of the beams. In the remaining length spacing should not exceed d/2 as shown in Fig. 4.

$$V_u = 1.4\left[\frac{M_{u,}^{bL}\,lim + M_{u,}^{bR}\,lim}{h_{st}}\right]$$

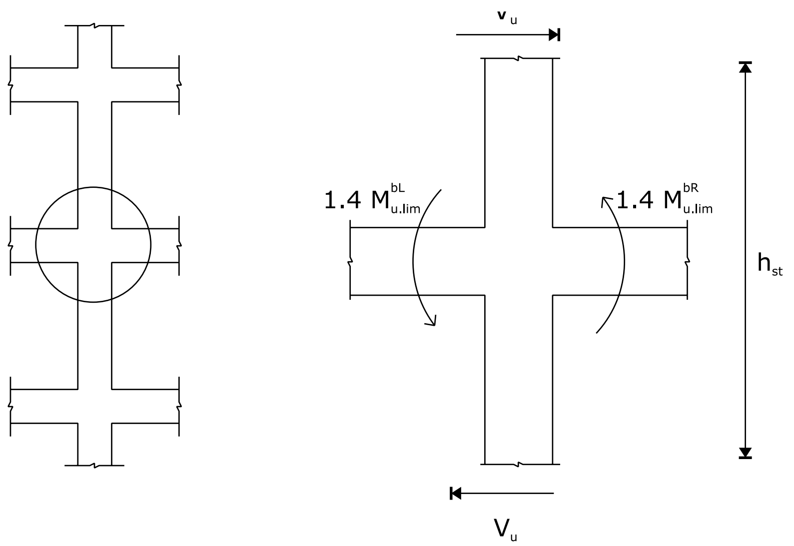
Detailing of Columns

a) Column Section

In view of earthquake force acting in all directions, square section of columns is better than rectangular.

b) Longitudinal Steel

Vertical reinforcement should be distributed on all the faces of the columns. Use of eight vertical bars is preferable to four bars of equal area; minimum diameter of bars should be 12mm. Splicng of column bars should not be done at the bottom but should be done where the B.M due to lateral load is nearly zero. Namely at the middle of the column.



$$V_u = 1.4\left(\frac{M^{bL}_{u,\,lim} + M^{bR}_{u,\,lim}}{h_{st}}\right)$$

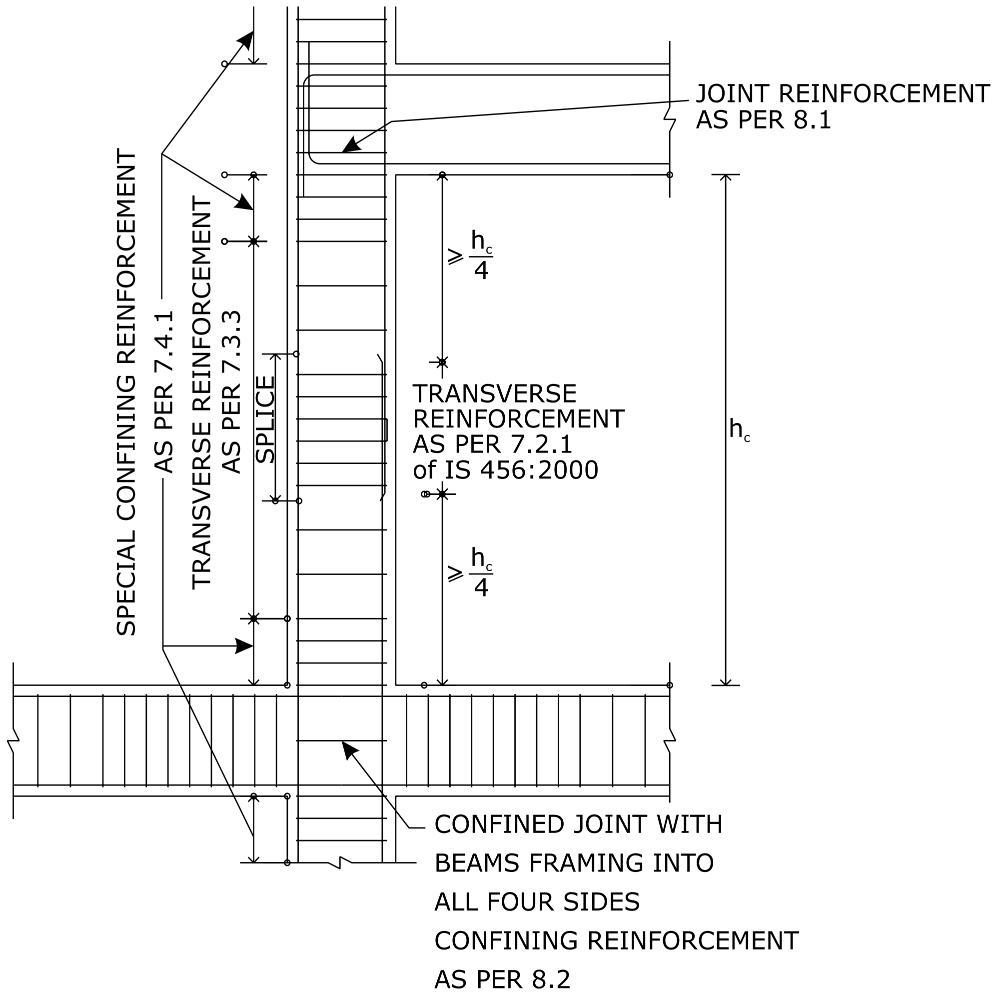


Fig.4 Column reinforcement details

c) Lateral Reinforcement

Concrete confined within the closely spaced laterals or spirals is stronger as well as much more ductile as compared with plain concrete or that containing widely spaced stirrups. The behavior of columns can be much improved by using closely spaced ties with adequate anchorage at ends in the form of suitable hooks. In a length of about 450mm near the ends of columns, a spacing not more than 100mm may be adopted for achieving adequate ductility. (Fig.5).

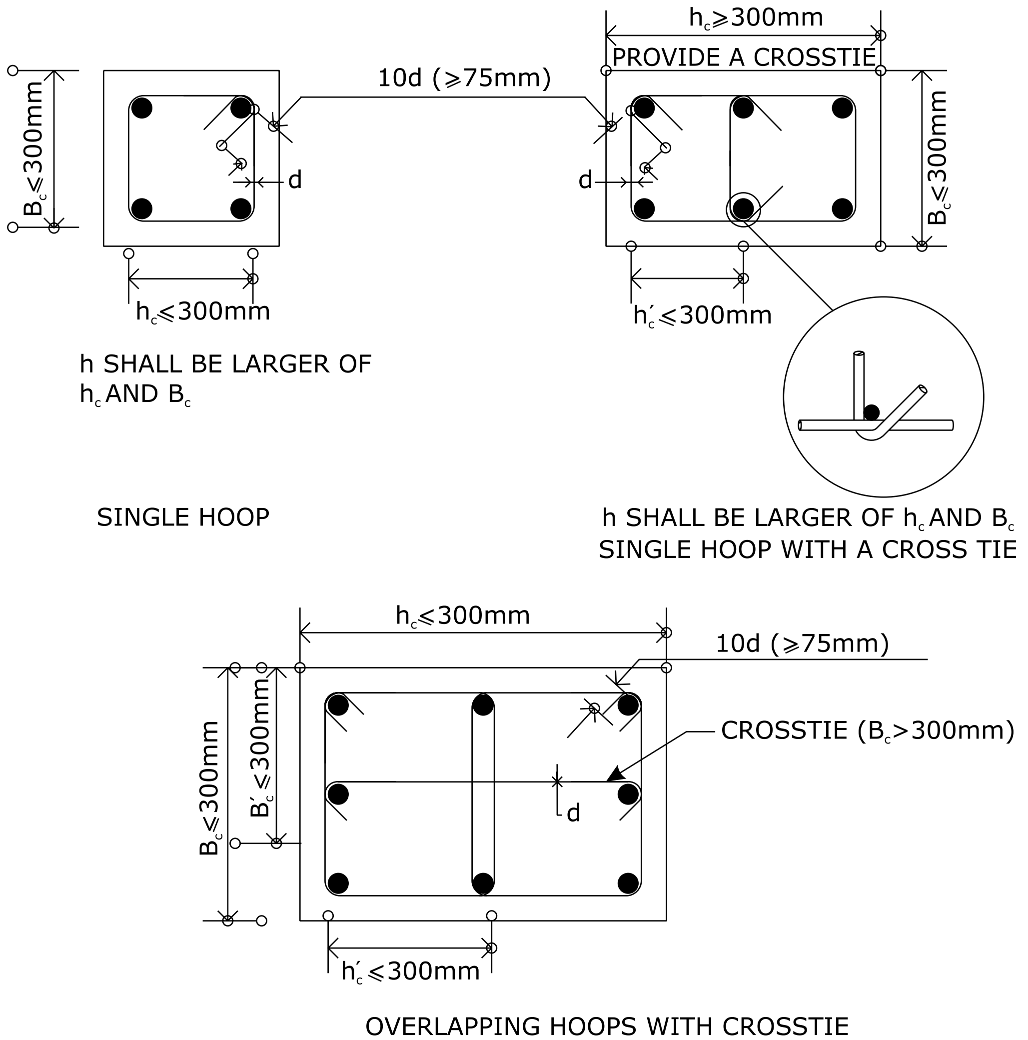


Fig.5. Column Details

d) Corner Column

The corner columns of buildings are stressed more than any other column due to biaxial bending and must therefore have steel distributed on all faces and have closely spaced lateral ties.

Connection

In the connections, the beam and column bars must be well anchored in the compression zone so as to achieve their full strength.

Where beams on all four sides do not confine the joint, it will be necessary to place the closely spaced ties in the column throughout the height of the joint as well. A typical beam column joint is shown in Fig.6.

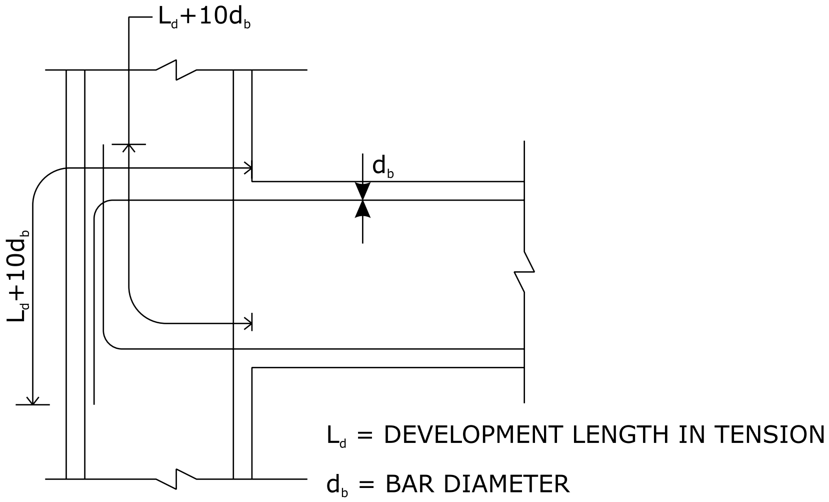


Fig.6 Beam column joint details

Detailing of foundation

Foundation should be provided with adequate anchorage and confining steel as shown in Fig.7.

Note:

1- Special confining Reinforcement e” 300mm

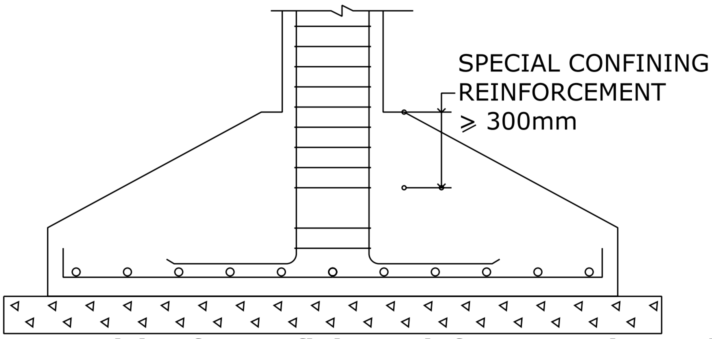


Fig.7. Provision for Confining Reinforcement in Footing

Architectural features

Any area of a column that extends more than 100 mm beyond the confined core due to architectural requirements, shall be detailed in the following manner. In case the contribution of this area to strength has been considered, then it will have the minimum longitudinal and transverse reinforcement.(Fig.8)

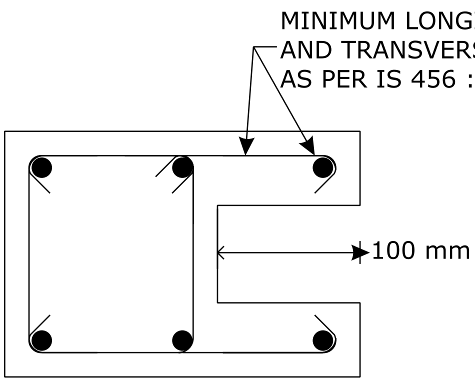


Fig.8 Detailing of Architectural features

4.8 Construction and Planning Aspects for Cyclones

General consideration for preventing Wind Damages:

The following constructional and planning aspects will help in reducing damages during cyclones and heavy winds.

4.8.1 Overhangs

i. For the purpose of reducing wind forces on the roof, a hipped or pyramidal roof is preferable to the gable type roof.

ii. In the areas of high wind or those located in regions of high cyclonic activity, light weight(GI or AC sheets) low pitch roofs should either be avoided or strongly held down to purlins. Pitched roofs with slopes in the range 22-30 degree i.e. pitch of 1/5 to 1/ 3.5 of span will not only reduce suction on roofs but would also facilitate quick drainage of rain water.

4.8.2 Wall Opening

Openings in general are areas of weakness and stress concentration, but needed essentially for lightning and ventilation. The Openings in load-bearing walls should not be within a distance of h/6 from inner corner for the purpose of providing lateral support to cross walls, where 'h' is the storey height up to eave level.

The Opening just below roof level should be avoided except that of two small vents without shutter. These should be provided in opposite walls to prevent suffocation.

The failure of any door or window on wind-ward side may lead to adverse uplift pressures under roof. Hence the openings should have strong holdfasts as well as closing/Locking arrangement.

4.8.3 Glass Paneling

i. One of the most damaging effects of strong winds or cyclones is the extensive breakage of glass panes caused by high local wind pressure or impact of flying objects in air. The large size glass panes may shatter because they are too thin to resists the local wind pressure.

ii. The way to reduce this problem is to provide well-designed thicker glass panes.

iii. Pasting thin plastic film or paper strips can strengthen the glass panes during cyclone seasons.

4.8.4 Foundations

Buildings usually have shallow foundations on stiff sandy soil and deep foundations in liquefiable or expansive clayey soils. It is desirable that information about soil types be obtained and estimates of safe bearing capacity made from the available records of past constructions in the area and by proper soil investigation. The tidal surge effect diminishes as it travels on shore, which can extend even up to 10 to 15 km. Flooding causes saturation of soil and this significantly affects the safe bearing capacity of the soil. In flood prone areas, the safe bearing capacity should be taken as half of that for the dry ground. Also the likelihood of any scour due to receding tidal surge needs to be taken into account while deciding on the depth of foundations and the protection works around a raised mound be used for locating cyclone shelters or other community buildings.

4.8.5 Building on Stilts

Where a building is constructed on stilts it should be properly braced in both the principal directions. This will provide stability to the complete building under lateral loads. Knee braces will be preferable to full diagonal bracing so as not obstruct the passage of floating debris during the storm surge.

4.7.2 Care in Concrete Construction

In reinforced concrete work, the most important requirement for good behavior is good quality of concrete, which is not usually achieved in non-engineered construction. Here simple guidelines are given for making concrete of adequate strength and durability.

a) Measuring Materials

In non-engineered reinforced concrete constructions the proportions of concrete mix are usually to be kept as 1:1½:3 by volume of cement: sand: aggregate. Under no circumstance w/c ratio more than 0.45 should be adopted. In non costal areas M20 and M30 in costal area should be the minimum strength adopted. In costal areas w/c ratio should be restricted to 0.4. The aggregate may be in the form of river shingle, or crushed stone, of maximum 20mm size. A 50kg cement sack has a nominal volume of 0.0317m^3. It will be best to make the concrete mixture using whole bags of cement. For measuring sand and aggregate, a wooden box with handles having a volume equal to one sack of cement will be most accurate as well as convenient to use. The measurement box can also be made of steel sheets.

b) Mixing Materials

Where mixing is done manually without using a power driven mixer, it should be done on an impervious platform, say, using iron sheets or cemented floor. For making a mix of 1:1½:3, six boxes of aggregates should first be measured and flattened on the platform, and then three boxes of sand should be spread on the aggregate and finally two full sack of cement opened on top. The material should first be mixed thoroughly in dry state so as to obtain uniform colour and then water should be added. The quantity of water should be enough to make a soft ball of the mixed concrete in hand. A little wetter mix is better for hand compaction and drier mix where vibrator is used for compaction. On any account water excess of 0.45 w/c ratio should not be used. It is advisable to limit w/c ratio to 0.4. If necessary, suitable plasticizers can be used for enhancing workability of mix.

c) Formwork

The quality of not only the concrete surface but also the strength of concrete depends on the quality of the formwork and its imperviousness to the leakage or oozing out of the water and cement through the joints. Wooden or steel sheet formwork with well-formed surface and joints between planks or sheets should be used. Use of water resistant plywood for the skin of the formwork will give very good surface finish for the concrete.

d) Placing of Reinforcement

While placing reinforcing bars, the following points must be taken care of otherwise the structure will get into undefined weakness. Minimum clear cover to the reinforcement: 20mm to the bars in slabs, 25mm to bars in beams and 40mm to the bars in columns. In large columns, say 450mm in thickness, the cover should be 50mm. For achieving proper cover mortar brickets of required size should be made. They should be properly installed between the bars and formwork. Tying with bars with thin soft binding wire will ensure the proper placement of bar. Mortar brickets should be of good quality so that they do not introduce local weakness below the rebar's.

The following precautions are necessary while tying the reinforcement cage:

- Tying of longitudinal bars with transverse bars and stirrups and links at each crossing with soft binding wire.
- Minimum overlap in bars: 60 times the diameter of the bar for plain mild steel and 45 times the diameter for high strength deformed bar. The overlapping portion should preferably be wound with binding wire through the lap length.
- Shape of links and stirrups: the ends of bars should be hooked by bending through 180° in mild-steel bars and 135° in deformed bars.
- The binding wire should be turned inward after binding so that they do not touch the erected formwork.

e) Casting and compacting Concrete

The concrete should normally be cast in one continuous operation so as to avoid discontinuity of more than one hour. Mixed concrete should not be allowed to stay on the platform by more than 45 minutes and must be placed in the forms and compacted continually. Hand compaction must be done by rodding through the freshly placed concrete. Simply leveling the surface with trowels will leave voids in the mass. It may be mentioned that lack of compaction results in large reduction in concrete strength, hence utmost attention should be given to this factor. For rodding, good results will be obtained by using 16mm diameter rods about 50cm long. When vibrators are used, form work should be checked to ensure proper water tightness and to withstand vibration effects of wet concrete.

f) Curing of Concrete

Concrete work requires water curing for a minimum of 14 days so as to gain strength, Otherwise the gain in strength is low and concrete becomes brittle. Concrete slabs may be kept under water by ponding of water over it by making barriers around the edges. Columns should be kept covered with wet empty gunny bags. Keeping the side forms intact on the beam webs and column sides will prevent the evaporation of water from the concrete surface and help in curing. Covering any concrete surface with polythene sheets after wetting the surface will help retain the moisture for longer period of time. Curing should be continuous and not intermittent.

g) Construction Joints

Where a joint is to be made, the surface of the concrete shall be thoroughly cleaned and all laitance removed. The surface shall be thoroughly wetted, and covered with a coat of neat cement slurry immediately before placing of new concrete. Construction joints in floors shall be located near the middle of the spans of slabs, beams or girders, unless a beam intersects a girder at this point, in which case the joints in the girder shall be offset a distance equal to twice the width of the beam. Provision of keys should be made for transfer of shear through the construction joint. Polymer bonding agent between old and new concrete can be used for good performance of construction joints.

Typical Material Properties required

Concrete is made to have the desired strength for the required use. The strength is defined on the basis of 28 day cube crushing strength.

The concrete mix is accordingly designed for M20 or M30 grade concrete. It is preferable to use M30 grade concrete in costal areas. The mass density of RC is about 24 kN/m^3 and modulus of elasticity is related with the concrete strength. Since the stress-strain characteristics are non-linear, the value of modulus of elasticity is ambiguous.

It is important to know that the tensile strength of concrete is only about one-tenth of the compressive strength. The diagonal tension caused by seismic shear forces, if not thoroughly protected by well-designed stirrups or ties, can lead to wide cracking and failure.

Concrete is a brittle material and weak against impact shock and vibrations. The reinforcing steel imparts ductility to it. The compressive strength as well as straining capacity can be greatly increased by using closely spaced lateral stirrup ties or spiral reinforcement. This is an important method for improving the earthquake resistance of reinforced columns and frames.

The critical zones in reinforced concrete frames where ductility of sections and confinement of concrete by closely spaced stirrups or spiral is essential are:

1. Ends of beam upto a length of about twice the depth of the beam where large negative moments and shears develop are likely locations for plastic hinges. Here shear and moment reversal is possible under large lateral forces.
2. Ends of columns where maximum moments develop due to lateral forces. Values of maximum column moments closely approaching plastic moment capacity can be expected and these moments are likely to under-go full reversal. High lateral shears can be developed based on moments of opposite sign at the column ends and these shears can undergo full reversal. The length of such zones is about one-sixth of the clear height of the column between floors or the dimension of the column section in the plane of the frame.
3. Joint regions between beams and columns undergo very high local shears, there full reversal is likely and therefore diagonal cracking and local deformation may cause significant part of rotation at joint increasing the lateral displacement of frame.

APPENDIX 1

LIST OF IS CODES AND FURTHER REFERENCES

1. Published by Bureau of Indian Standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002, Tel: +91 11 23234062.

   email: info@bis.org.in, Web:www.bis.org.in/

   a) IS:1893-2002: Criteria for Earthquake Resistance Design of Structures, Part1: General Provision and Buildings.

   b) IS:4326-1993: Earthquake Resistance Design and Construction of Buildings- Code of Practice.

   c) IS:13827-1993: Improving Earthquake Resistance of Earthen Buildings-Guidelines.

   d) IS:13828-1993: Improving Earthquake Resistance of Low Strength Masonry Buildings-Guidelines.

   e) IS:13920-1993: Ductility Detailing of Reinforced Concrete Structures Subjected to Seismic Forces-Code of Practice.

   f) IS:13935-1993: Repair and Seismic Strengthening of Buildings - Guidelines.

   g) IS 15498 : 2004, "Indian Standard – Guidelines for Improving the Cyclonic Resistance of Low Rise Houses and Other Buildings/ Structures", Bureau of Indian Standards, New Delhi, 2004.

   h) IS:456-2000: Code of Practice for plain and Reinforced Concrete.

2. Produced by 'The International Association for Earthquake Engineering, Tokyo'; "The Guidelines for Earthquake Resistant Non-Engineered Construction" A.S.ARYA, et al, oct.1986, Reprint by Indian Society of Earthquake Technology, Roorkee-247667.

3. Lakshmanan, N., and Shanmugasundaram, J., "Guidelines for Design and Construction of Buildings and Structures in Cyclone Prone Areas", Report of SERC-UNDP Project on "Engineering of Structures for Mitigation of Damage due to Cyclones" , SERC, Madras, January 1995.

4. Published by 'Building Material and Technology Promotion Council', Core 5-A, First Floor, India Habitat Center, Lodi Road, New Delhi-110 003. Tel: +91 11 24638096, Fax: +91 11 24642849, email: info@bmtpc.org, Web: htpp://www.bmtpc.org/

   a) Improving Earthquake Resistant Buildings-Guidelines by Arya A.S. et al -1999.

   b) Improving Wind/Cyclone Resistant Buildings-Guidelines by Arya A.S. et al -1999.

   c) "Reconstruction and New Construction of Building in Chamoli Earthquake affected areas of Uttar Pradesh" by Arya.A.S. January 2000.

5. Earthquake Resistant Construction and Seismic Strengthening, Govt. of India, Maharastra Emergency Rehabilitation Program. Revenue and Forest Department, Mumbai, India.

6. General Guidelines Part I and Technical Guidelines Part II for reconstruction of Houses affected by Tsunami in Tamilnadu- Revenue Administration – Govt. of Tamilnadu.

APPENDIX 2

Building Categories for Various Multihazard Resisting Features

In this guideline, it is intended to cover specified features of design and construction for multihazard resistance of building of conventional type. In cases of other special buildings, detail analysis of earthquake/wind forces will necessary.

For the purpose of specifying the earthquake resisting features in conventional buildings; the buildings have been categorized into four categories based on multihazard forces they are intended to resist as shown in table below:

Building Categories for Various Multihazard Resisting Features

Building Category	Soil type	Seismic Zone	Wind zone (Basic wind speed)	Importance Factor
IV	Type I	II	V_bd”33m/s	1
III	Type III	III	34e”V_b3"39m/s	1
II	Type IV	IV	40e”V_be”49m/s	1.5
I	Type V	V	V_be”50m/s	1.5

The building categories is fixed based on maximum vulnerability level if soil type/seismic zone/wind zone/importance factor/as per the above table.

APPENDIX 3

Design for Physically Challenged and Aged

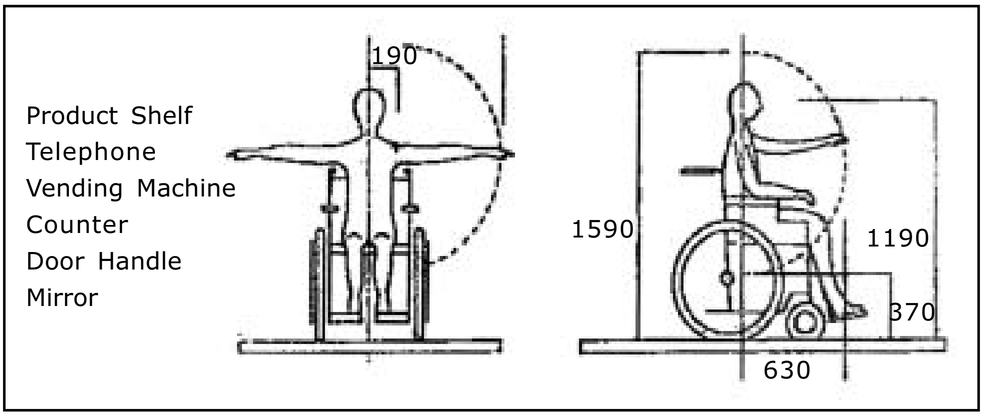
Recommended Minimum Access provision for the Physically challenged :

S.No.	Type of building	Minimum Provision
1	Single detached, single dwelling units	A minimum of 2% of the total number of units to be constructed with barrier-free feature
2	Staff housing, Multiple dwellings and high residential units	A minimum of 1 unit for every 25, plus 1 additional unit for every 100 units thereafter. Entrance and exit to be accessible
3	Tenement house, row houses and town houses	A minimum of 1 unit for every 150, plus 1 additional unit for every 100 units thereafter to be accessible
4	Post office, banks and financial service institutions	A minimum of 1 lowered service counter on the premises
5	Shops and single stories	Accessible shopping area
6	Food center	A minimum of 1 table without stool or seats attached to the floor for every 10 tables.
7	Community centers, village halls, concert halls, theaters and place for public assembly	Accessible entrance, exit and toilet should be provided. A minimum of 4 wheel chair spaces for seating capacity from over 100 to 400 seats.

Anthropometrics and Ergonomics of Physically Challenged and Aged:

Range of Reach:

- A wheelchair user's movements pivots around his or her shoulders. Therefore, the range of reach is limited, approximately 630mm for an adult male.
- While sitting in a wheelchair, the height of the eye from the floor is about 1190mm for an adult male.



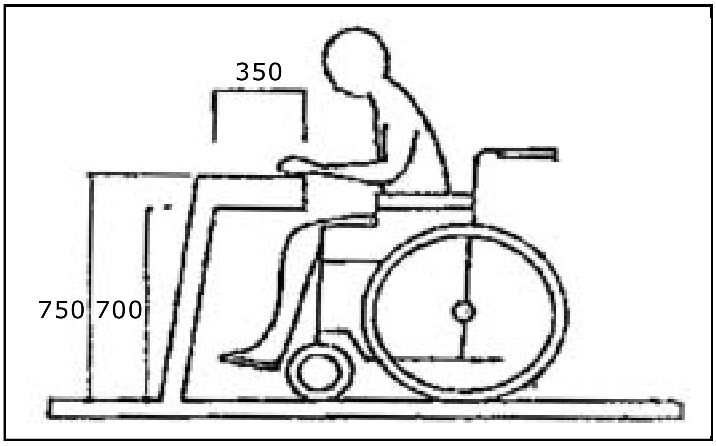
Range of Reach

- A wheelchair has a footplate and leg rest attached in front seat (the footplate extends about 350mm in front of the knee). The footplate may prevent a wheelchair user from getting close enough to an object.

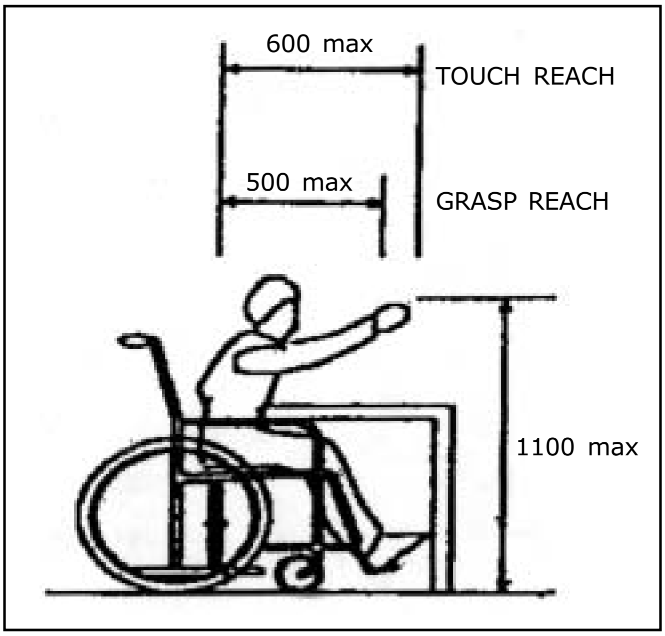
a) Manually operated equipment must be designed to be easily accessible from wheel chair.

b) Make sure that the coin slots of vending machines etc are located no higher than 1200 mm.

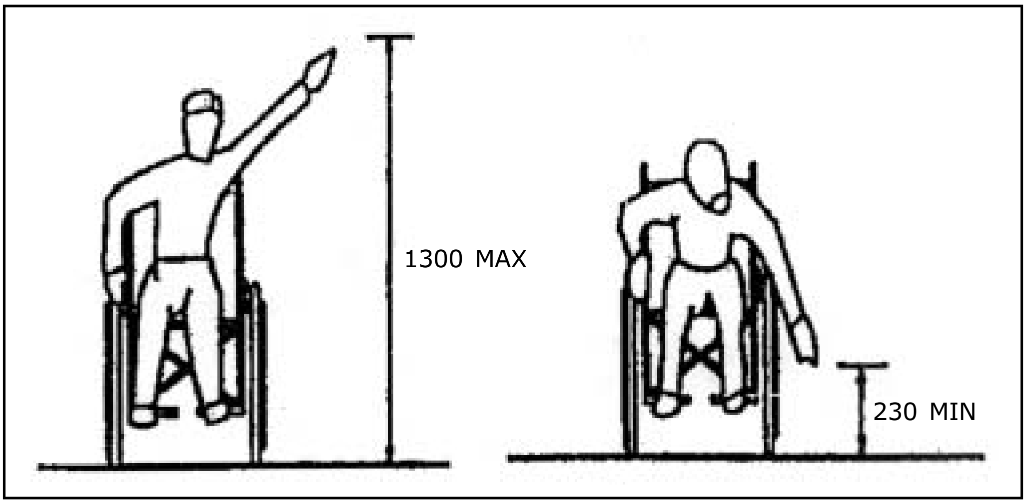
c) Allow a space at least 350mm deep and 700mm high under a counter, stand etc.



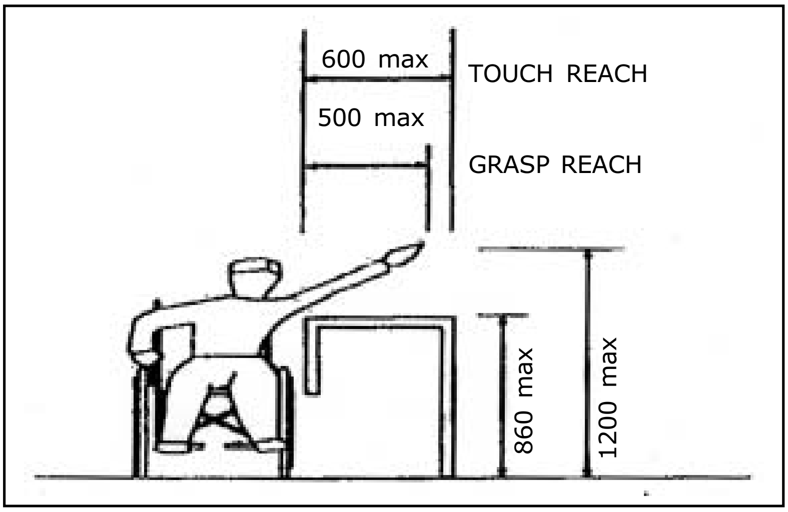
Space Required for Wheelchair Footplate



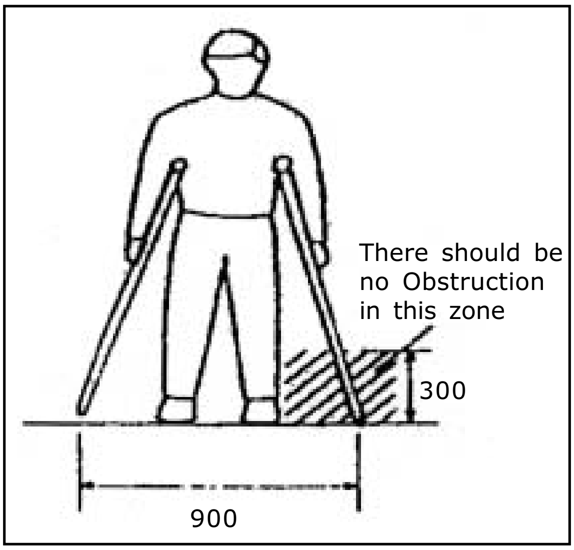
Forward Reach over Obstruction



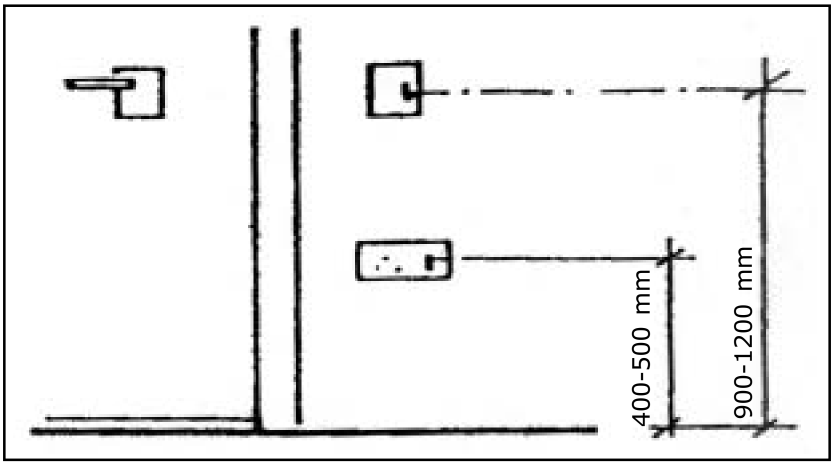
Side Reach without Obstruction



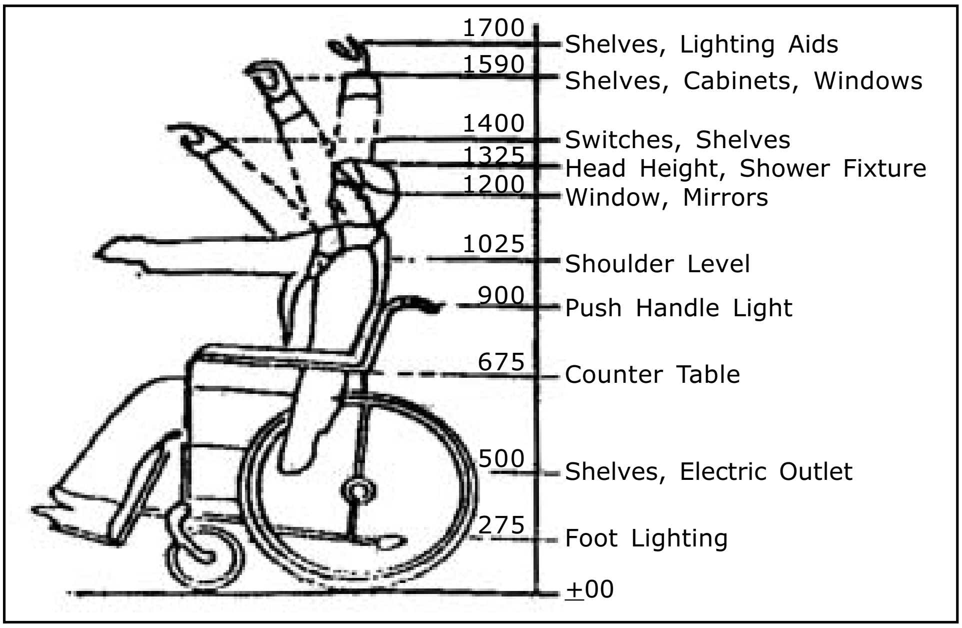
Side Reach over Obstruction



Space Allowance



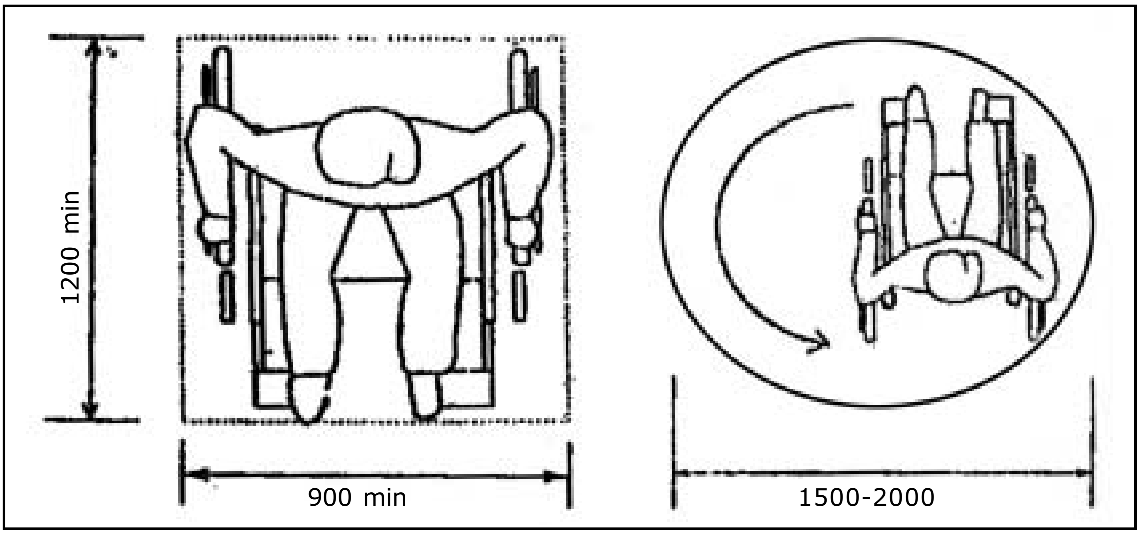
Height of Switches, Doors, Handrails



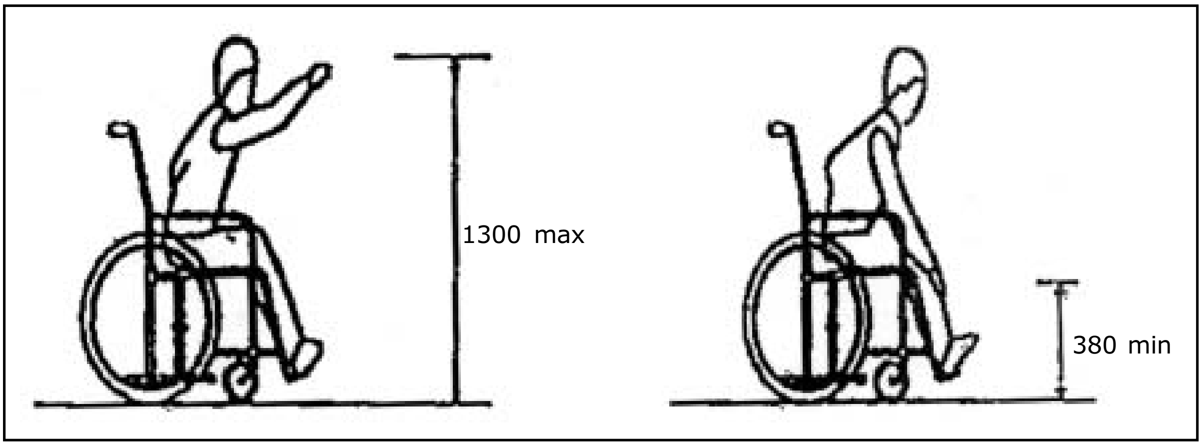
Typical Dimensions for Essential uses with in Easy Reach

Controls:

- For locking and opening controls for windows and doors should no be more than 1400mm from finished floors usable by one hand.
- Switches for electric light and power as well as door handles and other fixtures and fitting should be between 900mm to 1200mm from finished floor:
- Power points for general purposes should be fixed between 400 to 500mm from the finished floor.

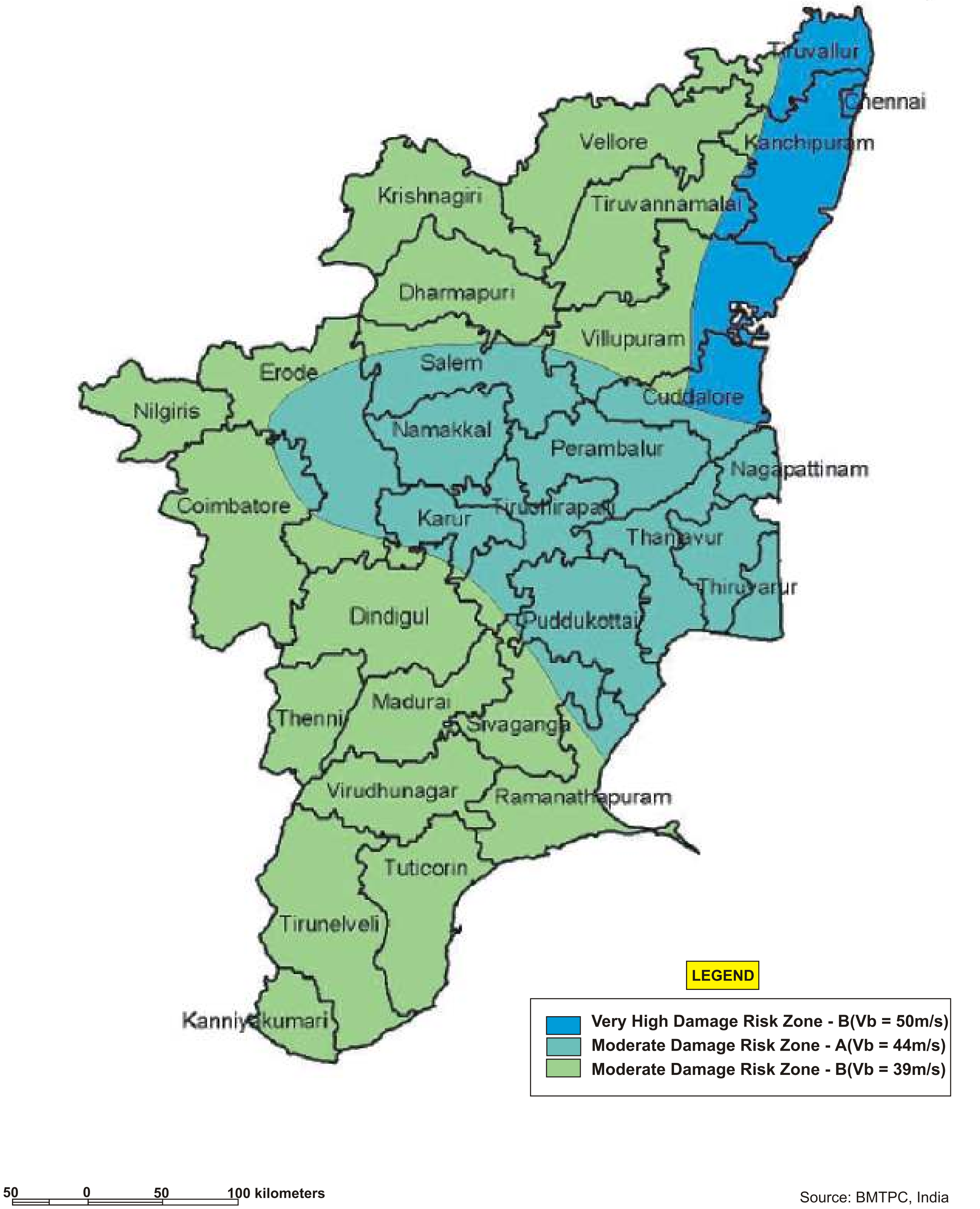


Space Allowance



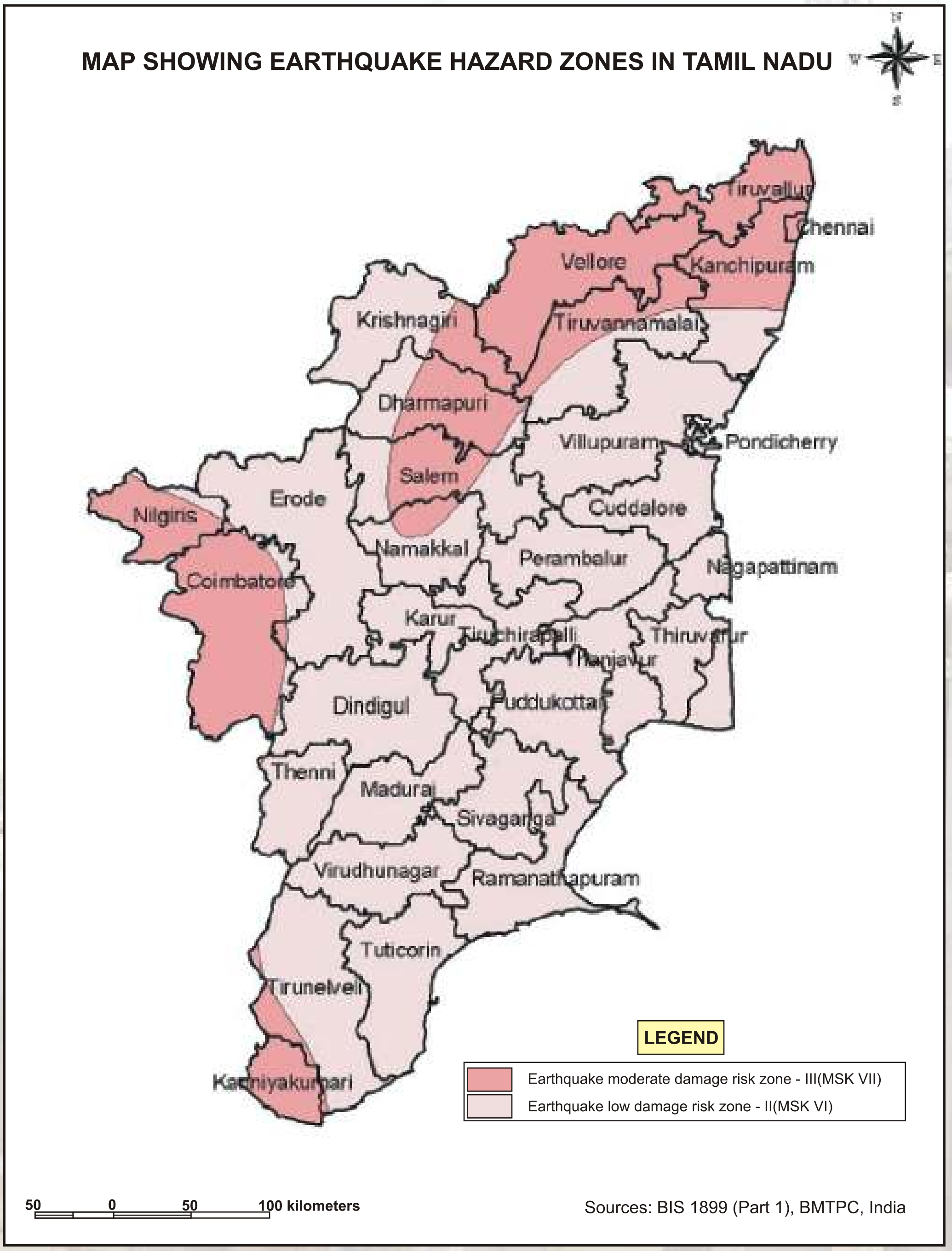
Forward Reach without Obstruction

MAP SHOWING WIND & CYCLONE ZONES IN TAMIL NADU



Source: BMTPC, India

MAP SHOWING EARTHQUAKE HAZARD ZONES IN TAMIL NADU



These guidelines have been prepared by the Disaster Management and Mitigation Department, Revenue Administration, Government of Tamil Nadu with support from UNDP. Technical inputs were provided by Prof. A.R. Santhakumar and the Expert Committee.

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