International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 8 ǁ August 2023 ǁ PP. 226-301

"Analysis and Design of G+3 Building Using ETABS"

Department of Civil Engineering, BGSIT, ACU

Date of Submission: 15-08-2023 Date of acceptance: 31-08-2023

I. INTRODUCTION

This study presents structural analysis and design ideas for a planned residential building at. All analyses and criteria for structural design input are included in this document. It is the basis for the structural engineer's plans to analyse, design, and detail the structure so that it is safe, stable, strong, and cost-effective in accordance with Indian Standards and other building standards. Structural analysis and design calculations use this report's parameters. This report addresses the minimal design need to develop the unified design base that constitutes the structural design philosophy for the proposed construction.

The design will aim to achieve

- Stability and function.
- Desirable service design load structural performance.
- Earthquake resistance.
- Structural, serviceable, durable, and economical.

II. LITERATURE REVIEW

Varalakshmi V et.al (2014) [1] built the skeleton of a G+5 home from the ground up. IS 875(Part I & II)-1987 dead and live loads and IS 1986-1985 HYSD bars were employed in this study. They observed that a reinforced concrete structure's safety depends on its structural analysis, design, and reinforcing characteristics.

Chandrashekar et.al (2015) [2] ETABS was used for both the assessment and planning of the multi-story structure. A G+5 building's response to lateral wind and seismic loads was analysed in ETABS. They considered fire spread and the best fireproof material. They offered the innovative and user-friendly ETABS application for high-rise structures to save design time.

Balaji.U and Selvarasan M.E (2016) [3] multi-story structures' static and dynamic loads were analysed and designed using ETABS. The effects of an earthquake on a G+13 house were analysed using ETABS. For both static and dynamic analyses, linear material characteristics were used. Behaviour in areas of high seismicity and soil type II was analysed using a non-linear model. Base shear and displacements were charted and analysed.

Geethu et.al (2016) [4] compared STAAD.Pro with ETABS multi-story building analysis and design. They designed residential and commercial buildings. The Auto CAD-drafted plan followed the national construction code. ETABS software had greater bending moment and axial force readings.
Nagaratna et.al Multi-storey structural analysis and design project RCC building analyses multi-storey buildings using structural analysis methodologies and software (ETABS). E-TABS software analyses beams and columns, while IS: 456-2000's "LIMIT STATE METHOD" designs slabs and footings. Uses M-25 concrete and Fe-415 steel.

Maruthi T et.al In Civil Engineering, a building is a structure with many parts such a base, ETABS' input, output, and Building-type structures' physical and numerical properties are used to solve numerical problems. Architectural features include walls, columns, floors, roofs, doors, windows, ventilators, stairlifts, surface treatments, etc. Structural studies and design create a structure that can withstand all loads.

B. Anusha et.al. We understand the housing issues in this era of diminishing space, time, and expectation. Any institution now offers student hostels. G+4 building with stairs and elevator accommodates 120 students. The model is being prepared by ETABS. It is capable of handling complex structures as well as high-rise skyscrapers. It performs assessments on beams, columns, slabs, shear walls, and other structural elements. We are able to quickly analyse a wide variety of materials using ETABS, including concrete, steel, reinforced concrete, and others. Produce gravitational, lateral, and self-weights on its own automatically. (Varalakshmi V et al-2014).

Chandrakala V B et.al , Civil engineering constructions have foundations, walls, columns, floors, roofs, doors, windows, ventilators, stairs lifts, and surface treatments. Design and analysis create load-bearing structures. Structural analysis and design need geotechnical study.
Geotechnical site investigations design and install foundations. Structural engineers must carefully design the most cost-effective and functional building for its intended application.

Nilendu Chakrabortty et.al, The successful plan and development of seismic tremor safe structures have a lot more significance worldwide, so designs are trying to use various materials to their best advantage, keeping in mind the unique properties of each material. Combining the most desirable qualities of a single material with the functional and aesthetic requirements of the project results in the construction of the most robust and aesthetically pleasing buildings.

Nirmal S. et.al ETABS engineering software analyses and designs multi-storey buildings. Extended Three-Dimensional Building System Analysis is ETABS. CAD drawings may be used to create ETABS models or as templates for ETABS items. Software generates full reinforcement report. Building floor levels are identical, reducing modelling and design time. Similar storey model creation for speed. Structural components might be steel, RCC, composite, or user-defined.

Shah H. J. and Jain S. K. et.al, Have examined building earthquake performance utilising various load combinations. They also examined high-wind building performance. They also detailed structural components utilising Indian Standard Code. Restoring force depends on shear wall location.

Uma M and Nagarajan (2016) et.al , Changed the shear wall placement to get the best multistorey building structural layout. The shear wall at the building corner has minimal displacement and drifts, making it the best site. Shear wall material also affects building performance.

2.2 Objectives

Objectives from the literature review are:

- This study utilises ETABS to do an analysis as well as the design of a G+3 commercial structure.
- Using manual methods, design the beam, slab, column, and footing.
- Manual vs. ETABS outcomes.
- Auto CAD drawing and reinforcing of structural components.

III. METHODOLOGY

Stilt, 1st, 2nd, and one more level are planned for the residential construction. RCC beams and slabs support the structural framework. Columns are spaced for stability and utility with RCC shear walls.
Architectural planning and serviceability determine beam planning. Secondary beams are required.
The system resists the entire design force according to their lateral stiffness considering floor level interaction.
IS:1893(Part1)-2016 classifies the building as an SMRF. Horizontal diaphragms are floor slabs.
3-D ETAB Software will be utilised for structural system analysis and design/detail. All designs must adhere to Indian requirements.

3.1 SOFTWARS USED:

3.1.1 AUTOCAD.

Drafters create drawings and designs using CAD. Autodesk AutoCAD. Drafters create product drawings. Engineers, surveyors, architects, and scientists utilise CAD graphics to design buildings, toys, and spaceships. CAD drafters know conventional drawing techniques too.
Drafting includes aeronautical, architectural, electrical, and mechanical specialties. AutoCAD drafters' tasks differ by specialty. Drafters utilise CAD software to sketch building proportions, materials, and construction steps. They show component-system relationships from numerous viewpoints. Drafters discuss design and layout with coworkers.
Drafters work with builders to define specifications and grasp design ideas. Drafters fix design flaws. Supervisors instruct entry-level drafters.

3.1.2 ETABS.

The acronym ETABS stands for "building structure-specific software." Building models may be created, modified, analysed, designed, and optimised with its assistance by structural engineers. These technologies have been thoroughly incorporated into a graphical user interface that is based on Windows and offers unrivalled levels of use, productivity, and power. ETABS is the latest structural analysis and design software. This latest version of ETABS incorporates forty years of continuous research and development and provides users with unmatched 3D object-based modelling and visualisation tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide range of materials, and insightful graphic displays, reports, and schematic drawings that help users quickly and easily understand a problem's results. ETABS can combine engineering design from concept to schematics. Drawing controls speed floor and elevation framing.
CAD designs may be used to create models and templates for use in ETABS and base plate capacity tests, and automated optimization.

It is possible to create realistic models, and the results may be shown on the structure itself. Structures made of concrete and steel could have frame designs, schedules, features, and cross-sections. Personalize each and every outcome of the analysis and design.

The capabilities that ETABS provides to structural engineers are unparalleled, and they may use it to design everything from one-story industrial buildings to the largest commercial high-rises.
Since its introduction many decades ago, ETABS has shown its ability to perform well while being simple to use. Its most recent iteration provides engineers with the technically advanced but user-friendly tools they need to be productive.
ETABS performs structural analysis and architectural design for residential buildings.

We choose ETABS for these reasons:
Easy interface, conforms to Indian Standard Codes, solves any sort of issue, accurate answer.

3.1.3 ADVANTAGES OF ETABS

- Most constructions use horizontal beams and vertical columns. ETABS may create any building structure, However, the geometry of a structure may be generated rapidly using a grid system of horizontal floors and vertical column lines.
- Building floors are similar. Numerically, this commonality reduces computation.
- Building terminology is used for input and output. Instead of defining models as a series of nodes and components as general-purpose programmes do, ETABS does it logically by floor, column, bay, and wall. Clarity and utility in structural definition.
- When comparing bay widths and storey heights, most structures have quite large elements. The rigidity of the frame is greatly affected by these measurements. ETABS accounts for this impact in the definition of member stiffness, while other general-purpose programmes do not.
- Program outcomes should be immediately useable by engineers. Generic purpose computer programmes generate general outputs that may require further processing for structural design.

3.1.4 APPLICATIONS OF ETABS

- Commercial high-rises.
- Staggered trusses.
- Steel-concrete construction.
- Multi-grid building.
- Concrete slab structures.
- Building exposed to any vertical, lateral, and automated wind and seismic load situations.
- Floor-to-wall load transmission.

IV. MATERIALS

4.1 INTODUCTION

This study resource interacts with students to teach them fundamental structural design principles for Reinforced Cement Concrete and Masonry structures. IS 456 general requirements for plain and reinforced concrete structural design, IS 1905, IS4326, IS 1893, etc. are covered in the study material. For readers, Indian Standards has been simplified and condensed.

4.2 REINFORCED CEMENT CONCRETE DESIGN REQUIREMENTS.

4.2.1 CEMENT

Table 4.1:- varieties of cements which are permitted to be used in concrete and mortars such as:

SL NO.	NAME OF CEMENT	INDIAN STANDARDS SPECIFICATION
1	Ordinary Portland Cement • 33 Grade • 43 Grade • 53 Grade • 43-S Grade • 53-S Grade	IS 269
2	Portland Pozzolana Cement – Fly Ash based	IS 1489 (Part-1)
3	Portland Pozzolana Cement – Calcined Clay based	IS 1489 (Part-2)
4	Portland Blast Furnace Slag Cement	IS 455
5	High Alumina Cement for Structural use	IS 6452
6	Rapid Hardening Portland Cement	IS 8041
7	Sulphate Resisting Portland Cement	IS 12330
8	Low Heat Portland Cement	IS 12600
9	White Portland Cement	IS 8042
10	Super Sulphated Cement	IS 6909
11	Hydrophobic Cement	IS 8043
12	Composite Cement	IS 16415
13	Micro-fine Ordinary Portland Cement	IS 16993

Portland Pozzolana Cement (PPC) or 43/53 grade regular Portland cement is recommended for mild to moderate environments (OPC). These kinds are mass-produced and typically uniform in quality. Though the performance of various cements under varied environmental circumstances is well understood, a particular kind of cement may be needed in the following scenarios;

Concrete needs extremely high early strength.

a) Concrete must be heat-resistant.

b) Concrete in sulphate-rich soil/water or other chemically hostile environments.

c) Cement alkalis may react with aggregate.

d) The concrete will be employed in a gigantic construction where the temperature increase may produce intolerable thermal strains.

e) Colored concrete is necessary.

f) The concrete may be exposed to heavy chloride-ion assault in a maritime or industrial environment.

g) Other unique criteria or combinations of aforementioned requirements.

4.2.2 Portland Pozzolana Cement (PPC)

Reactive silica may be found in pozzolana. The chemical reaction between calcium hydroxide and siliceous or siliceous and aluminous material at room temperature results in cementitious compounds. Cementitious calcium silicates (C-S-H) can only be produced by the reaction of finely split pozzolana with calcium hydroxide (liberated by hydration Portland Cement) and water. Based on the pozzolanic material used, the Indian requirements for Portland Pozzolana Cement are divided into two parts.

IS 1489, Part 1 and Part 2 specifies Portland Pozzolana Cement are fly ash based and calcined clay based respectively.

4.2.3 Sulphate Resisting Portland Cement (SRPC)

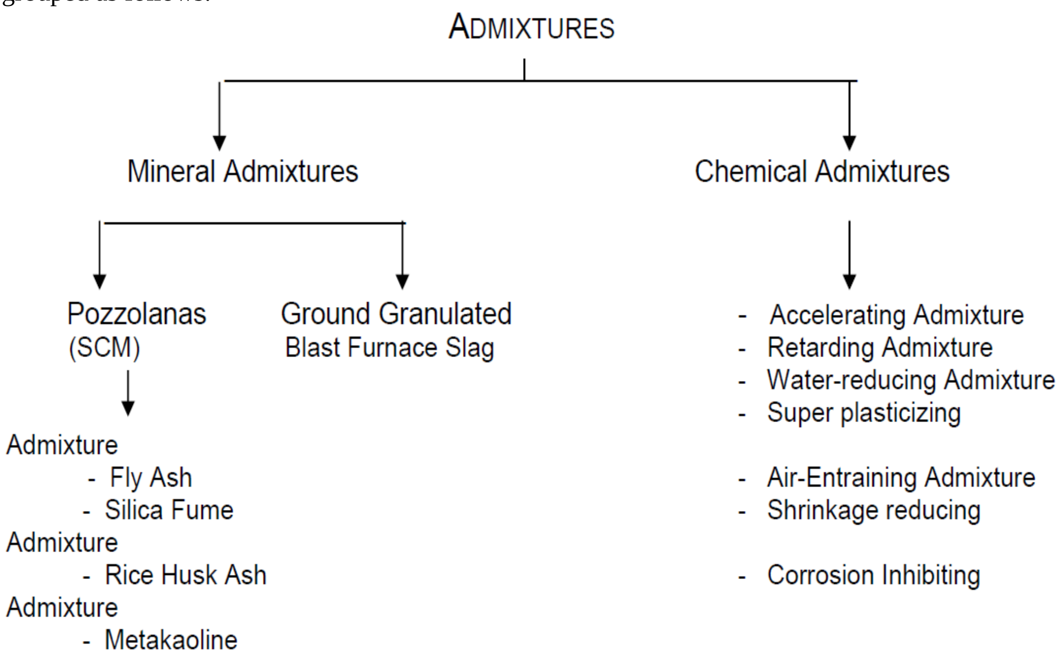
Sulphate Resistant Portland cement is referred to be Portland cement if it contains less than 5 percent tri-calcium aluminate (C_3A) and 2(C_3A +C_4AF). SRPC is especially useful in settings where concrete is at danger of degradation owing to sulphate assault, such as in contact with soils and ground fluids high in sulphates, in sea water, or immediately on the shore. Sulphate-resistant cement causes rebar corrosion in chloride-prone areas.

4.2.4 43 grade OPC:
PPC, PSC, and 43 grade OPC are common general-purpose cements. OPC 43 grade cement usage has fallen as PPC has become more prevalent. According to IS regulation, cement's compressive strength at 28 days should be 43–58 N/mm2. These guidelines' Annexures I and II list this cement physical and chemical characteristics. 43-grade OPC is often used for:

a. Common Building Construction Engineering Tasks
b. RCC works
c. Concrete roads, bridges and flyovers.
d. Blocks, tiles, pipelines, and other precast materials.
e. Non-structural works such as masonry mortars, plastering, flooring etc.

4.2.5 Microfine Ordinary Portland Cement
Rock grouting, grouting concrete buildings, subterranean construction for leak prevention, soil stabilisation, etc. may be done using IS: 16993.

4.3 ADMIXTURES
To enhance concrete characteristics, additive usage has expanded in recent years. different qualities and functions. They're grouped as follows:



4.3.1 MINERAL ADMIXTURE
Mineral admixtures or supplementary cementing materials (SCM) like pozzolanas (including fly-ash, silica fume, and metakaoline) and Ground Granulated Blast Furnace Slag may be used to make concrete if they match Indian Standards. If suitable and within pozzolana restrictions, such additions may be considered in concrete composition for cement content and water-cement ratio.

4.3.2 POZZOLANA or Supplementary Cementing Materials (SCM)
Pozzolana, a siliceous material without cementitious properties, reacts with calcium hydroxide at room temperature to produce cementitious compounds when finely divided and dissolved in water.

Different building projects employ different pozzolanas. Pozzolanas increase concrete's workability, cohesiveness, impermeability, resistance to hostile fluids, heat of hydration, and alkali-aggregate reactivity. Construction type will determine the relative relevance of these qualities. Pozzolana is a siliceous material without cementitious properties that, when finely split and in water, reacts with calcium hydroxide to form cementitious compounds at room temperature.

Pozzolanas vary every construction project. Pozzolanas improve concrete's workability, cohesiveness, impermeability, resistance to hostile fluids, hydration heat, and alkali-aggregate reactivity. These qualities are different depending on the kind of construction. At room temperature and in the presence of calcium hydroxide,

the inert siliceous material known as pozzolana may create cementitious compounds via a series of chemical reactions.
Pozzolanas vary every construction project. Pozzolanas improve concrete's workability, cohesiveness, impermeability, resistance to hostile fluids, hydration heat, and alkali-aggregate reactivity. These attributes depend on construction type.

4.3.3 CHEMICAL ADMIXTURE
Adding a superplasticizer to cement concrete during mixing is necessary to achieve the quality specified in IS 9103:1999 Specification for admixtures for concrete (first revision).

4.3.4 Accelerating Admixture or Accelerator
Additives speed up hydraulic cement hydration, set time, hardening, and strength development in concrete, mortar, and grout.

4.3.5 Retarding Admixture or Retarder
An additive that slows cement paste and cement-based compositions like mortar and concrete.

4.3.6 Water Reducing Admixture or Workability Aid
An aid that allows freshly mixed mortar or concrete to be worked with less water or that makes it workable without adding water.

4.3.7 Air-Entraining Admixtures
A chemical compound that is used to boost the workability, resistance to freezing and thawing, and disruption of deicing salt in concrete or mortar by introducing minute air bubbles during the mixing process. This is accomplished by the usage of the chemical compound.

4.3.8 Super-plasticizing Admixtures
A mortar or concrete additive that increases workability or decreases water content.

4.4 AGGREGATES.

- IS 383 governs aggregates. Prefer natural aggregates whenever feasible.
- Slag and crushed, overburned brick or tile may be excellent additions to otherwise plain concrete components, providing such components with increased strength, durability, and safety. However, the amount of sulphates present in the aggregates in the form of SO3 shouldn't be more than 0.5 percent, They shouldn't absorb more than 10% of their bulk in water.

4.5 WATER

- Concrete mixing and curing usually use potable water. Water must be at least 6 Ph.

Table 4.2:-Concrete's Solids-Water Mixing Limit.

Sl No	Tested as per	Permissible Limit, Max
Organic	IS 3025 (Part 18)	200 mg/l
Inorganic	IS 3025 (Part 18)	3000 mg/l
Sulphate (as SO3)	IS 3025 (Part 24)	400 mg/l
Chloride (as Cl)	IS 3025 (Part 32)	2000 mg/l for concrete not containing embedded steel and 500 mg/l for reinforced concrete work.
Suspended Matter	IS 3025 (Part 17)	2000 mg/l
Note: 1000 mg/l chloride in water for reinforced concrete work can be permitted provided the chloride content of hardened concrete is checked at the time of concrete mix design and conforms to requirement of total chloride content in the concrete as per the code.		

4.6 REINFORCEMENT

Steel reinforcement used shall be,
(a) below Fe415 (conforming to IS:1786)
(b) Thermomechanically treated high-strength ribbed bars with elongation more than 14.5 percent and adhering to IS: 1786 are grade Fe-500 D and Fe-550 D. Tensile test results for steel bars must not exceed their characteristics by more than 20%. There has to be between 1.15 and 1.25 times the ultimate strength for every unit of yield tensile strength. The elasticity of steel is 2 x 105 MPa.

4.7 CONCRETE

When fewer than 5% of test results fail, we say that the material is at its usual strength. It's fck.

Grades of concrete Group	Grade designation	Specified characteristic compressive strength of 150 mm cube at 28 days in N/mm^2
Ordinary concrete	M 10	10
	M 15	15
	M 20	20
	M 25	25
Standard Concrete	M 30	30
	M 35	35
	M 40	40
	M 45	45
	M 50	50
High strength Concrete	M 55	55
	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

Compressive strength in N/mm2 of a 150 mm cube after 28 days, Concrete Mix M.

<u>Properties of Concrete</u>

- **Characteristic Modulus of Elasticity**

  $E_{ck} = 10000\ [f_{ck}]^{0.3}$; where, f_{ck} is the characteristic strength of the concrete
- **Poisson's ratio** to be taken equal to **0.2** for uncracked concrete

  0.0 for cracked concrete
- **Characteristics Modulus of rupture**

  $$f'_{cr} = 0.5\sqrt{f_{ck}}$$
- **Characteristics splitting tensile strength**

  $$f'_{cst} = 0.33\sqrt{f_{ck}}$$
- **Flexural Tensile Strength** $f_{cr} = 0.7\sqrt{f_{ck}}$

4.7.1 Creep Strain

a) **Creep of concrete**: Without changing tension, concrete creeps. Mixture proportioning, ambient circumstances, curing conditions, and concrete member geometry affect creep.
loading and stress. The creep co-efficient μ(t,to) is:
where
$\varepsilon cc(t)$ = creep strain at time $t > t0$, (This does not include the instantaneous strain in concrete

upon loading)
εci(t0) = initial strain at loading, and
t0 = age of concrete at the time of loading.

b) Shrinkage Strain

The degree to which components, member size, and environmental factors affect concrete shrinkage varies. The total quantity of water used in the mixing process has the biggest influence on the shrinkage of concrete at a particular humidity and temperature. The cement content has a secondary function in the shrinkage of concrete.

Table 4.3:- Concrete grade, reinforcing steel, and pre-stressing allowed.

Grade of Concrete	Grade of Reinforcing Steel							
	Fe 415	Fe 415D	Fe 500	Fe 500D	Fe 600	Fe 650	Post tesnsioning	Pre tensioning
M20	✓	✓	✓					
M25	✓	✓	✓		Not Permitted			
M30	✓	✓	✓	✓				
M35	✓	✓	✓	✓			✓	
M40	✓	✓	✓	✓	✓		✓	✓
M45	✓	✓	✓	✓	✓	✓	✓	✓
M50	✓	✓	✓	✓	✓	✓	✓	✓
M55	✓	✓	✓	✓	✓	✓	✓	✓
M60	✓	✓	✓	✓	✓	✓	✓	✓
M65	✓	✓	✓	✓	✓	✓	✓	✓
M70	✓	✓	✓	✓	✓	✓	✓	✓
M75	✓	✓	✓	✓	✓	✓	✓	✓
M80	✓	✓	✓	✓	✓	✓	✓	✓
M85	✓	✓	✓	✓	✓	✓	✓	✓
M90	✓	✓	✓	✓	✓	✓	✓	✓
M95	✓	✓	✓	✓	✓	✓	✓	✓
M100 or higher	✓	✓	✓	✓	✓	✓	✓	✓

4.8 WORKABILITY OF CONCRETE

Concrete workability means ease of use. Five workability levels:

Degree of workability	Placing condition
Very low	In highway construction a layer of lean concrete with very low workability is used and it is compacted using roller
Low	Low Mass concreting (like, dam construction) light reinforced section of slab, beam, and column.
Medium	Heavily reinforced section of slab, column beams and when pumping of concrete is required.
High	In-situ piling
Very high	In-situ piling using tremie pipe.

4.9 DURABILITY OF CONCRETE

Durability considerations include,
The result depends on the weather, integrated steel cover, component kind and quality, concrete cement content and water/cement ratio, member shape and size, and the quality of the compaction and curing operation.

Design and details Maintenance

4.10 EXPOSURE CONDITIONS:

Five environmental exposures:

Some of the potential deterioration mechanisms causing durability problems:

A. Corrosion of reinforcement due to

a) Permeation of ambient carbon dioxide in concrete (carbonation-induced corrosion) b) Significant chloride ion in concrete (chloride induced corrosion)

B. Physical deterioration processes;

Abrasion, freezing and thawing, weathering, shrinkage etc.

C. Chemical deterioration processes;

Sulphate attack, alkali aggregate reaction etc.

Table 4.3:-Environmental Exposure Condition

Sr. No.	ENVIRONMENT	Exposure condition
1.	Mild	Concrete surface protected against weather.
2.	Moderate	Concrete surface sheltered from severe rain, saturated air in coastal areas, concrete continuously under normal water and in contact with non –aggressive soil.
3.	Severe	Concrete surface exposed to severe rain, alternate wetting and drying, completely immersed in sea water, exposed to coastal environment.
6.	Very severe	Concrete surface exposed to sea water spray, corrosive fumes, and severe freezing condition and in contact with aggressive soil/ground water.
5.	Extreme	Surface of member in tidal zone or in direct contact with liquid/solid aggressive chemicals.

4.11 CONCRETE MIX PROPORTIONING

During concrete mix design, cement, coarse aggregate, fine aggregate, water, and sometimes additives are calculated to achieve the required workability of fresh concrete and strength, durability, and surface quality of hardened concrete.

Concrete may be mixed in one of two ways:

i. Design mix concrete

ii. Normal mix concrete

M20 and higher should use design mix. Only M20 and weaker concrete may utilise nominal mix.

Table 4.4:- Grades of concret

Grade of concrete	Nominal Mix proportion (cement: sand: coarse aggregate)
M10	1:3:6
M15	1:2:4
M20	1.1.5:3

4.12 CURING

Curing keeps concrete wet.

Low water cement ratios need concrete moisture retention. Curing has two main types:

i. Moist curing
ii. Membrane curing

V. STRUCTURAL DESIGN CONSIDERATION

4.1 The purpose of design is to accommodate the following conditions:
(1) Safety
(2) Economy
(3) Durability
(4) Robustness
(5) Integrity
(6) Serviceability
(7) Aesthetic
(8) Sustainability

5.2 LOADS

There are 2 sets of loads
▪ Force Loads
▪ Displacement Loads
Force Loads
✓ Dead Load
✓ Wind Load
✓ Snow Load
✓ Earth Pressure
✓ Water Pressure
✓ Blast Load
✓ Imposed Load
✓ Impact Load
✓ Prestressing Force
✓ Construction/ Erection Load
Displacement Loads
✓ Temperature Load
✓ Shrinkage Load
✓ Creep Load
✓ Elastic Shortening Load
✓ Foundation Settlement/ Movement/ Rotation
✓ Earthquake Ground Shaking

5.3 FIRE RESISTANCE

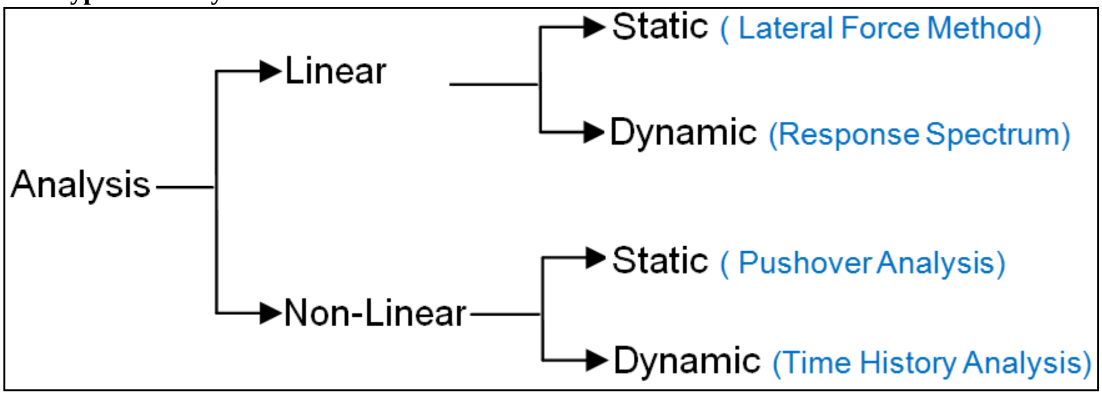
➢ Using fire-resistant materials and covering steel makes a structure fireproof. Fire resistance is measured in hours.

Table 5.1:- fire resisting ratings

Member	*Condition of Member*	*Type of Aggregate*	*Minimum Nominal Cover (mm) for Fire Resistance Rating (hours)*				
			1.0	*1.5*	*2.0*	*3.0*	*4.0*
Slabs	***Simply Supported***	**Siliceous**	**20**	**25**	**35**	**45**	**55**
		Carbonaceous	**20**	**20**	**30**	**40**	**50**
		Light Weight	**20**	**20**	**25**	**35**	**45**
	Continuous	**Siliceous**	**20**	**20**	**25**	**35**	**45**
		Carbonaceous	**20**	**20**	**20**	**30**	**40**
		Light Weight	**20**	**20**	**20**	**25**	**35**
Beams	***Simply Supported***	**Siliceous**	**20**	**20**	**40**	**60**	**70**
		Carbonaceous	**20**	**20**	**35**	**55**	**65**
		Light Weight	**20**	**20**	**30**	**50**	**60**
	Continuous	**Siliceous**	**20**	**20**	**30**	**40**	**50**
		Carbonaceous	**20**	**20**	**25**	**35**	**45**
		Light Weight	**20**	**20**	**20**	**30**	**40**
Prestressed Beams	***Simply Supported***	**Siliceous**	**40**	**55**	**70**	**80**	**90**
		Carbonaceous	**40**	**50**	**65**	**75**	**85**
		Light Weight	**40**	**45**	**60**	**70**	**80**
	Continuous	**Siliceous**	**30**	**40**	**55**	**70**	**80**
		Carbonaceous	**30**	**35**	**50**	**65**	**75**
		Light Weight	**30**	**30**	**45**	**60**	**70**
Ribs of Waffle Slabs	***Simply Supported***	**Siliceous**	**20**	**35**	**45**	**55**	**65**
		Carbonaceous	**20**	**30**	**40**	**50**	**60**
		Light Weight	**20**	**25**	**35**	**45**	**55**
	Continuous	**Siliceous**	**20**	**20**	**35**	**45**	**55**
		Carbonaceous	**20**	**20**	**30**	**40**	**50**
		Light Weight	**20**	**20**	**25**	**35**	**45**

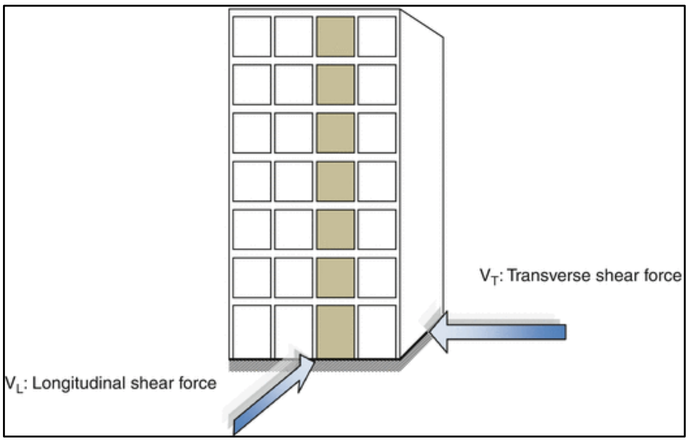
Columns	*Fully exposed to fire*	**Siliceous**			**50**	**60**	**70**
		Carbonaceous			**45**	**55**	**65**
		Light Weight			**40**	**50**	**60**
	50% exposed to fire	**Siliceous**			**50**	**55**	**60**
		Carbonaceous			**45**	**50**	**55**
		Light Weight			**40**	**45**	**45**
	One face exposed to fire	**Siliceous**			**40**	**45**	**50**
		Carbonaceous			**40**	**40**	**45**
		Light Weight			**40**	**40**	**40**
Walls	*Two faces exposed to fire*	**Siliceous**			**50**	**60**	**70**
		Carbonaceous			**45**	**55**	**65**
		Light Weight			**40**	**50**	**60**
	One face exposed to fire	**Siliceous**			**50**	**55**	**60**
		Carbonaceous			**45**	**50**	**55**
		Light Weight			**40**	**45**	**45**

5.4 Types of Analysis



5.4.1 Static Lateral Force Method

The similar static lateral force approach gives an easy alternative for constructing against the dynamic loads of an expected earthquake. The whole seismic force, denoted by the symbol V, has been assessed along two horizontal axes that are perpendicular to the primary axis of the structure.



It presupposes lateral response. To eliminate subsurface torsional movement, the structure must be low-rise and symmetrical. Seismic forces must not affect the building in both directions.

5.4.2 Linear Dynamic (Response spectrum) analysis

Construction uses reaction spectrum analysis (RSA). Modal decomposition and the response spectrum simplify response history analysis (RHA). Peak response is quickly determined without response history analysis. This is crucial because response spectrum analysis (RSA) uses fast and simple calculations, unlike time history analysis, which solves the differential equation of motion over time. The response spectrum represents earthquake risk.

The greatest reaction of an SDOF system versus time during an earthquake creates a response spectrum (or frequency). The damping ratio's maximum response locus determines the SDOF system's response spectrum. Response spectra allow peak structural responses in the linear response range to determine earthquake-induced lateral forces. Peak structural responses in linear response range enable this.

SDOF system response is determined by time- or frequency-domain analysis. The study determines the largest reaction over a certain time period. This applies to all SDOF ages. The last figure shows the damping ratio and input ground motion response spectrum 103. Damping ratios determine response spectra.

5.4.3 Non-linear Static (Push-over) Analysis

Pushover analysis—a nonlinear static analysis—loads a structure arbitrarily. Loading exacerbates structural weaknesses and failure mechanisms. A modified monotonic force-deformation criteria and damping approximations characterise cyclic behaviour and load reversals. Structural engineers assess structure strength using static pushover analysis. Performance-based design may use this research.

An evaluation of a pushover based on performance. The ATC-40 states that in order for performance-based design to be possible, demand and capacity must first exist (Applied Technology Council, Seismic Evaluation and Retrofit of Concrete Buildings). The shaking of the ground and buildings that occurs as a result of an earthquake is an analogy for demand. Nonlinear static analysis gives preliminary approximations of structural displacements or deformations in order to take into account demand. Evaluation of earthquake resistance is often done using capacity as the criterion. Key aspects of performance include capacity as well as the ability to satisfy requirements. As a consequence of this, earthquake resilience is an essential component of the building's overall design.

Pushover analysis using the displacement coefficient and capacity spectrum technique.

Pushover analysis—a nonlinear static analysis—loads a structure arbitrarily. Loading exacerbates structural weaknesses and failure mechanisms. A modified monotonic force-deformation criteria and damping approximations characterise cyclic behaviour and load reversals. Static pushover analysis is a method that structural engineers use to evaluate the true strength of a structure. This study may be seen of as a possible strategy for performance-based design.

An evaluation of a pushover based on performance. The ATC-40 states that in order for performance-based design to be possible, demand and capacity must first exist. The shaking of the ground and buildings that occurs as a result of an earthquake is an analogy for demand. Nonlinear static analysis gives preliminary approximations of structural displacements or deformations in order to take into account demand. Evaluation of earthquake resistance is often done using capacity as the criterion. Key aspects of performance include capacity as well as the ability to satisfy requirements. As a consequence of this, earthquake resilience is an essential component of the building's overall design.

5.4.4 Nonlinear Dynamic (Time History) Analysis

Time-history analysis. Nonlinear structural seismic analysis needs it. This investigation needs a structure's representative seismic time history. Time history analysis steps through a structure's dynamic reaction to a variable loading. Time history analysis determines a structure's seismic response under representative earthquake dynamic loads.

VI. ANALYSIS AND DESIGN OF PROPOSED G+3 RESIDENTIAL BUILDING

6.1 Salient Features of Project:

G+3 residential building. It has two tales and a feature piece. Drawings show the site's normal floor arrangement and functioning. The building has a stairwell.
Each level will cover:

6.2 PROPOSED PROJECT

Ground-floor, two-story residential building is proposed. Bangalore's executing.

Table 6.1:- Project details

1.Type of structure	Residential building
2.Layout	As shown in the plan
3.Number of storey	G+3
4.Storey height	3.0m
5.Depth of foundation	2.1
6.Wall	230mm thick
7.Live Load	IS 875(Part-2)1987
8.Material	M20 grade concrete&Fe500 steel
9.Design Philosophy	Limit state method conforming to IS456-2000

6.3 Structural Plan:

Floor-to-floor structural plans vary according to customer needs. Sometimes the architect may propose alternative plans for different levels, considering the aesthetics and space requirements of a structure. The structural plan mostly deals with the column-beam arrangement. Floor plans will vary in this project. The floor plans of the building are shown below.

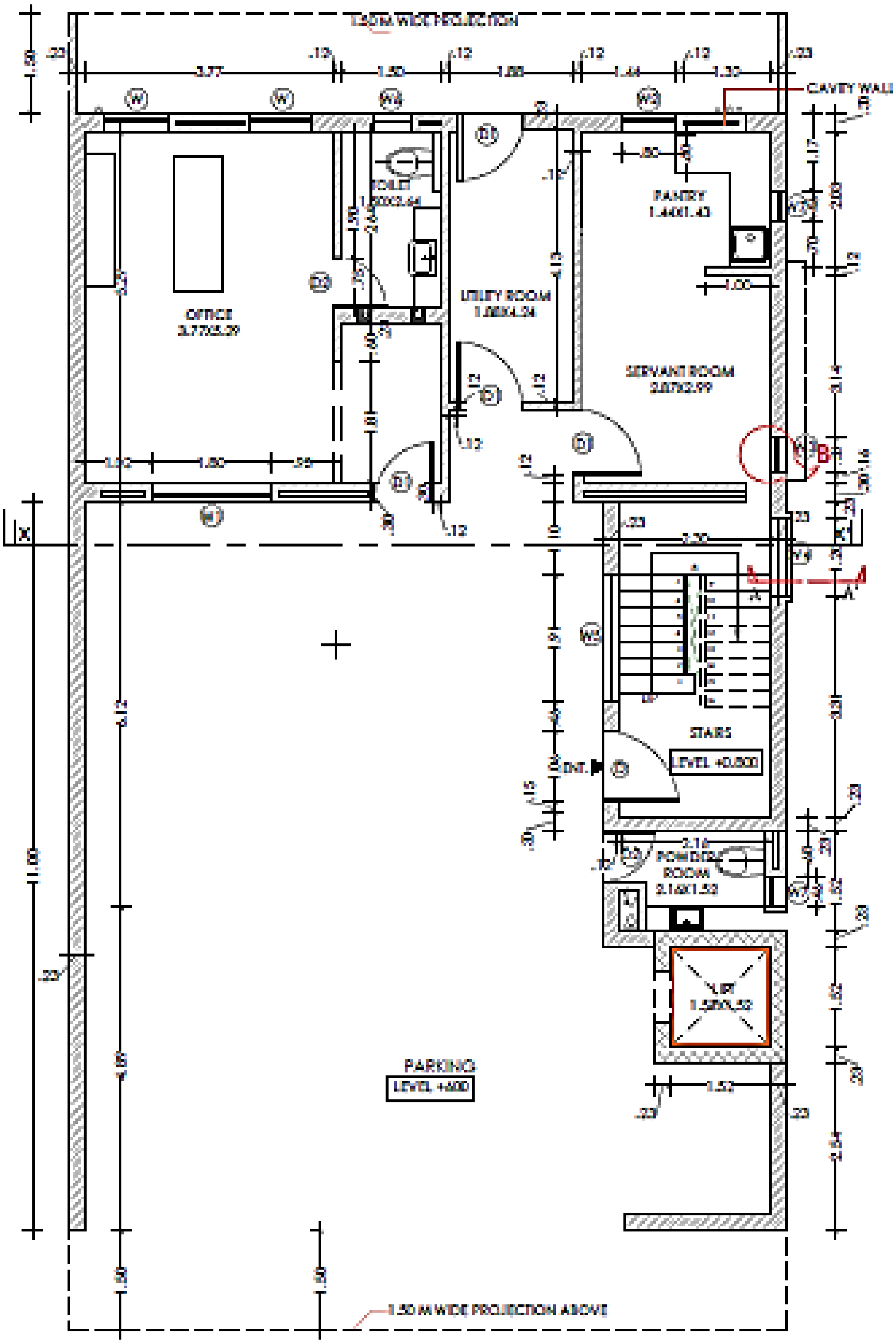


Fig 6.1:- Ground floor

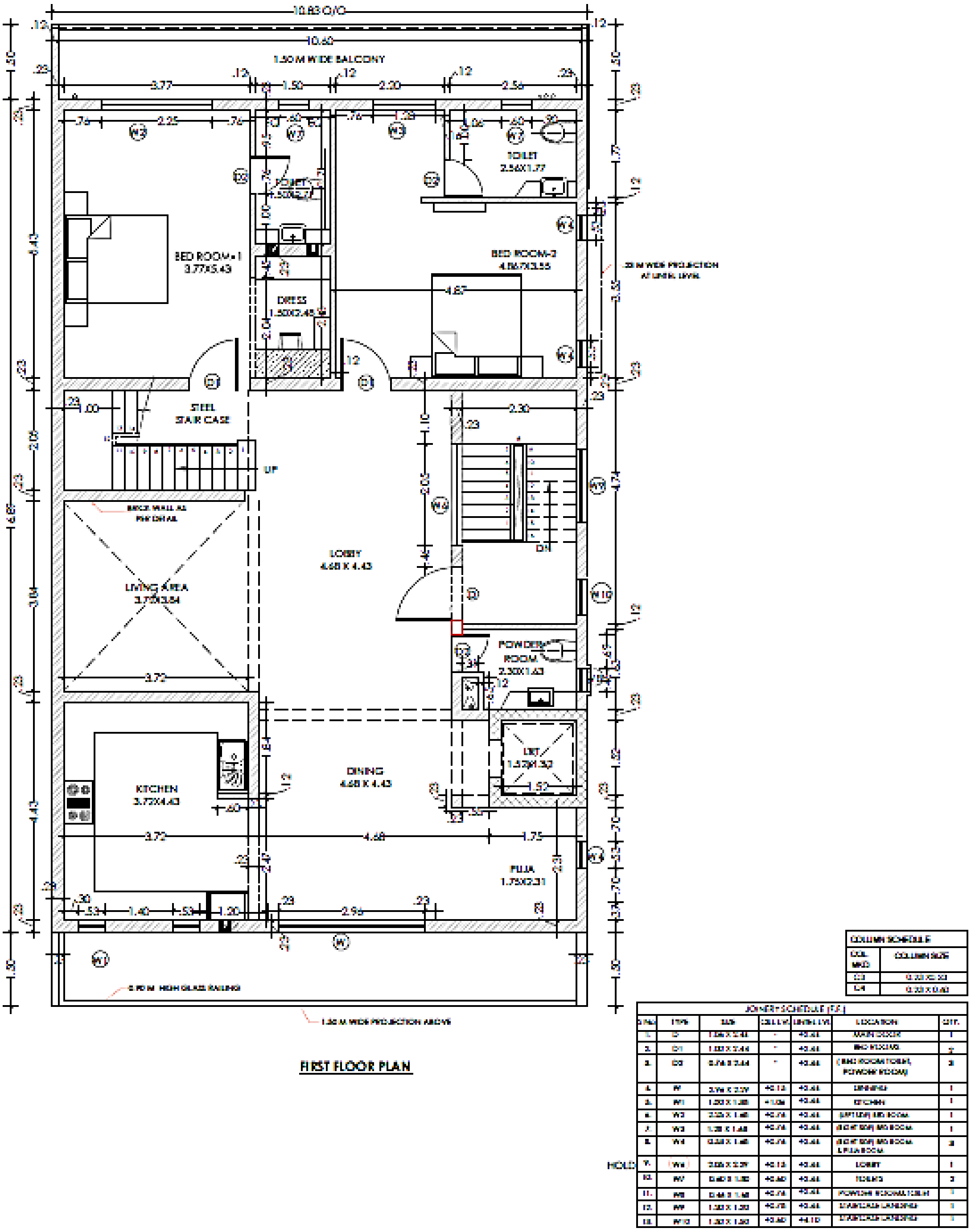


Fig 6.2 :- first floor

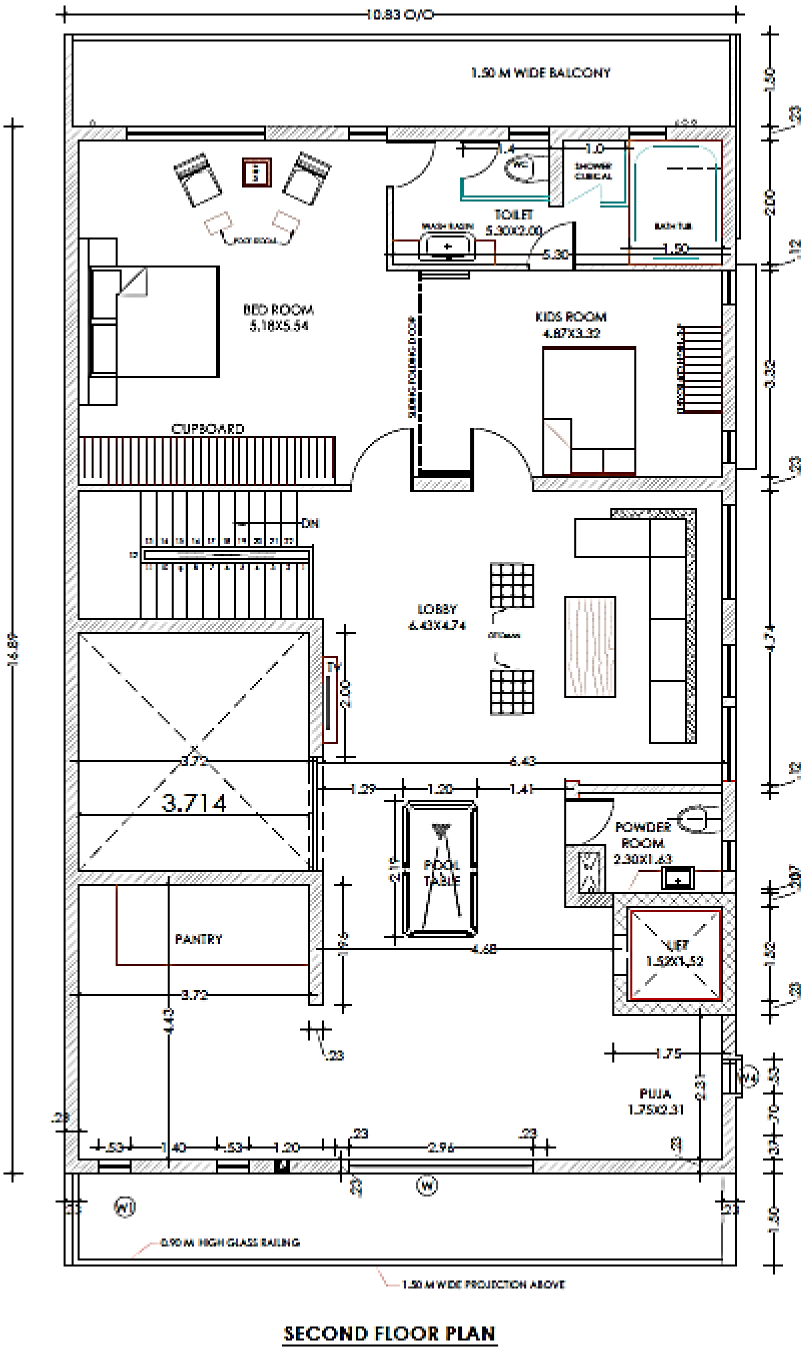


Fig 6.3:- Second floor

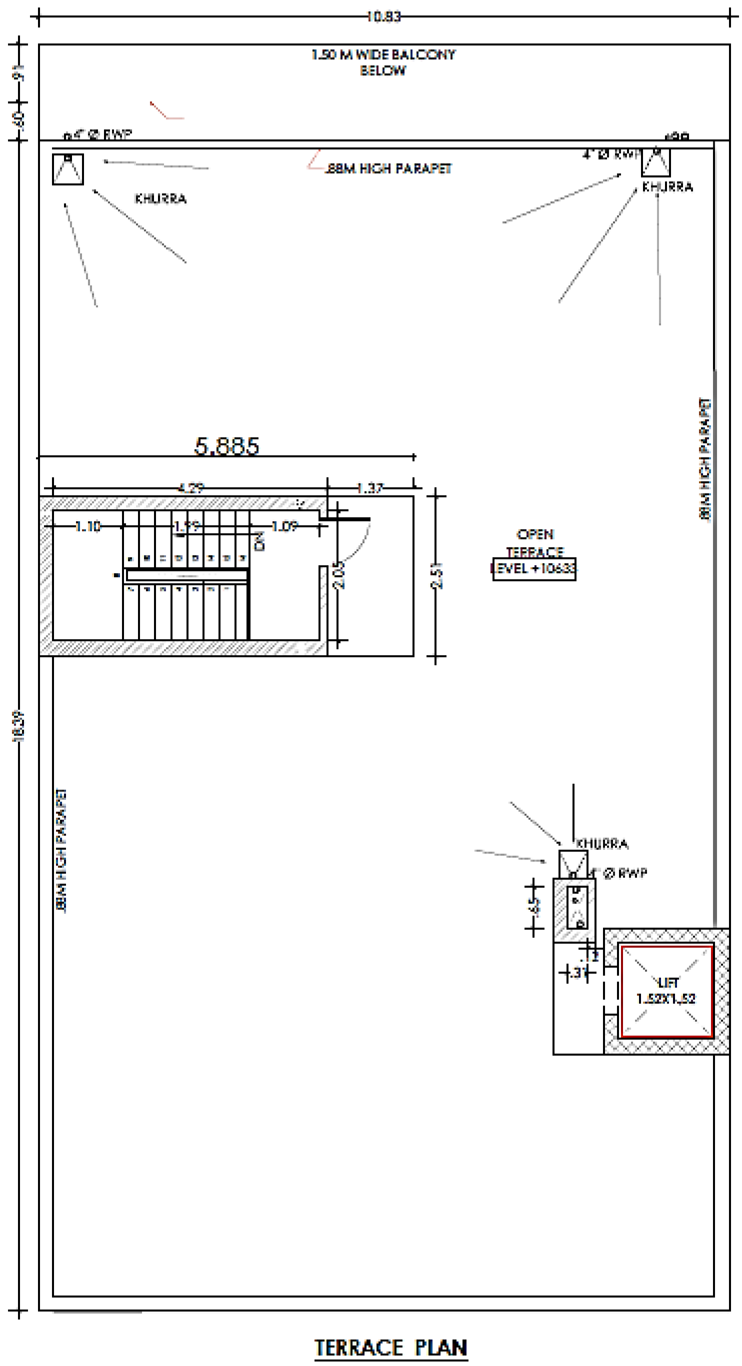


Fig 6.4:- Terrace floor

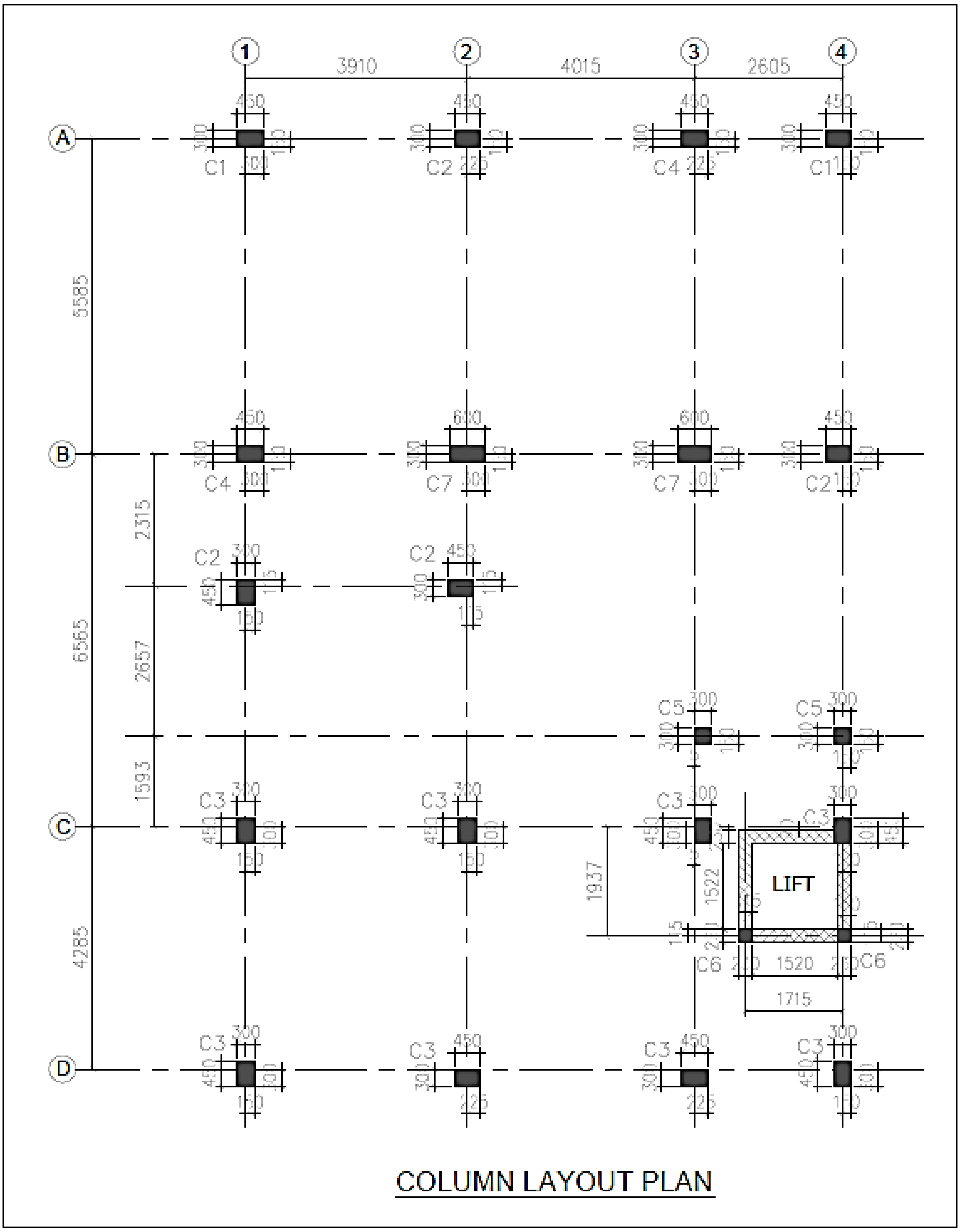


Fig 6.5:- Column layout plan

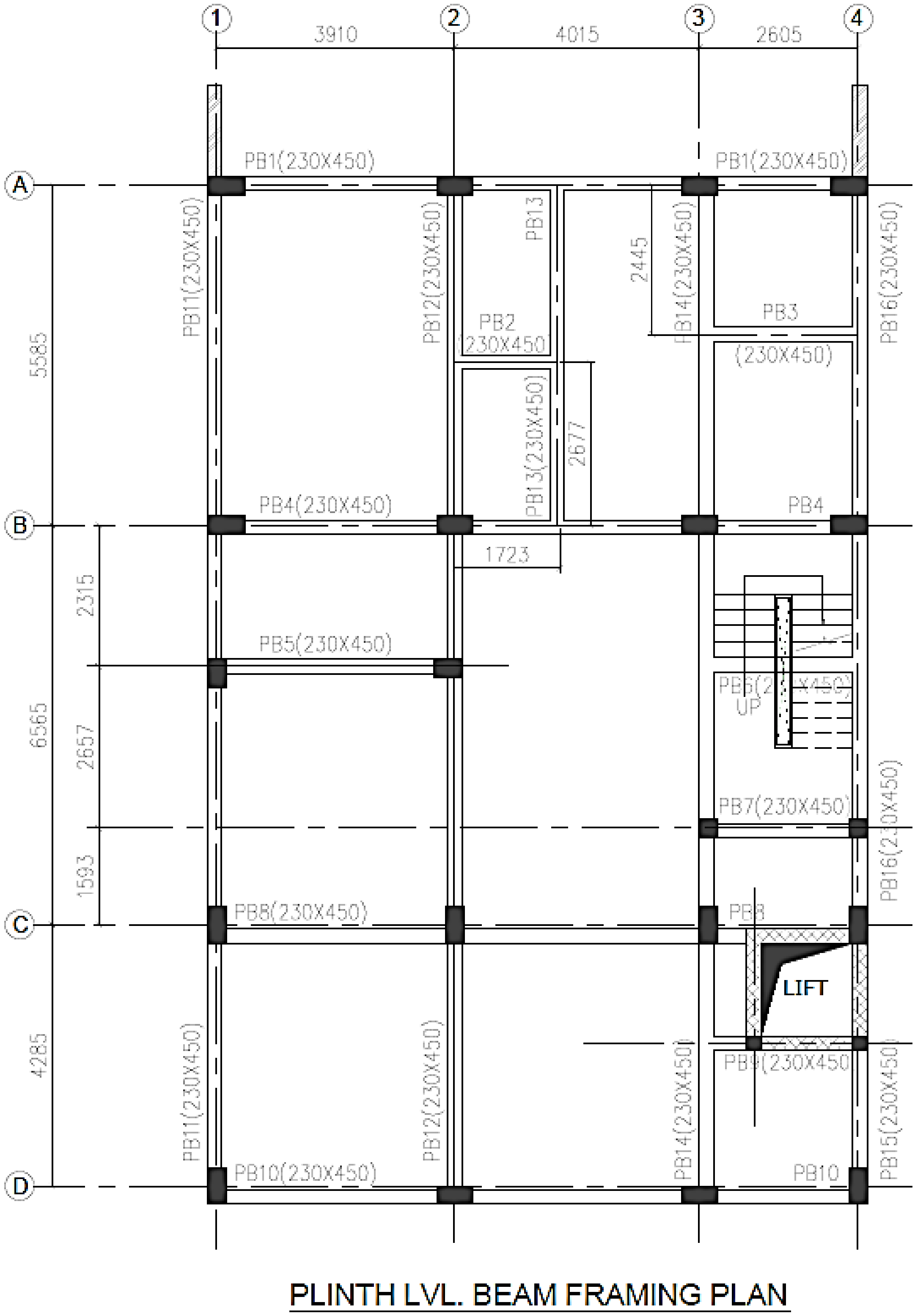
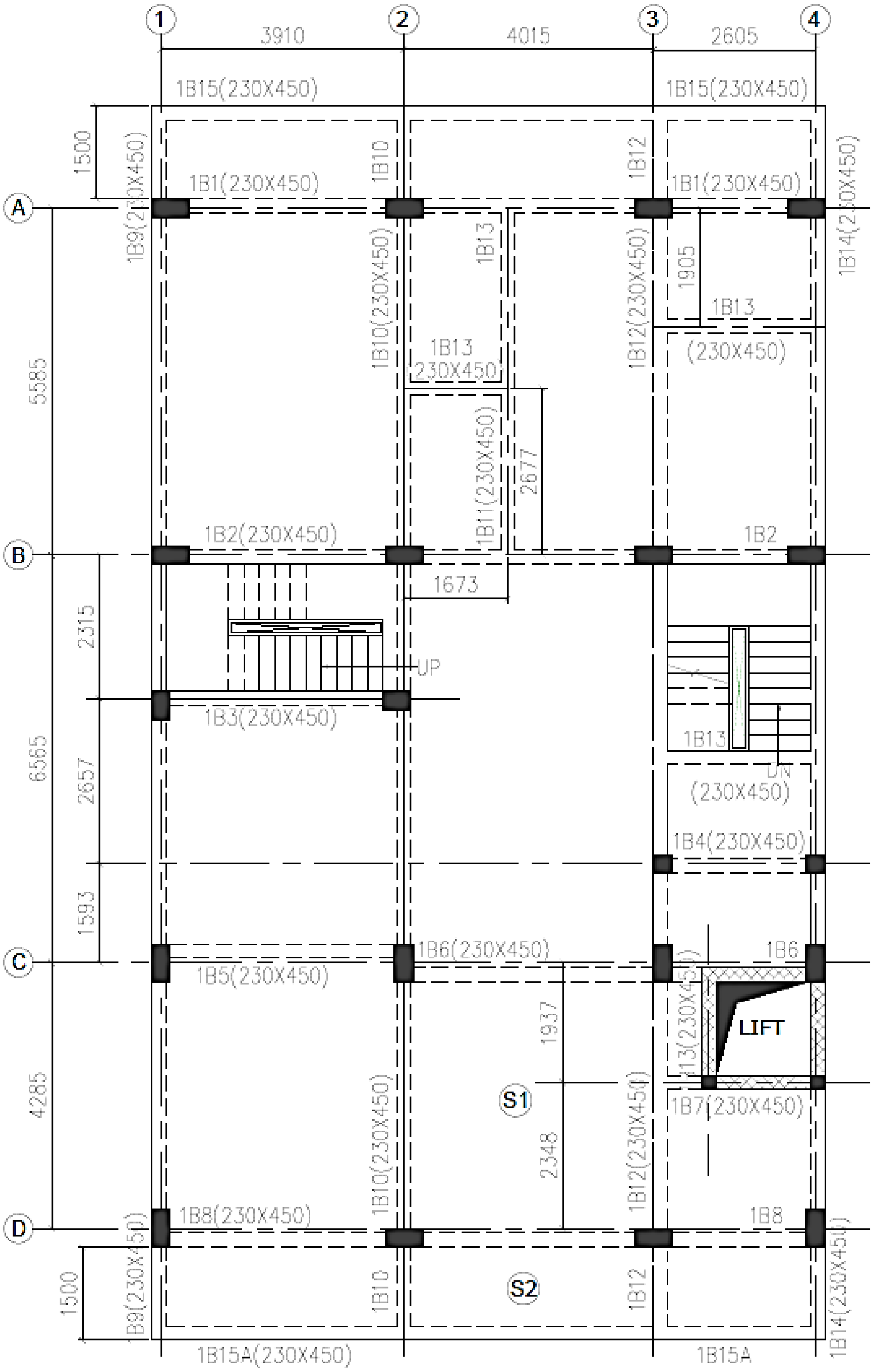
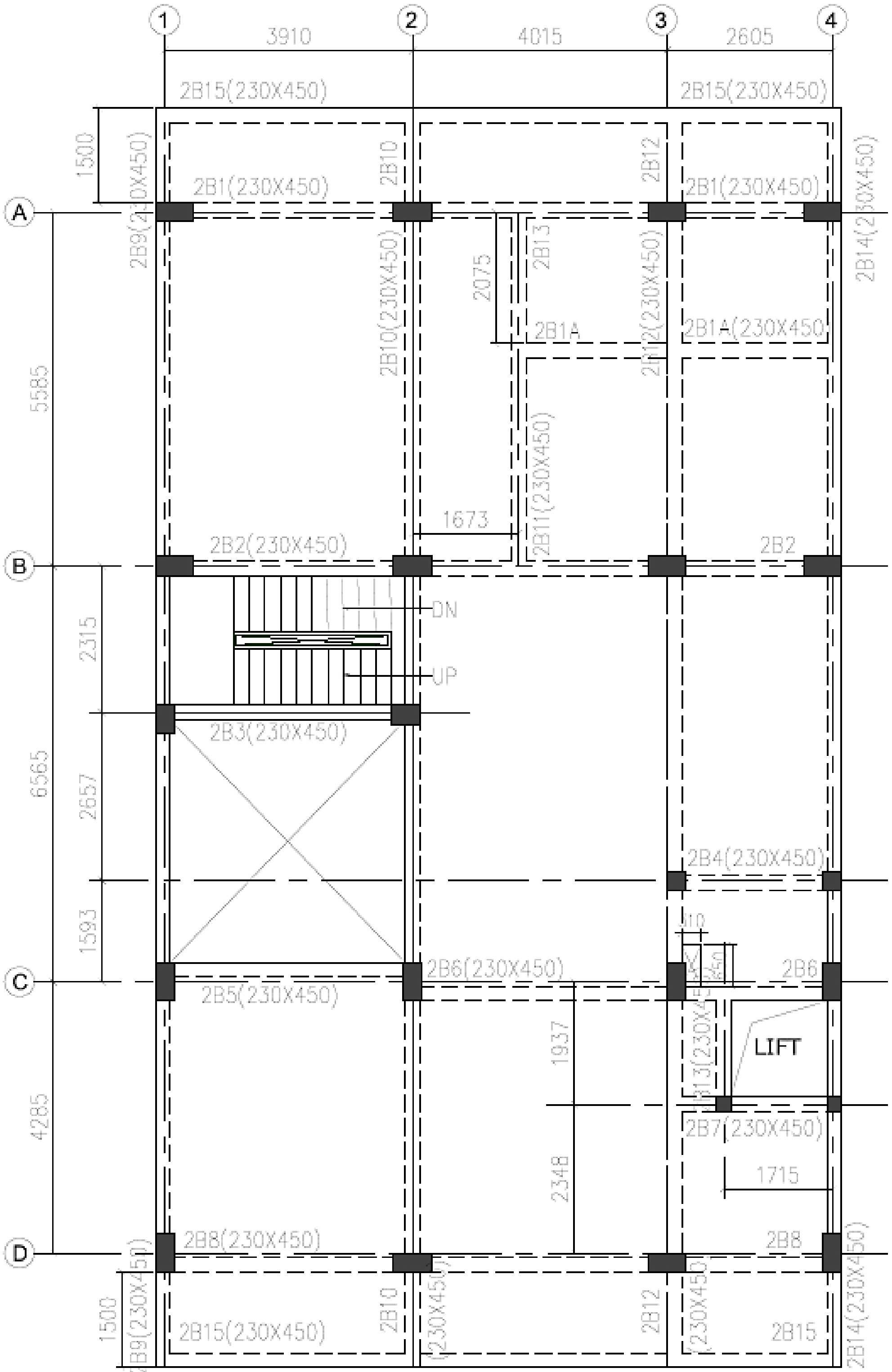


Fig 6.6:- Plinth Beam layout plan



STILT FLOOR ROOF LVL. BEAM FRAMING PLAN

Fig 6.7:- Stil floor Beam layout.



1st FLOOR ROOF LVL. BEAM FRAMING PLAN

Fig 6.8:- 1st Floor roof lvl. beam framing plan

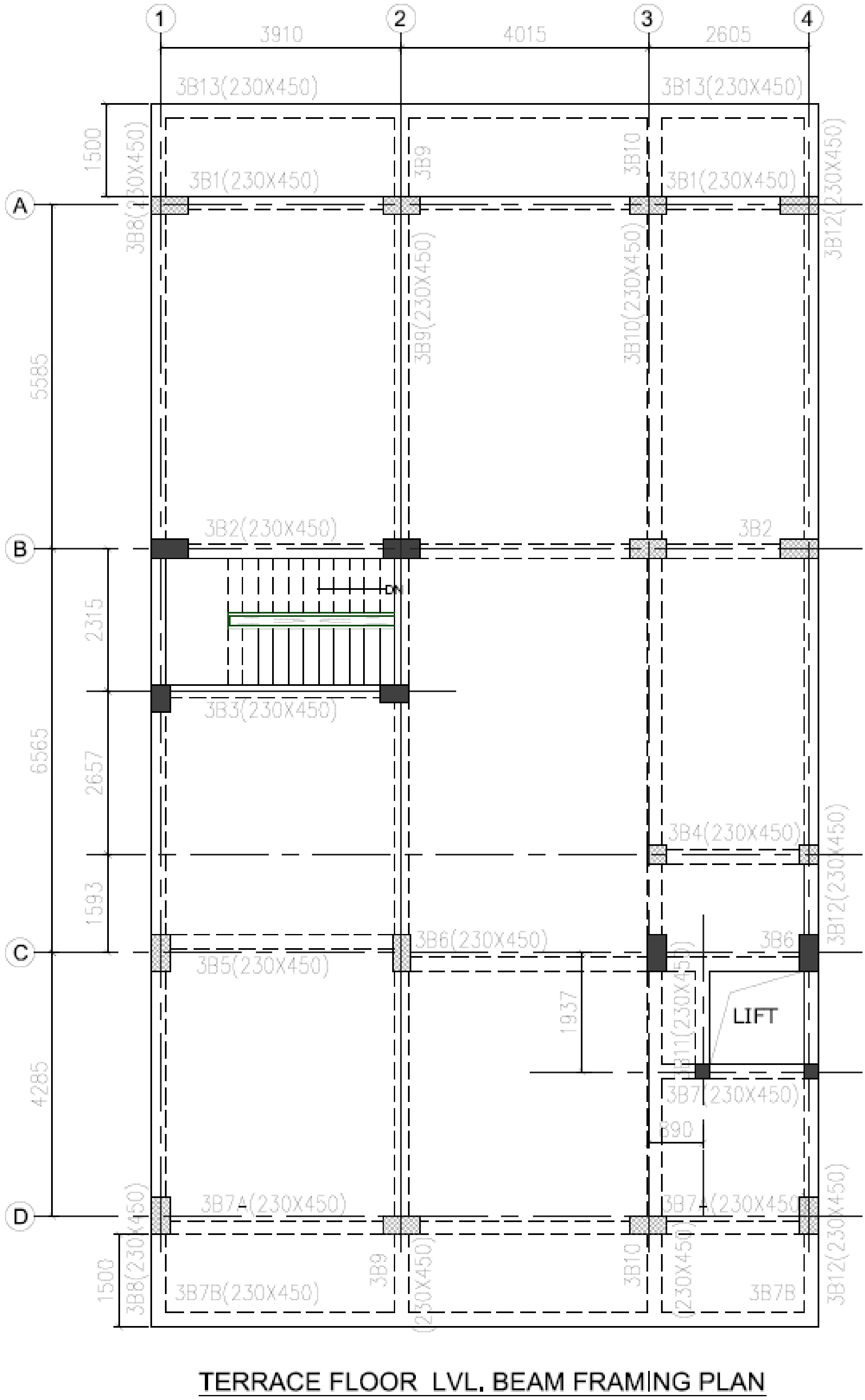


Fig 6.9:- Terrace Floor lvl. beam framing plan

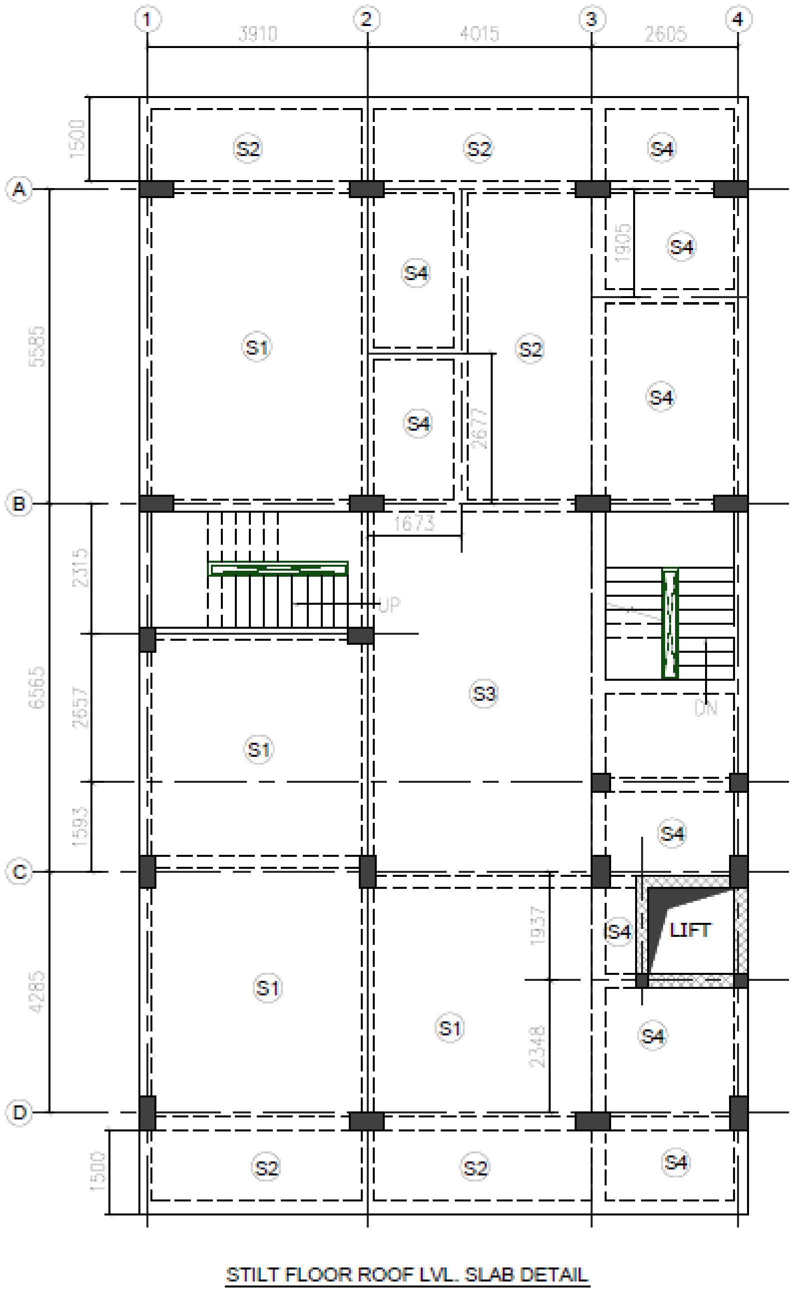
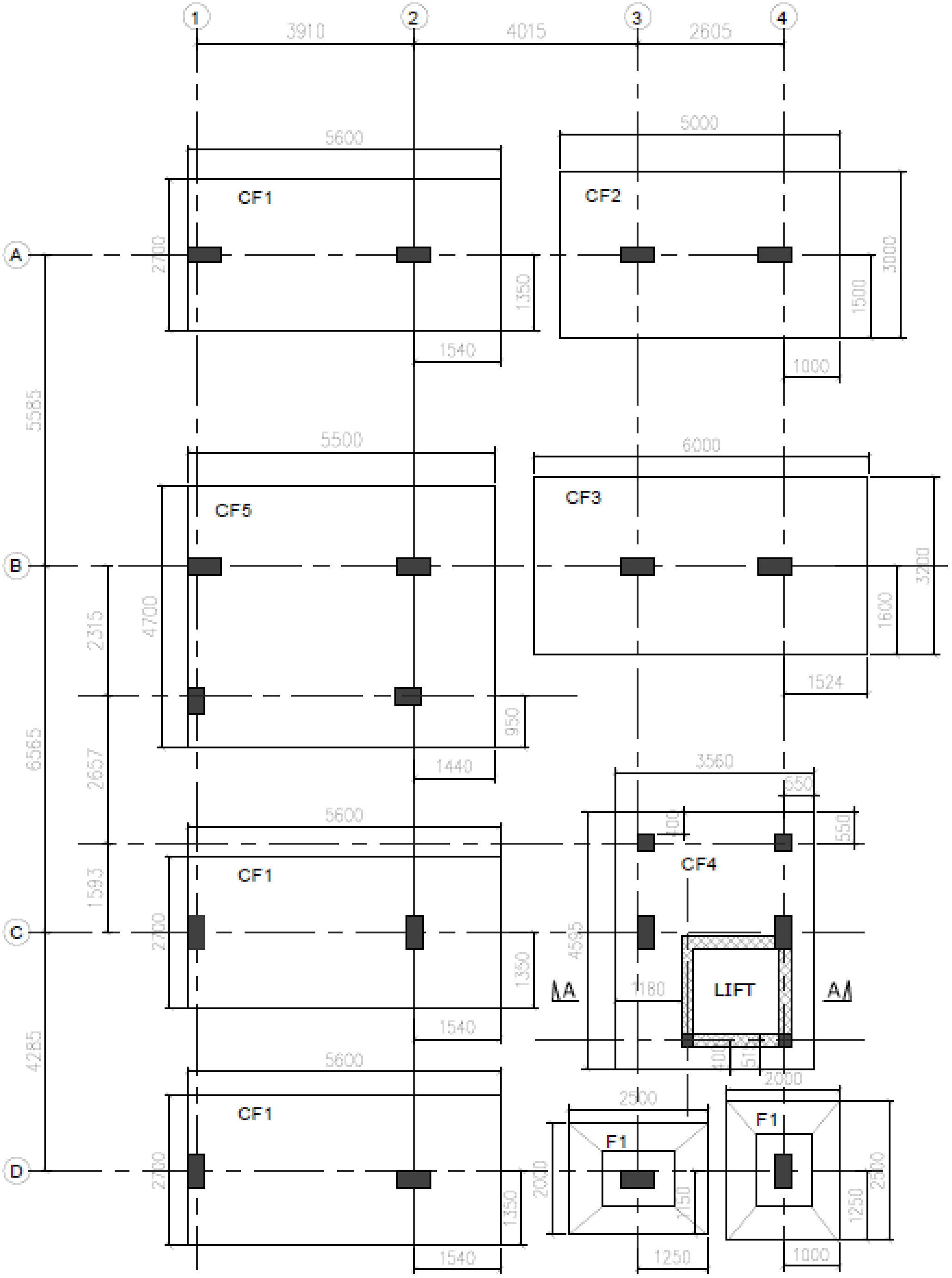


Fig 6.10:- Terrace Floor lvl. Beam framing plan



FOUNDATION LAYOUT PLAN

Fig 6.11:- Foundation layout plan

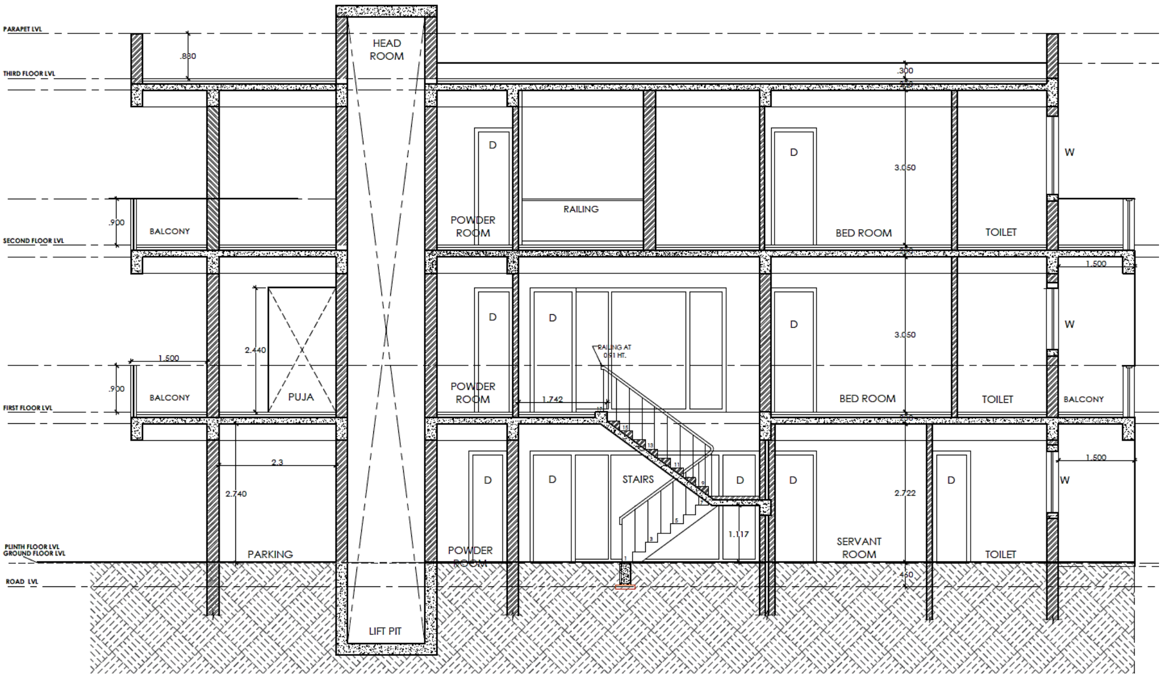


Fig 6.12:- Section elevation

VII. LOADING PARAMETERS

7.1 Design Data:

ETABS software analysed and designed a three-story reinforced concrete asymmetrical frame structure. Residential building. Assuming infinite rigidity in its plane, the building floor moves like a rigid body. Linear static analysis was done. Seismic zone II and medium soil host the building.

7.2 Building details:

Length	= 19.89m
Width	= 10.83m
No. of Storey	= G+3
Storey Height	= 3.0 m
Total No. of Column	= 22
Rectangular Column size	= 230*450mm, 230*230mm, 300*300mm
Beam size	= 230*450
Slab thickness	= 125.00 mm
wall thickness	= 230.00 mm
SBC of soil	= 180 KN/m^2
Grade of concrete	= M20
Steel grade	= Fe500
Density of Concrete	= 25.00 kN/m^3
Density of Brick	= 18.85 kN/m^3

Table 7.1:- load calculation

Si No.	Descriptions	Width/ Thickness	Density	Height	Weight	Remarks
1	**DEAD LOAD - IS 875 (Part-1)**					
A	**Stilt floor lvl. (Plinth Level)**					
i)	**230mm Thick masonry load**					
	230mm thk, upto beam bottom	0.23	18.85	2.4	10.41	KN/m
	Wall Plaster	0.024	20.4	2.4	1.18	KN/m
			Total		11.58	**Say 12 KN/m**
ii)	**115mm Thick masonry load**					
	230mm thk, upto beam bottom	0.115	18.85	2.4	5.20	KN/m
	Wall Plaster	0.024	20.4	2.4	1.18	KN/m
			Total		6.38	**Say 6.5 KN/m**
B	**First floor lvl.**					
i)	**230mm Thick masonry load**					
	230mm thk, upto beam bottom	0.23	18.85	2.83	12.27	KN/m
	Wall Plaster	0.024	20.4	2.83	1.39	KN/m
			Total		13.66	**Say 14 KN/m**
ii)	**115mm Thick masonry load**					
	230mm thk, upto beam bottom	0.115	18.85	2.83	6.13	KN/m
	Wall Plaster	0.024	20.4	2.83	1.39	KN/m
			Total		7.52	**Say 8 KN/m**
iii)	**Parapet wall (balcony)**					
	115mm thk, 900mm height	0.115	18.85	0.9	1.95	KN/m
	Wall Plaster	0.024	20.4	0.9	0.44	KN/m
			Total		2.39	**Say 2.5 KN/m**
iv)	**Floor (Slab) load 125mm thk.**					
	125mm thk slab	0.125	25		3.13	KN/Sqm
	Flooring 105mm thk.					
	cement mortar 65mm thk	0.065	20.4		1.33	KN/Sqm
	40mm thk Kota stone	0.04	23.25		0.93	KN/Sqm
			Total		5.38	**Say 5.5 KN/Sqm**
C	**Second & Third floor lvl.**					
i)	**230mm Thick masonry load**					
	230mm thk, upto beam bottom	0.23	18.85	2.83	12.27	KN/m
	Wall Plaster	0.024	20.4	2.83	1.39	KN/m
			Total		13.66	**Say 14 KN/m**
ii)	**115mm Thick masonry load**					
	230mm thk, upto beam bottom	0.115	18.85	2.83	6.13	KN/m
	Wall Plaster	0.024	20.4	2.83	1.39	KN/m
			Total		7.52	**Say 8 KN/m**
iii)	**Floor (Slab) load 125mm thk.**					
	125mm thk slab	0.125	25		3.13	KN/Sqm
	Flooring 105mm thk.					
	cement mortar 65mm thk	0.065	20.4		1.33	KN/Sqm
	40mm thk Kota stone	0.04	23.25		0.93	KN/Sqm
			Total		5.38	**Say 5.5 KN/Sqm**
D	**Terrace floor lvl.**					
i)	**Mumty room**					
	230mm Thick masonry load					
	230mm thk, upto beam bottom	0.23	18.85	2.3	9.97	KN/m
	Wall Plaster	0.024	20.4	2.3	1.13	KN/m
			Total		11.10	**Say 11.5 KN/m**
ii)	**Parapet wall**					
	230mm Thick masonry load					
	230mm thk, upto beam bottom	0.23	18.85	0.9	3.90	KN/m
	Wall Plaster	0.024	20.4	0.9	0.44	KN/m
			Total		4.34	**Say 4.5 KN/m**
iii)	**Floor (Slab) load 125mm thk.**					
	125mm thk slab	0.125	25		3.13	KN/Sqm

	Waterproofing 150mm thick (brick coba)	0.15	20.4		3.06	KN/Sqm
			Total		6.19	**Say 6.5 KN/Sqm**
E	**Mumty/Machine floor**					
	Floor (Slab) load 125mm thk.					
i)	125mm thk slab	0.125	25		3.13	KN/Sqm
	Waterproofing 150mm thick (brick coba)	0.15	20.4		3.06	KN/Sqm
			Total		6.19	**Say 6.5 KN/Sqm**
2	**LIVE LOAD - IS 875 (Part-2)**					
A	**First floor**					
i)	All rooms, Kitchen, toilet and bathrooms				2	KN/Sqm
ii)	Corridor, passages, staircases including fire escape and store rooms				3	KN/Sqm
B	**Second floor**					
	Floor Slab (Typical floors)					
i)	All rooms, Kitchen, toilet and bathrooms				2	KN/Sqm
			Total		2.0	**Say 2 KN/Sqm**
ii)	Corridor, passages, staircases including fire escape and store rooms				3	KN/Sqm
			Total		3.0	**Say 3 KN/Sqm**
C	**Terrace floor**					
i)	Terrace				1.5	KN/Sqm
			Total		1.5	**Say 1.5 KN/Sqm**
D	**Mumty floor**					
i)	Water tank load		10	1.2	12.00	KN/Sqm
			Total		12.00	**Say 12 KN/Sqm**
E	**Machine room**					
i)	Live load				7.5-10	KN/Sqm
			Total		10.00	**Say 10 KN/Sqm**

7.3 Staircase Loading.
Loading Per Meter Width of Flight

R=150, T=250, Hence Sqrt ((150)^2+(250)^2)) = 291.5 ≅ 292mm
Waist Slab = [0.150 x 292 x 25]/250
= 4.38 KN/Sqm
Steps = (0.150 x 25)/2
= 1.875 KN/Sqm
Finishing = 1 KN/Sqm
Total = 7.3 KN/Sqm ≅ 7.5 KN/Sqm

7.4 Earthquake/Seismic Loads
Assessment of earthquake loading is performed in accordance with the requirements of IS: 1893-2016. You'll find Bangalore in Zone-III. The following considerations are made:
Seismic loads and how they are distributed across the building's height and throughout its numerous lateral load resisting parts as per the design.

Table 7.2 Seismic Load Calculations

BASIC LOAD CALCULATIONS						
Project : Live Project						
Location : Bangalore						
	DESCRIPTIONS	**CALCULATIONS**				**REMARKS**
1	**SEISMIC LOAD - IS 1893 (Part-1) : 2016**					
A	Zone Factor		0.16			Table -3
	Importance factor		1			Table -8
	Response Reduction Factor		5			Table -9
B	**Time Period Calculation**	**T= (0.09xh)/ Sqrt (d)**				**clause 7.6.2 ©**
	Height of the building =		16.902	m		
	Base dimension of building at plinth level (d_x) =		19.89	m		
	Base dimension of building at plinth level (d_z) =		10.83	m		
	Time period in X Direction (T_x) =		0.34	sec		
	Time period in Z Direction (T_z) =		0.46	sec		

Table: 7.2 Covers For Structural Elements

Structural Element	Nominal Cover to all reinforcement (as per IS 456:2000)		Nominal Cover Provided
	For Moderate Exposure condition	For Fire Resistance of 2.0 hrs.	
Beams	25mm	30mm	30mm
Slab	20mm	25mm	25mm
Columns	40mm	40mm	40mm
Footings	50mm		50m

Clause 21 of IS 456-2000 specifies minimum sizes for fire-resistant reinforced concrete members.

Table: 7.3 MINIMUM DIMENSIONS OF REINFORCED CONCRETE

Fire Resistance *h*	Minimum Beam Width *b*	Rib Width of Slabs b_w	Minimum Thickness of Floors *D*	Column Dimension (b or D) Fully Exposed	50% Exposed	One Face Exposed	Minimum Wall Thickness $p<0.4\%$	$0.4\% \leq p \leq 1\%$	$p>1\%$
	mm	mm	mm	mm	mm	mm	mm	mm	mm
0.5	200	125	75	150	125	100	150	100	100
1	200	125	95	200	160	120	150	120	100
1.5	200	125	110	250	200	140	175	140	100
2	200	125	125	300	200	160	–	160	100
3	240	150	150	400	300	200	–	200	150
4	280	175	170	450	350	240	–	240	180

NOTES

1 These minimum dimensions relate specifically to the covers given in Table 16A.

2 *p* is the percentage of steel reinforcement.

According to clause 21 of IS 456 -2000 (table above), minimum beam width for 30 minutes fire resistance is 200 mm and minimum column cover to reinforcement is 40mm. IS 13920-1993 requires 200mm beam width. Clause 7.1.2 requires 200mm columns.

7.5 FOUNDATION SYSTEM

Building footings will be segregated. The foundation will be constructed for 180 KN/m2 Net Safe Bearing Capacity using ETAB Model reaction.

7.6 DETAILING OF STRUCTURES

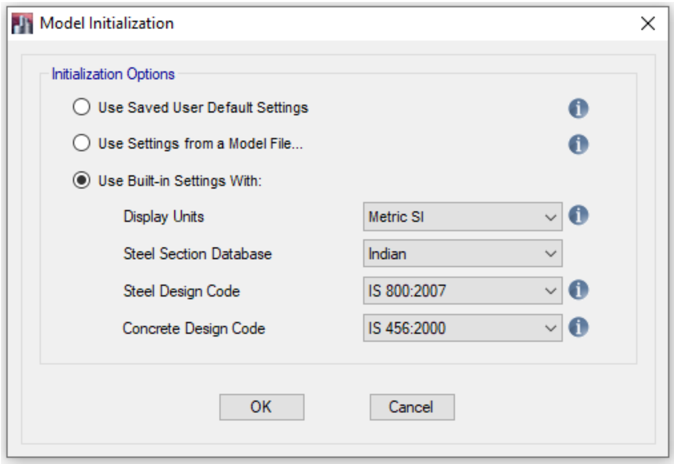
IS: 456 and SP: 34 detail all structural elements. Detailing should fulfil minimum and maximum R/F and bar spacing criteria.

VIII. MODELING USING ETABS

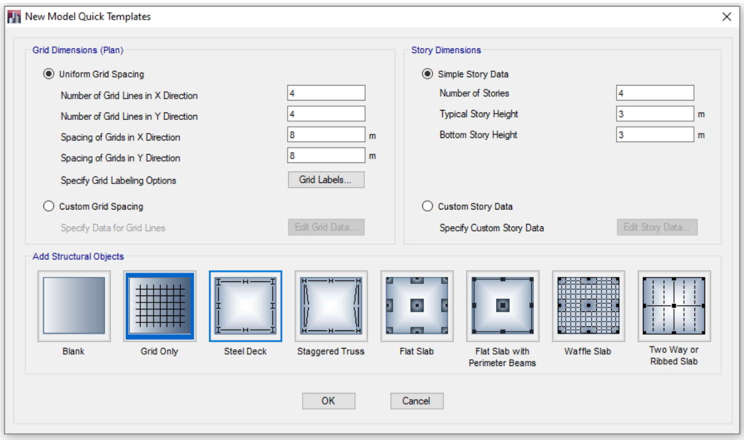
Step 1: Modeling using ETABS

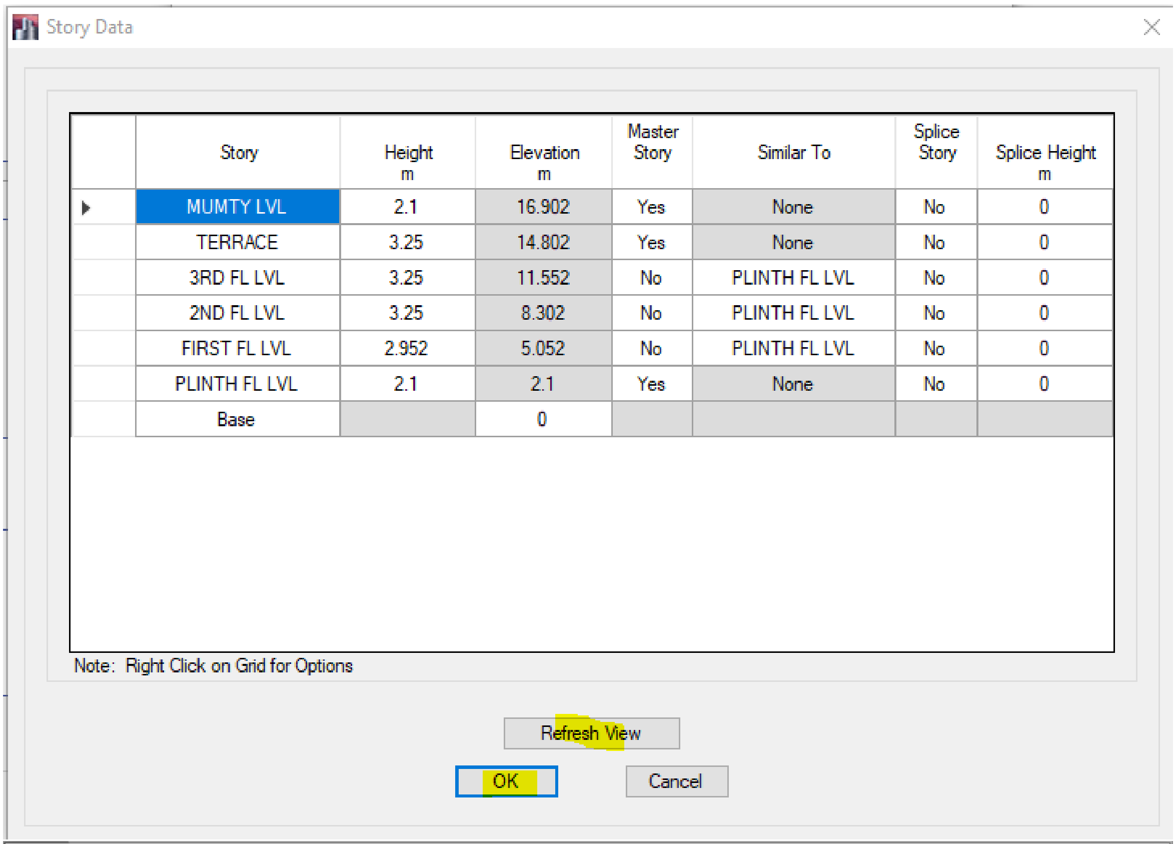
1) Start ETABS
2) In the drop-down box at the very right of ETABS, choose kN-m as the model units.
3) Select File>New model.

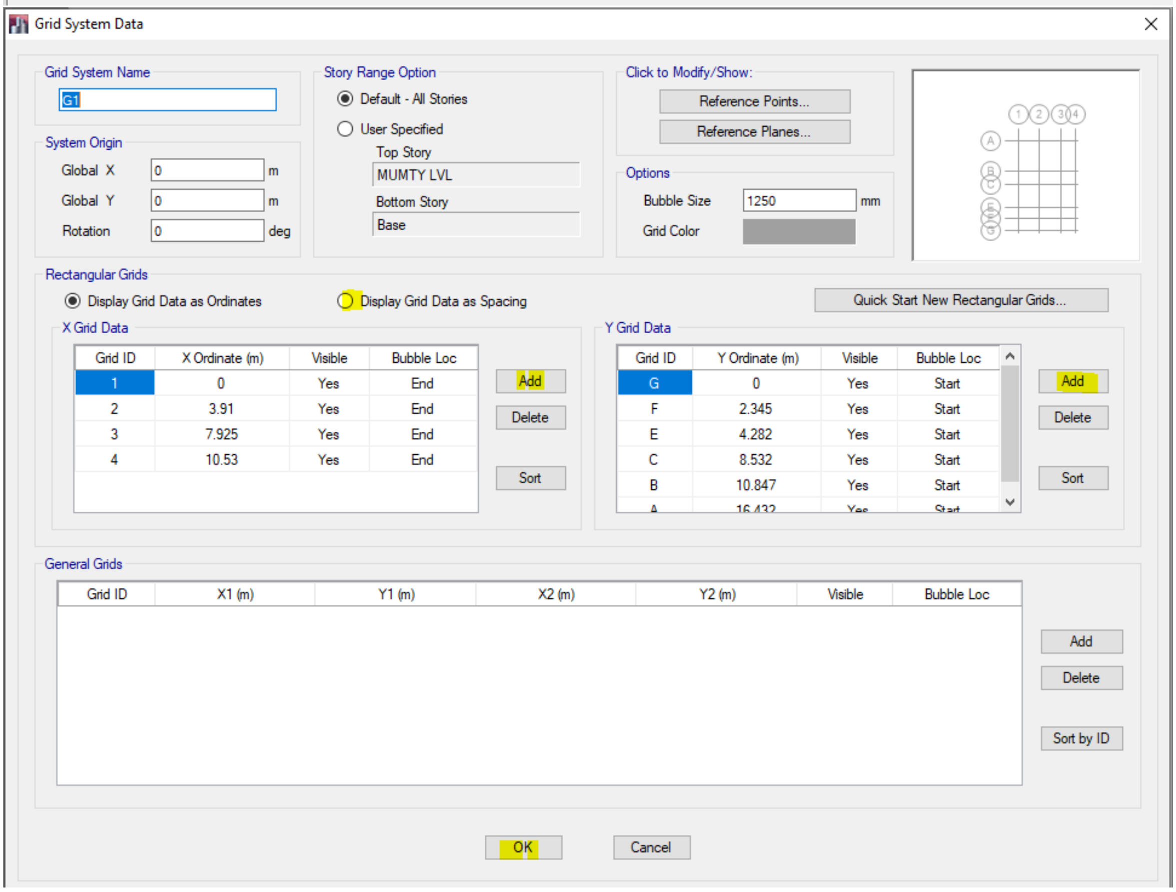
Change units, steel, and concrete codes and click OK.



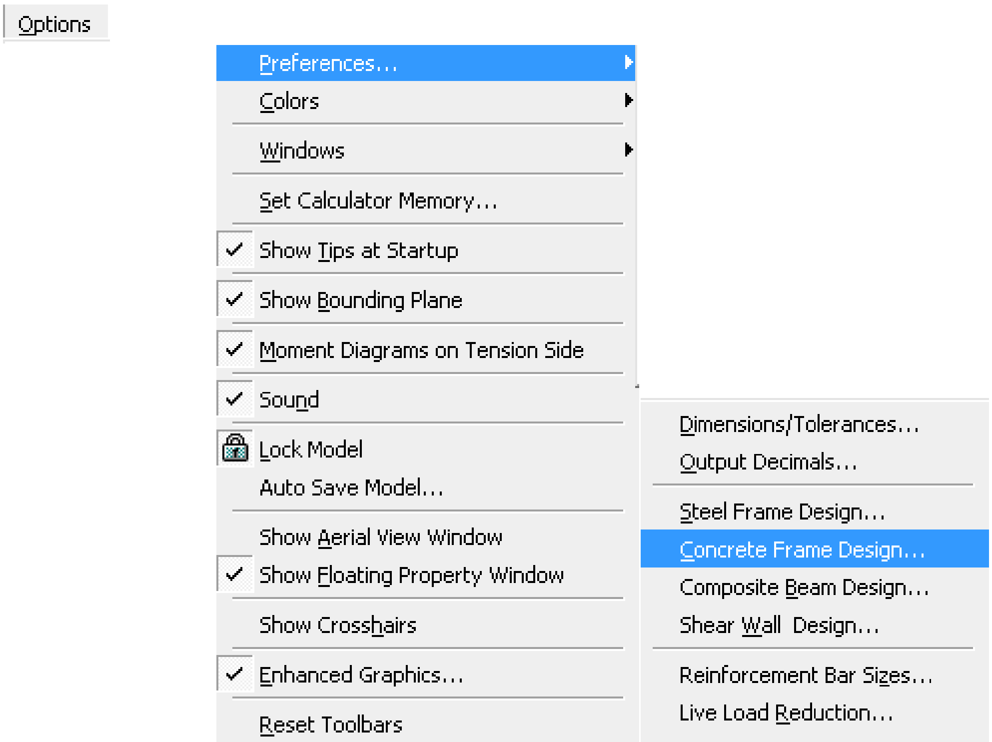
4) The next step is to define the building's data and the building's grid system. Alter the distance between each grid square. Grid spacing and custom storey data are used to determine building height. As seen in drawings.



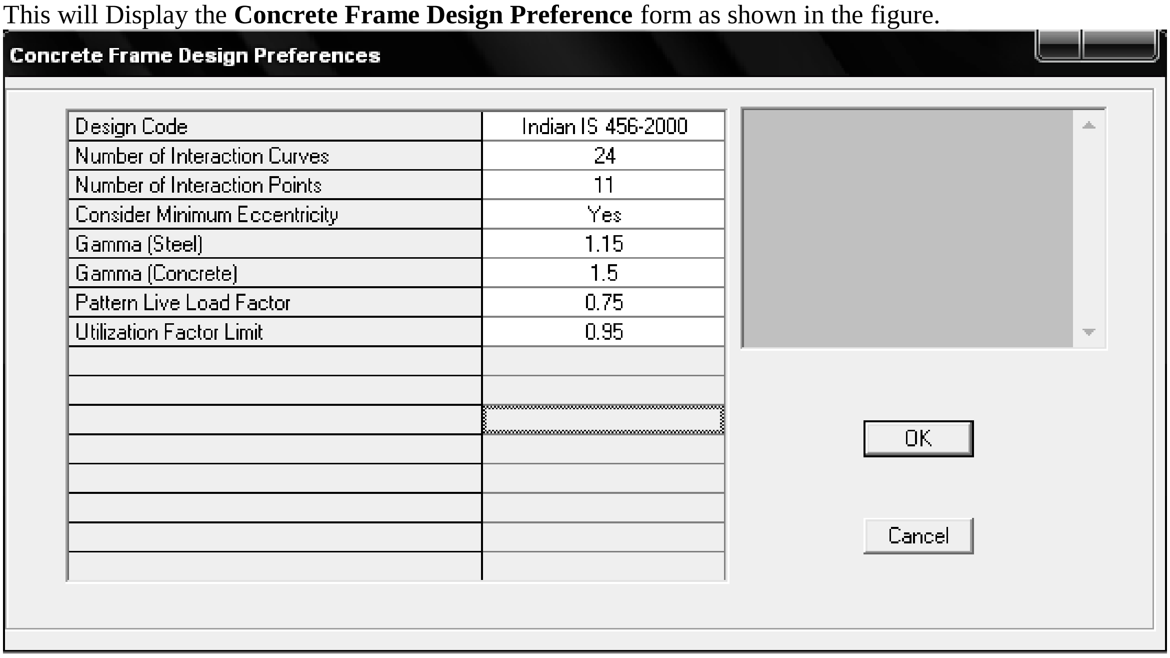

Story Data
Story
Height m
Elevation m
Master Story
Similar To
Splice Story
Splice Height m
MUMTY LVL 2.1 16.902 Yes None No 0
TERRACE 3.25 14.802 Yes None No 0
3RD FL LVL 3.25 11.552 No PLINTH FL LVL No 0
2ND FL LVL 3.25 8.302 No PLINTH FL LVL No 0
FIRST FL LVL 2.952 5.052 No PLINTH FL LVL No 0
PLINTH FL LVL 2.1 2.1 Yes None No 0
Base 0
Note: Right Click on Grid for Options
Refresh View
OK
Cancel


Grid System Data
Grid System Name
G1
System Origin
Global X 0 m
Global Y 0 m
Rotation 0 deg
Story Range Option
Default - All Stories
User Specified
Top Story
MUMTY LVL
Bottom Story
Base
Click to Modify/Show:
Reference Points...
Reference Planes...
Options
Bubble Size 1250 mm
Grid Color
Rectangular Grids
Display Grid Data as Ordinates
Display Grid Data as Spacing
Quick Start New Rectangular Grids...
X Grid Data
Grid ID X Ordinate (m) Visible Bubble Loc
1 0 Yes End
2 3.91 Yes End
3 7.925 Yes End
4 10.53 Yes End
Add
Delete
Sort
Y Grid Data
Grid ID Y Ordinate (m) Visible Bubble Loc
G 0 Yes Start
F 2.345 Yes Start
E 4.282 Yes Start
C 8.532 Yes Start
B 10.847 Yes Start
Add
Delete
Sort
General Grids
Grid ID X1 (m) Y1 (m) X2 (m) Y2 (m) Visible Bubble Loc
Add
Delete
Sort by ID
OK
Cancel

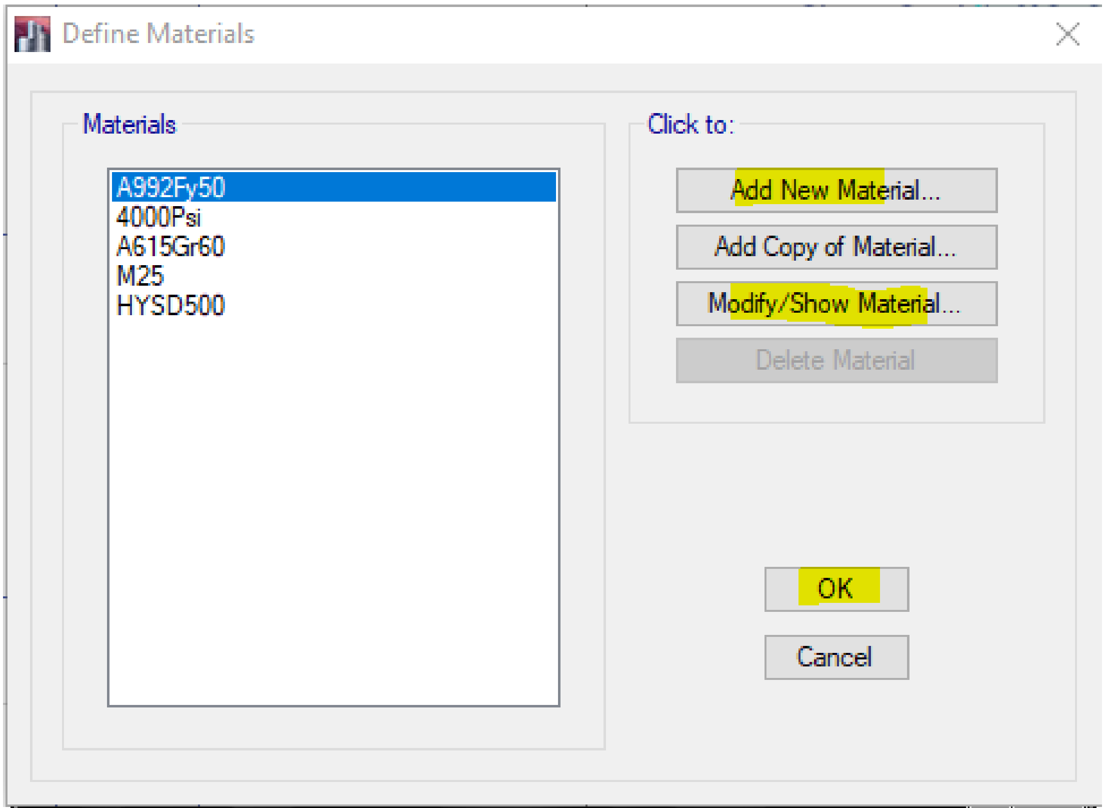
5) Choose Concrete Frame Design from the "Options" menu's "Preferences" to set the design code.
Command

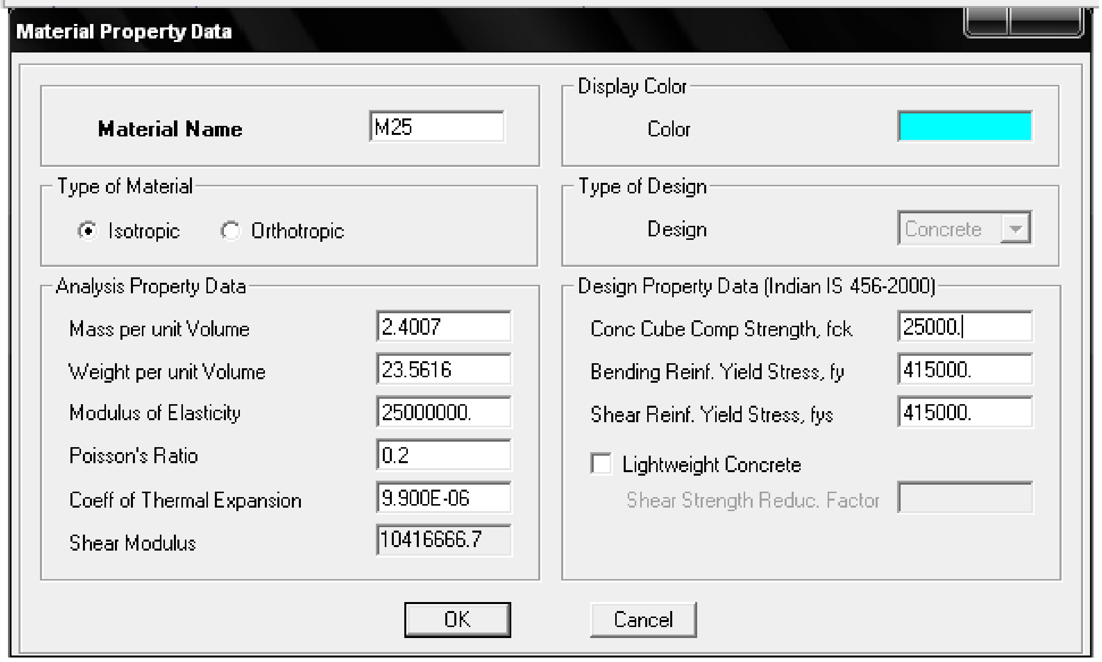


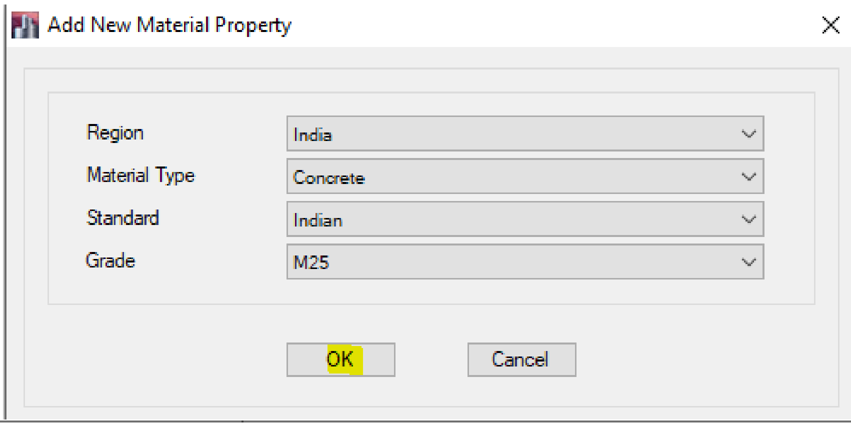
This will Display the **Concrete Frame Design Preference** form as shown in the figure.

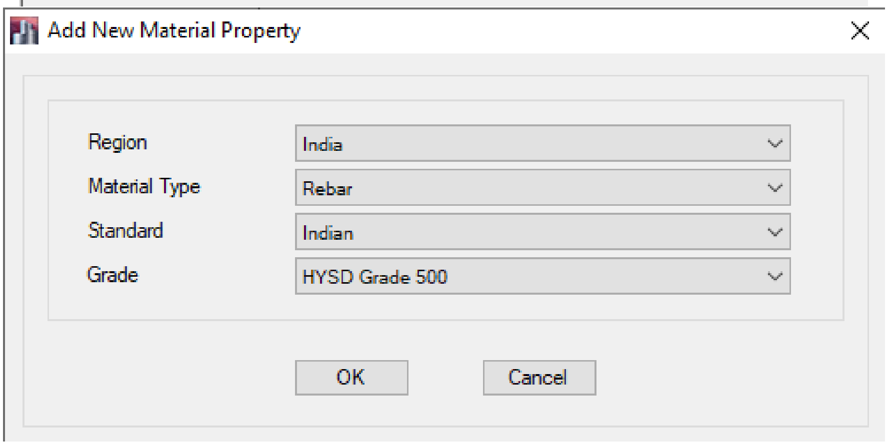


6) Click Define > Material Properties, then click Modify/Show Materials, and then click OK to add materials like concrete grade and steel grade by area. The numbers are below.

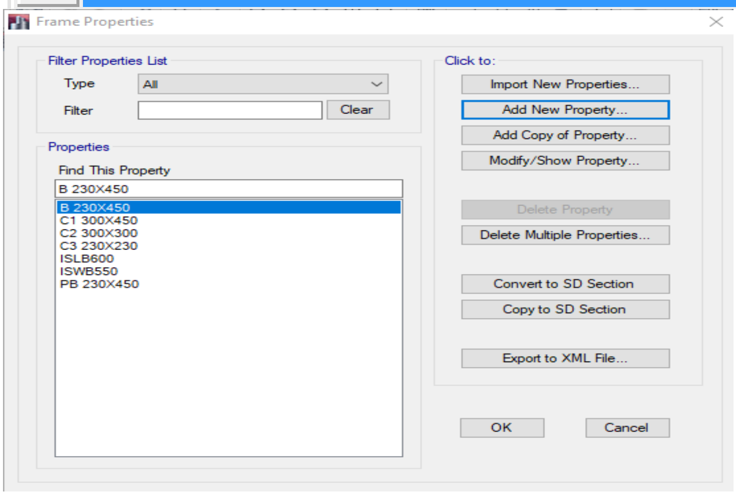

Define Materials
Materials
A992Fy50
4000Psi
A615Gr60
M25
HYSD500
Click to:
Add New Material...
Add Copy of Material...
Modify/Show Material...
Delete Material
OK
Cancel

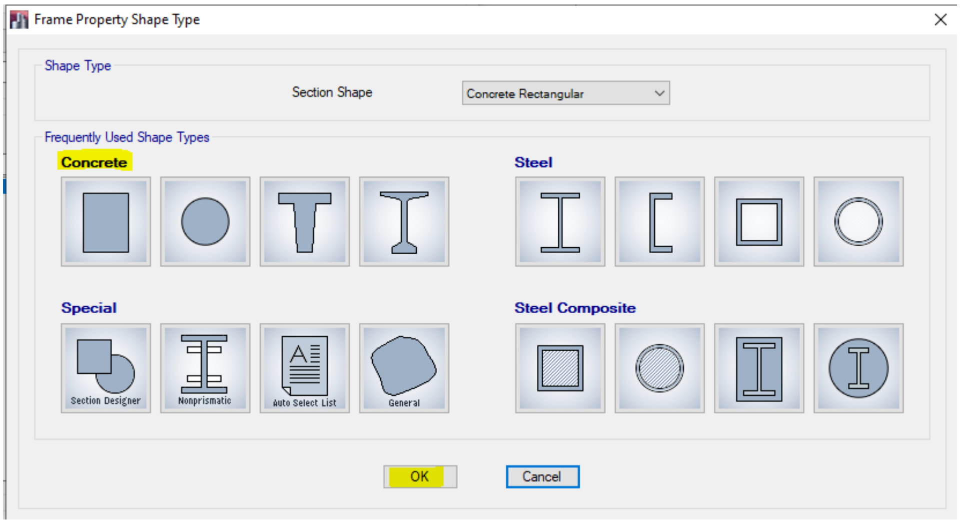

Material Property Data
Material Name
M25
Display Color
Color
Type of Material
Isotropic
Orthotropic
Type of Design
Design
Concrete
Analysis Property Data
Mass per unit Volume
2.4007
Weight per unit Volume
23.5616
Modulus of Elasticity
25000000.
Poisson's Ratio
0.2
Coeff of Thermal Expansion
9.900E-06
Shear Modulus
10416666.7
Design Property Data (Indian IS 456-2000)
Conc Cube Comp Strength, fck
25000.
Bending Reinf. Yield Stress, fy
415000.
Shear Reinf. Yield Stress, fys
415000.
Lightweight Concrete
Shear Strength Reduc. Factor
OK
Cancel



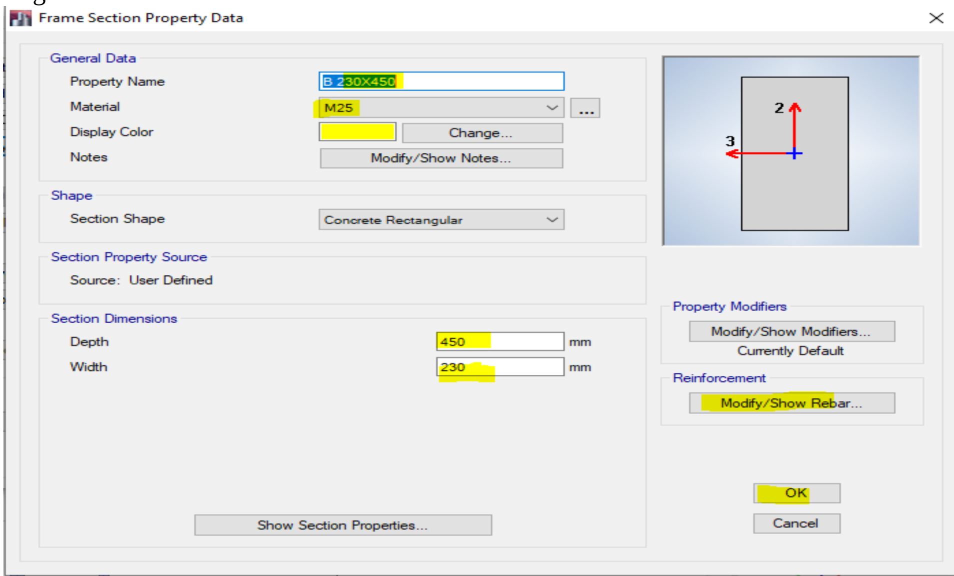


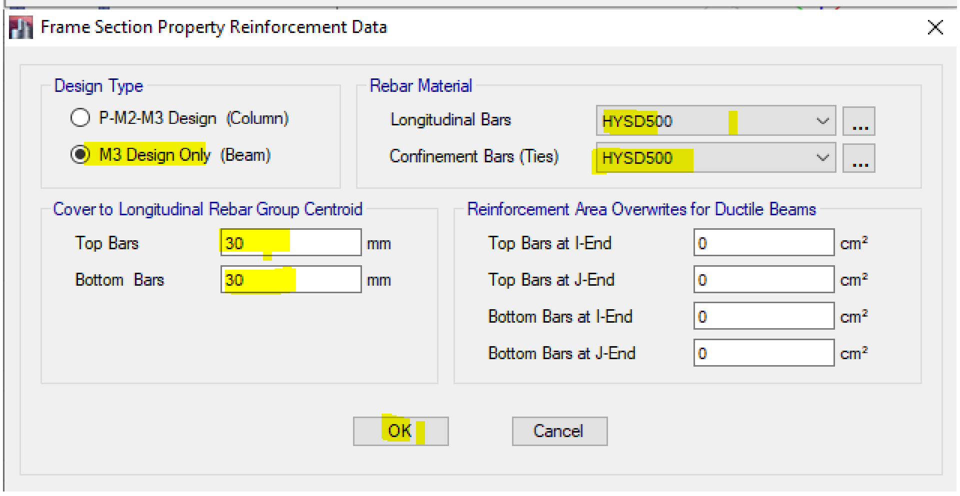
7) Columns and beams may be defined by selecting Define > Frame section.
Click add new property > click rectangle > ok



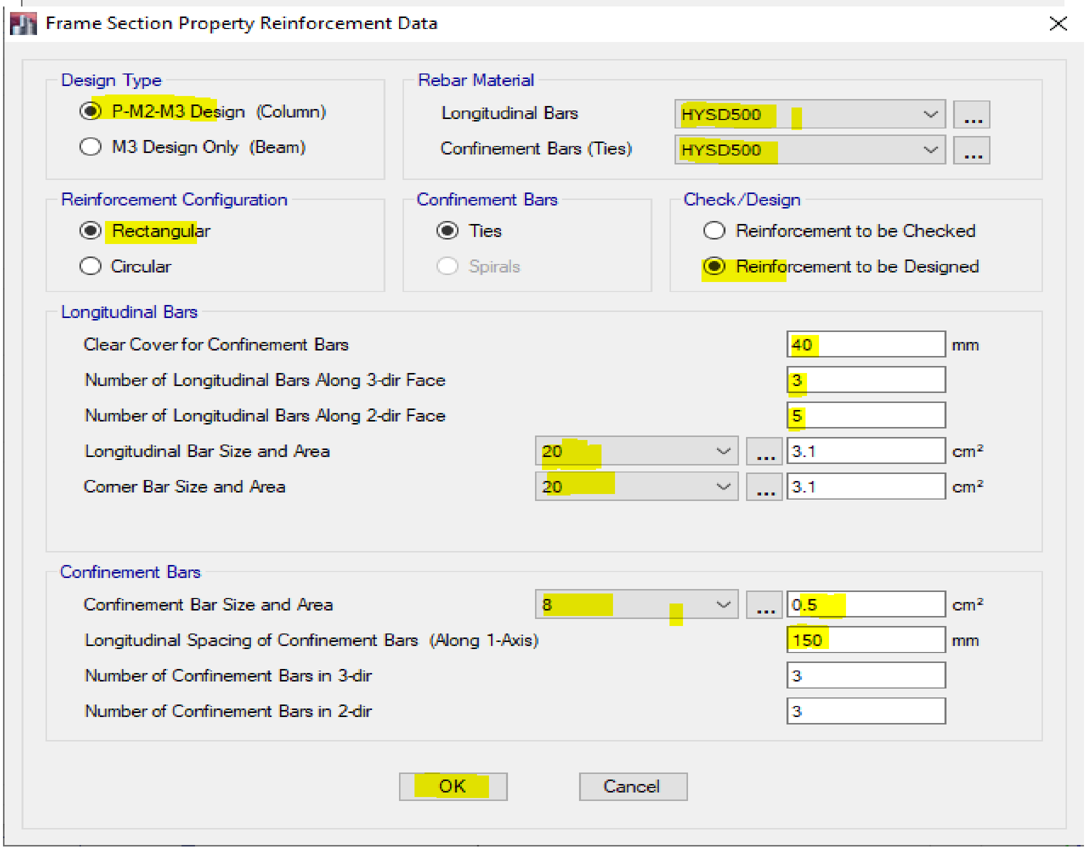


Define beam sizes, click Reinforcement, and cover columns with concrete. Checked or planned reinforcement. Prefer checking reinforcement.





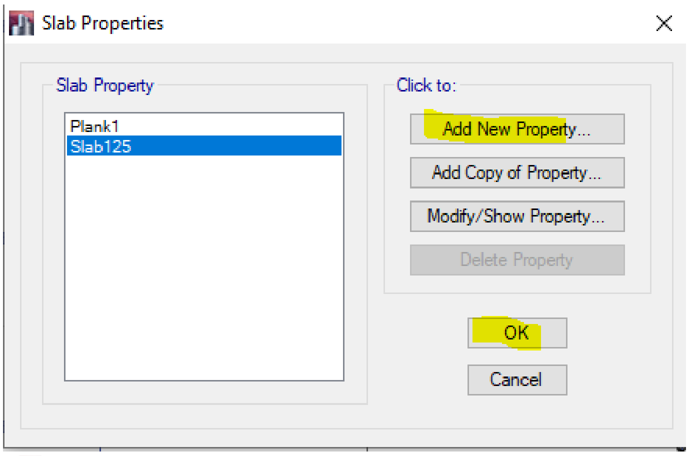

Frame Section Property Data
General Data
Property Name
C1 300X450
Material
M25
Display Color
Change...
Notes
Modify/Show Notes...
Shape
Section Shape
Concrete Rectangular
Section Property Source
Source: User Defined
Section Dimensions
Depth
450
mm
Width
300
mm
Show Section Properties...
Property Modifiers
Modify/Show Modifiers...
Currently Default
Reinforcement
Modify/Show Rebar...
OK
Cancel

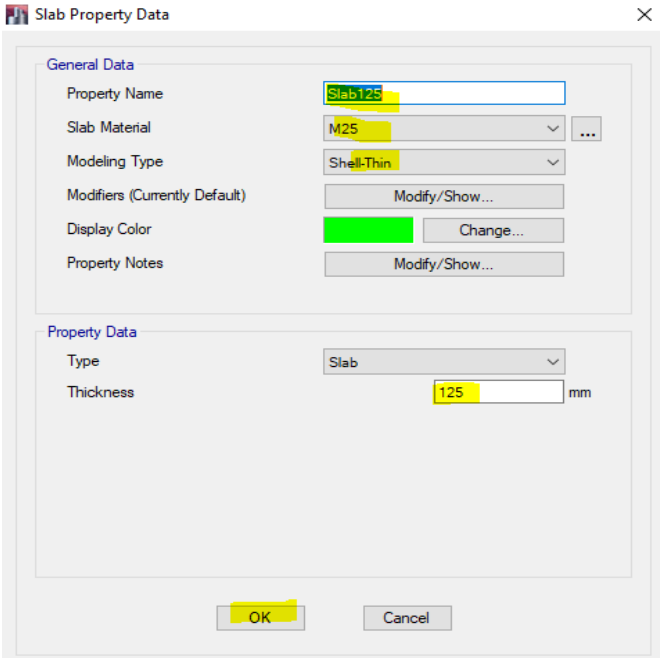

Frame Section Property Reinforcement Data
Design Type
P-M2-M3 Design (Column)
M3 Design Only (Beam)
Rebar Material
Longitudinal Bars
HYSD500
Confinement Bars (Ties)
HYSD500
Reinforcement Configuration
Rectangular
Circular
Confinement Bars
Ties
Spirals
Check/Design
Reinforcement to be Checked
Reinforcement to be Designed
Longitudinal Bars
Clear Cover for Confinement Bars
40
mm
Number of Longitudinal Bars Along 3-dir Face
3
Number of Longitudinal Bars Along 2-dir Face
5
Longitudinal Bar Size and Area
20
3.1
cm²
Corner Bar Size and Area
20
3.1
cm²
Confinement Bars
Confinement Bar Size and Area
8
0.5
cm²
Longitudinal Spacing of Confinement Bars (Along 1-Axis)
150
mm
Number of Confinement Bars in 3-dir
3
Number of Confinement Bars in 2-dir
3
OK
Cancel

8) Define wall/slab/deck.

Special one-way load distribution is used to describe a slab as a membrane or shell thin element and a one-way slab.

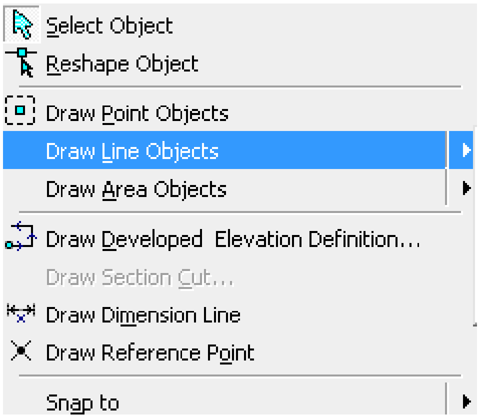
Slab-based features may be added or altered.

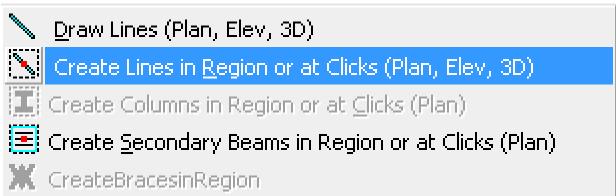


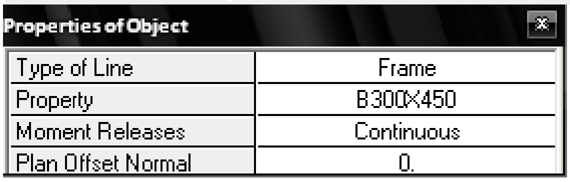


9) Generate the model

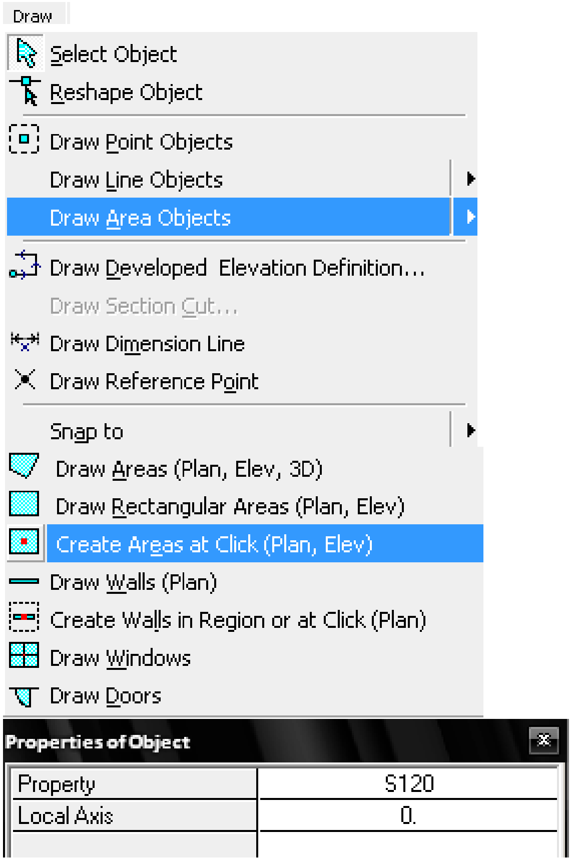
Make instructions for a line and a column to sketch a beam and a column.



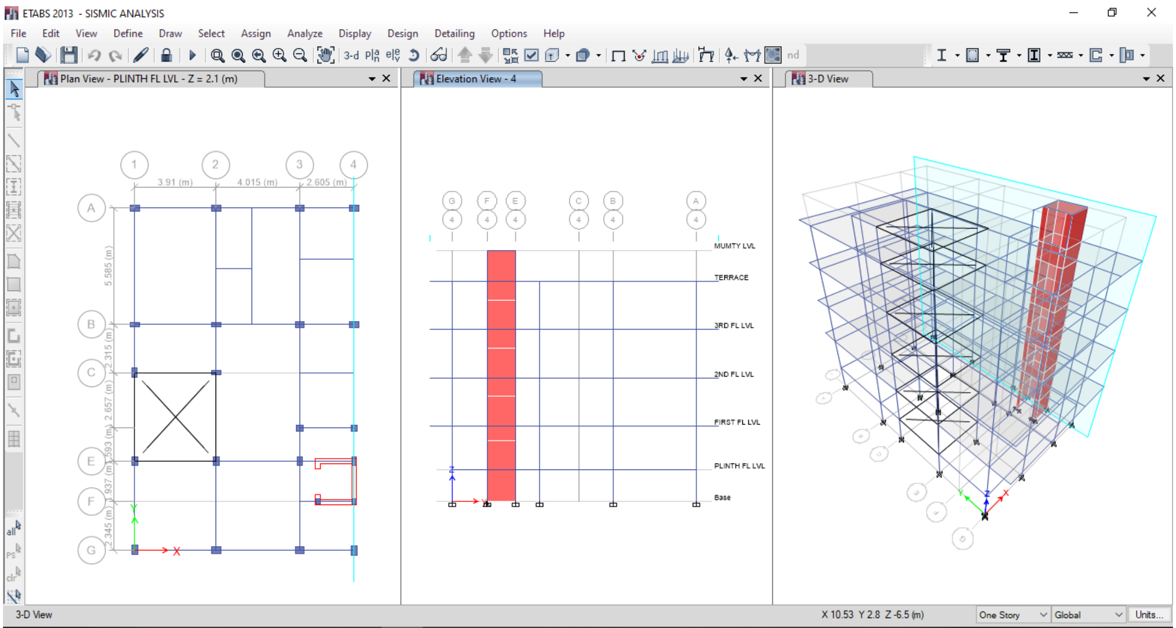




There are three ways to make a slab: (1) draw an area of any form; (2) draw a rectangular area; or (3) make an area in between grid lines.



The above choice created the model shown below.



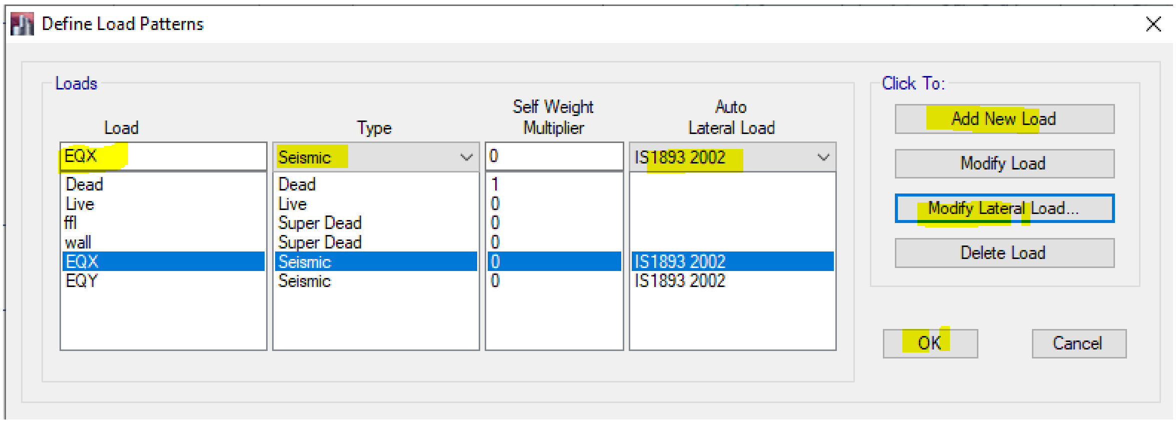
Go to define > load pattern > click

11) Seismic force calculation as per IS: 1893(Part 1) - 2002.

(a) Static Method

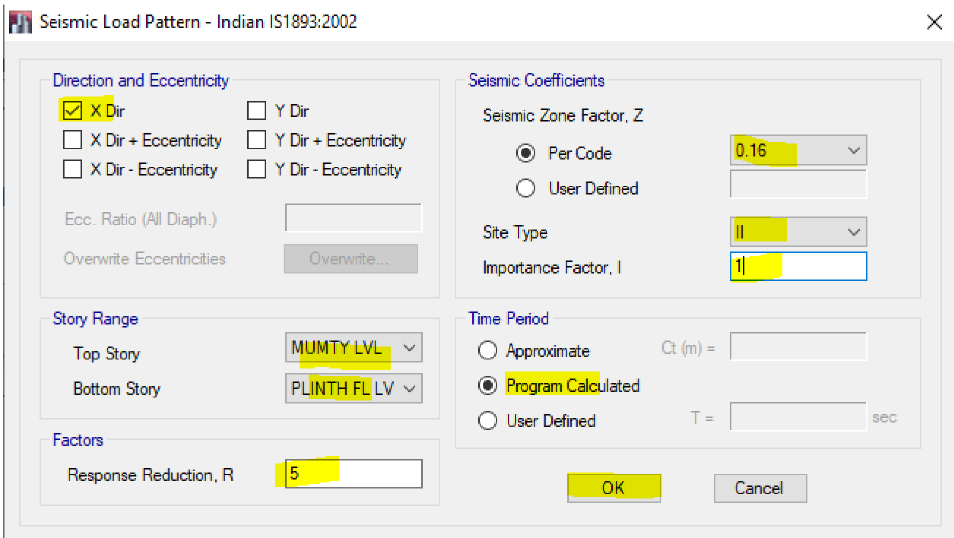
Create the model, analyse and design it (RCC design), and then verify it.

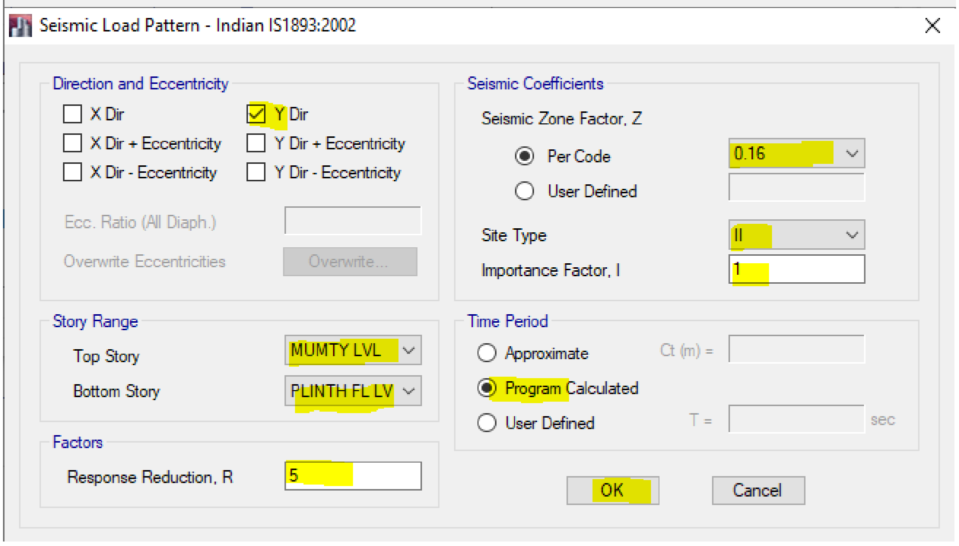
Break the model and define seismic load patterns as indicated below.



Dead Load: default self weight multiplier is 1.
Live or other defined load

Access the definition of static load by selecting Define > Static load.
Please adjust the lateral load to the amount provided below, and assign a different value in accordance with IS 1893-2005.

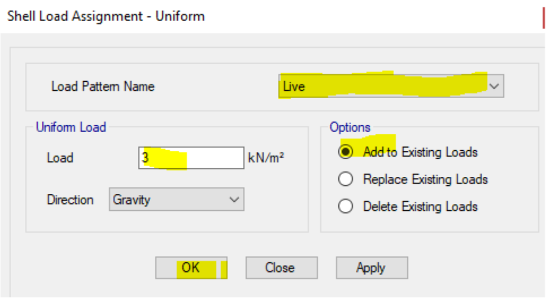




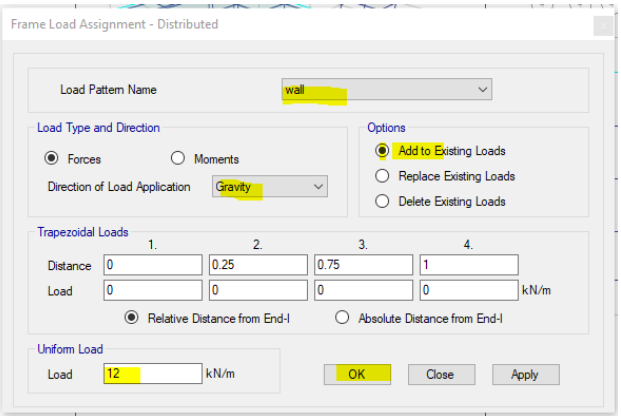
load combination, envelope, and model. Show tables and record these values after analysing the structure:
1. The Story Drift must not be more than 0.004 times the height of the storey.

The most extreme base reaction, FZ (When you're through, compare this number to the results of a straightforward analysis.)

12) Assigning the live , dead, ffl, and wall load
Click the assign button once you have chosen the person to whom this load will be assigned.
Assign > shell area loads > uniform > click ok

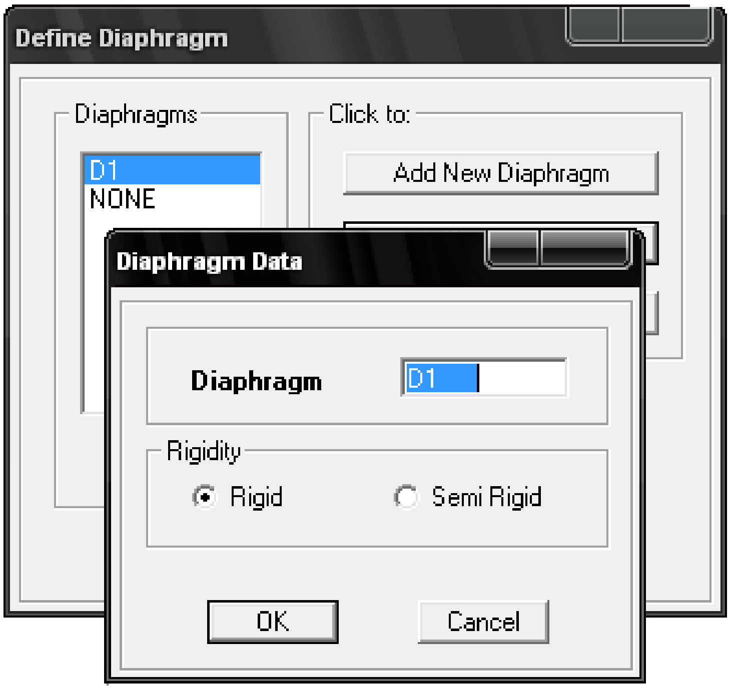


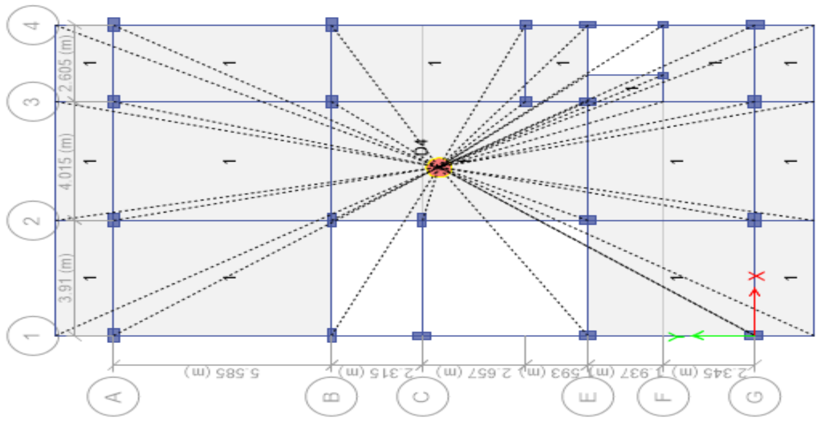
Frame load Assignment> uniformly spread Add the load pattern to existing loads > uniform load > ok > member element > ok.



13) Assign support condition
In the ETABS window's lower-right drop-down menu, choose the level you want to give the fixed support for using the "Create One Storey" button.
assign > Joint/Point>Restrain (Support) command> fixed
one storey bottom left corner and assign

14) Assigning the diaphgram
Earthquake analysis treats slabs as rigid members. First, diaphragm action is applied to all slabs for stiff or semi-rigidity.

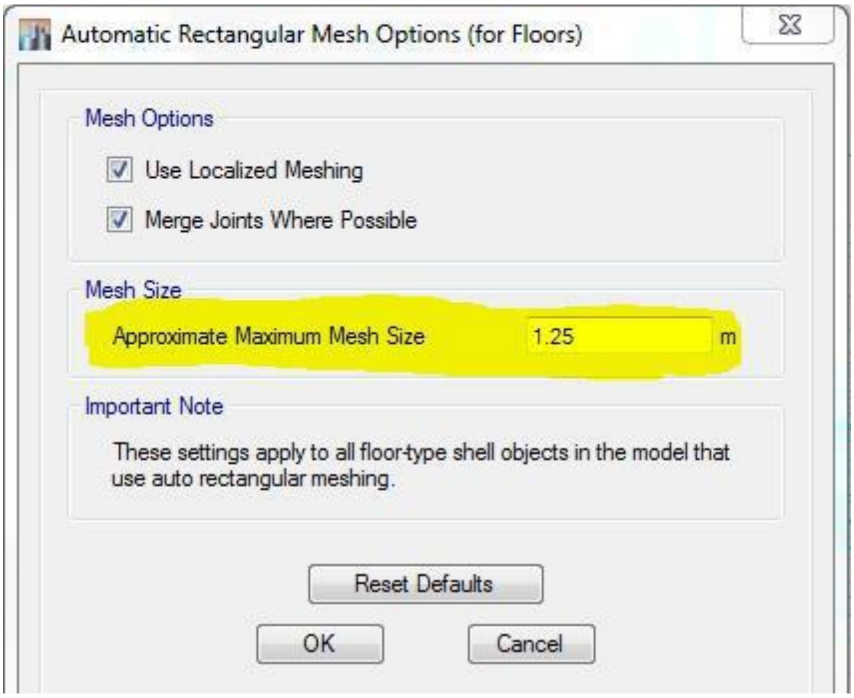




13) Meshing of Slabs

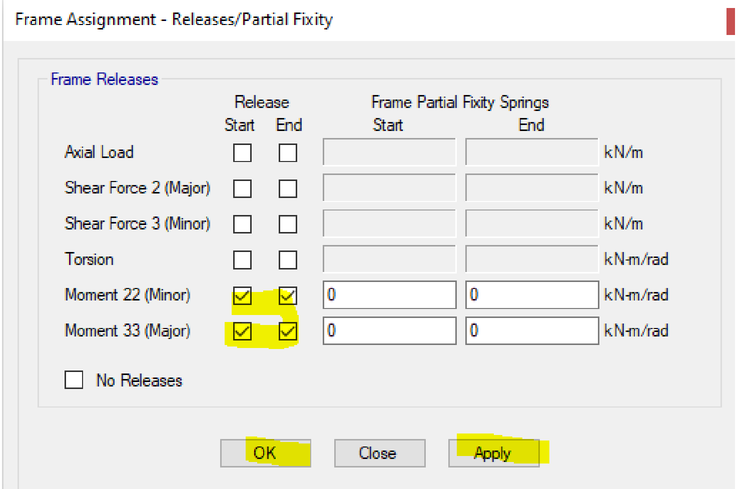
Select all of the slabs that will be used in the analysis (F5), then go to the Analyze menu, select Automatic rectangular mesh settings for floor, and then click on the Mesh customisation panel.

For best results, set the meshing size to 0.6 from the usual 1.25.



14) Assigning end release

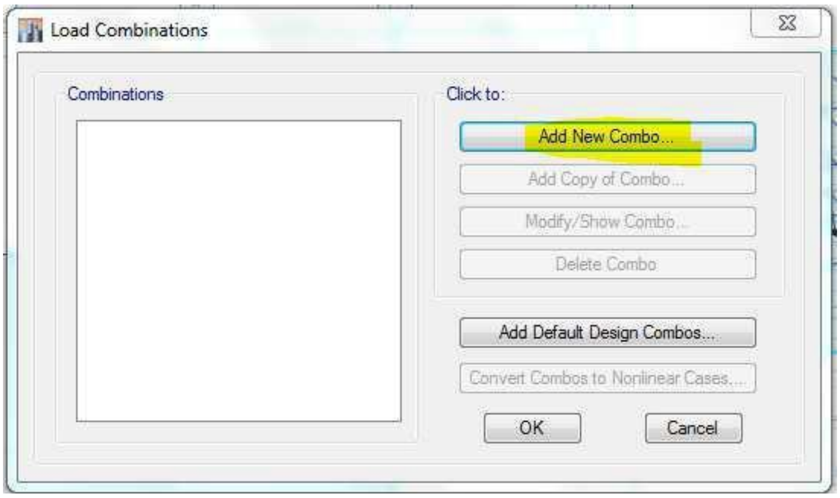
Assign>frame>partial fixity> then as indicated in figure.



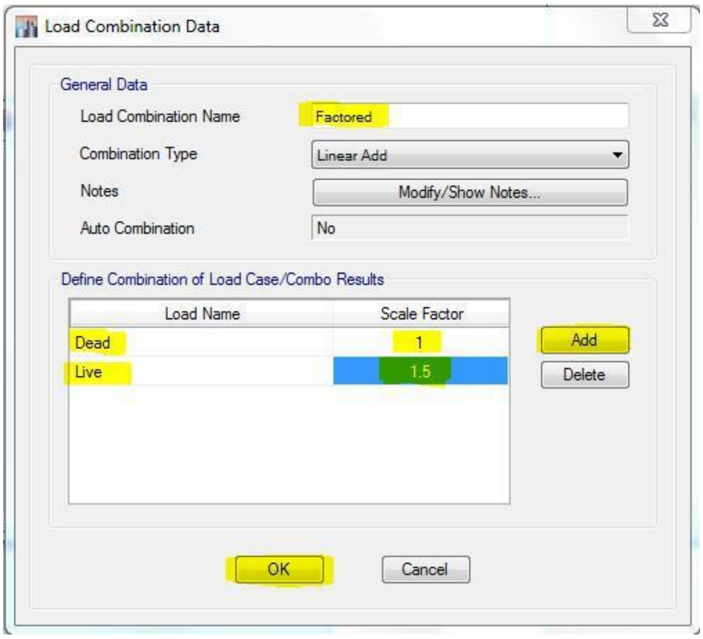
15) Load Combinations

If you want full creative control over your ideas, it's advisable to create your own load combination rather than rely on ETABS's proposed "UDCON2" load combination for dealing with the partial safety problem. Load combinations are created as follows.

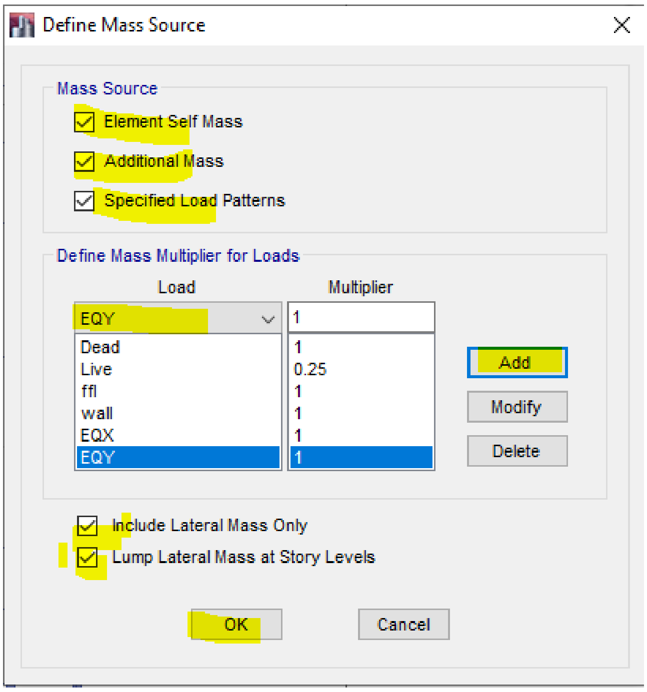
Define——>Load Combinations——> Click add new combination in that window.



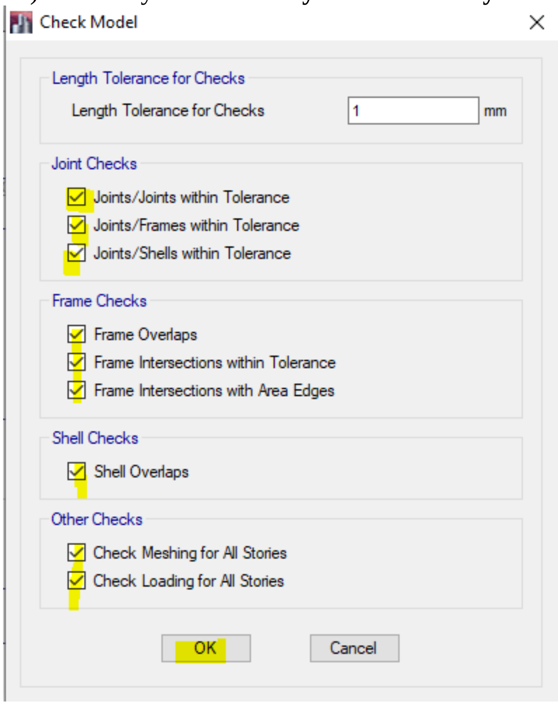
After clicking Add new combination, the safety factor window displays as shown below/next page (1 for DL and 1.5 for LL). The model may be analysed for post-processing outcomes when all load allocations and combinations are defined.

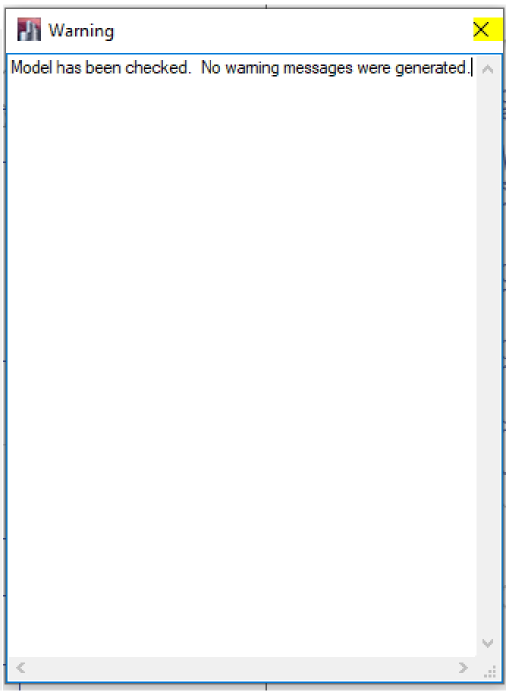


16) Define>mass source defines mass source. IS: 1893-2002 requires 25% live load (of 3 kN/m2) on all floors excluding roof.



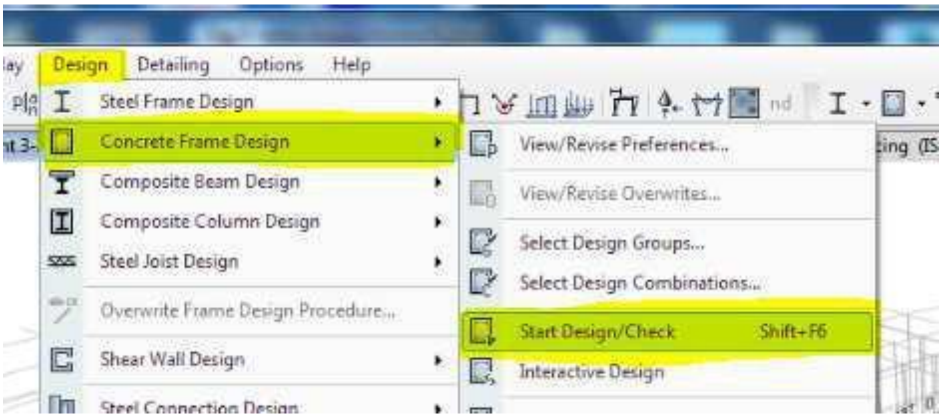
17) Run analysis from **Analysis > Run Analysis command**



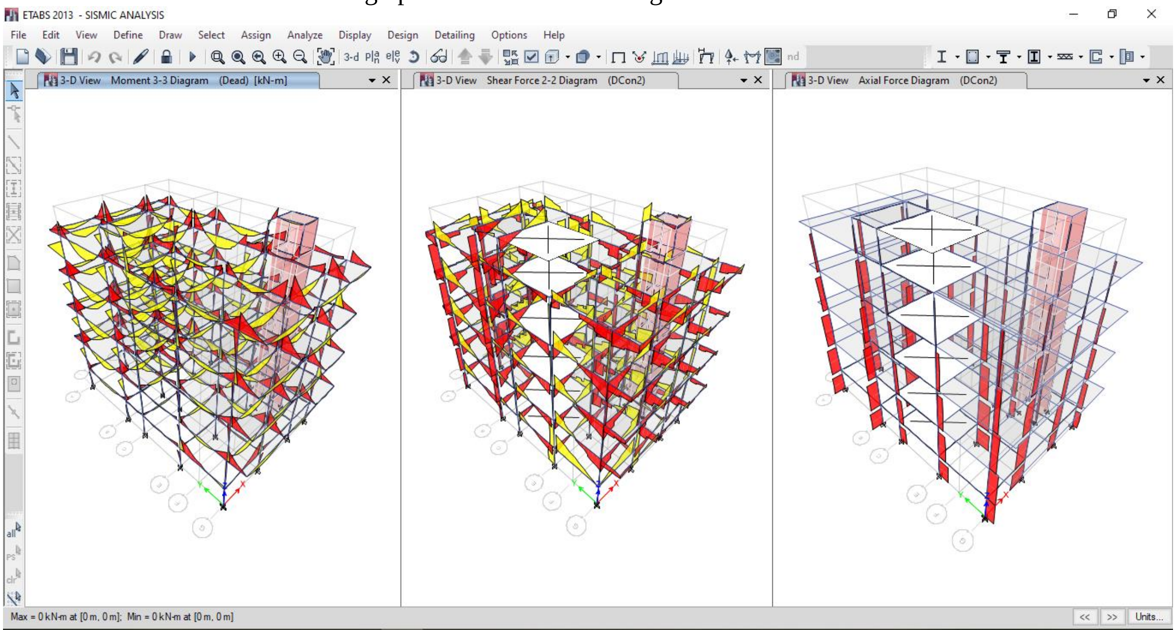


18) Concrete Design

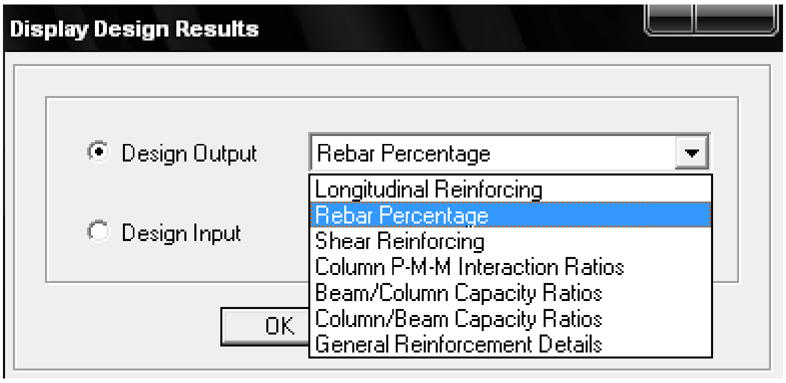
Click Design -> Concrete Frame Design -> Start Design / Check (Shortcut sft + F6) to begin concrete designing once you have finished modelling, allocating loads, and analysing load combinations. This will confirm your post-processing results (SFD & BMD).

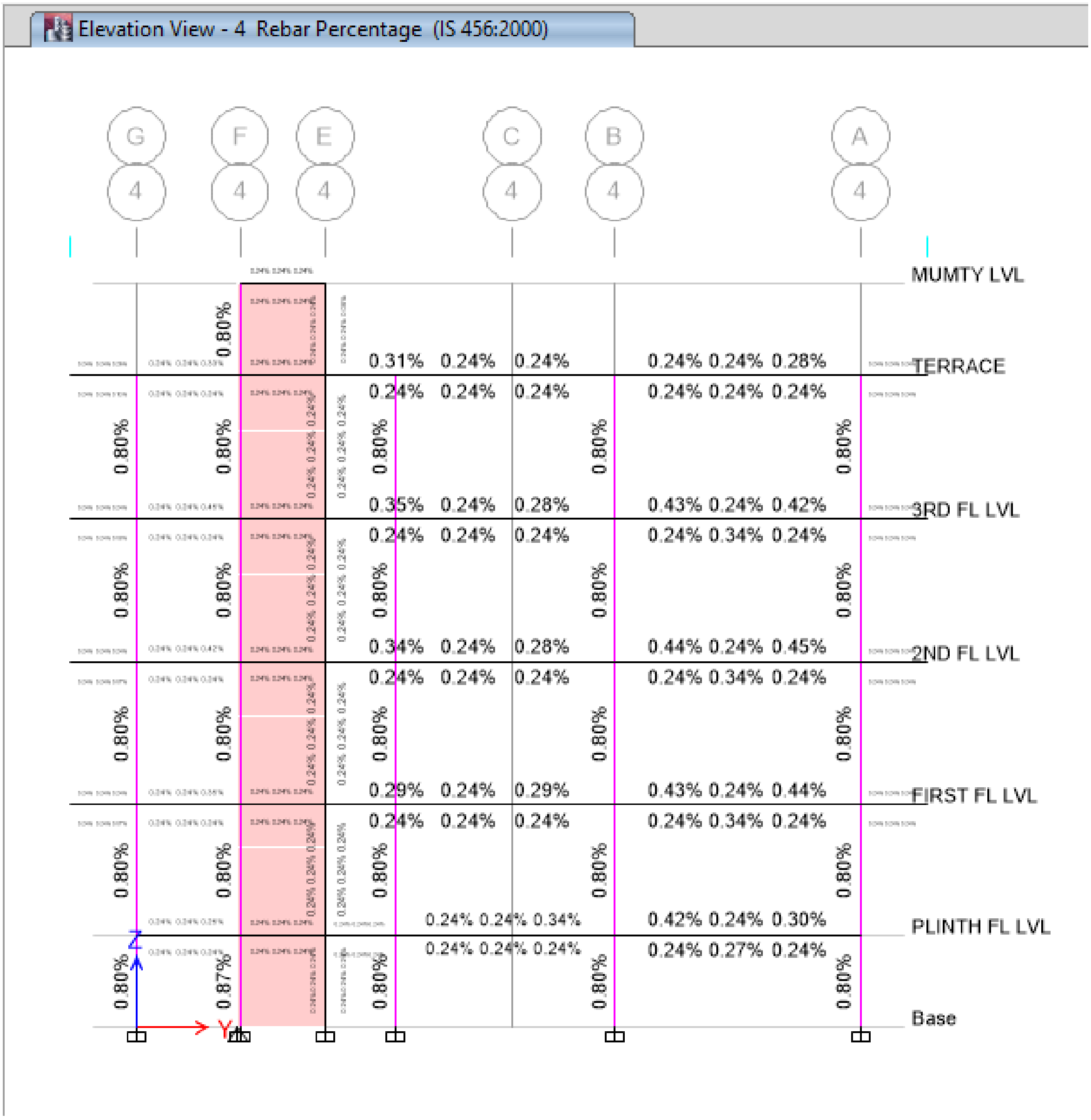


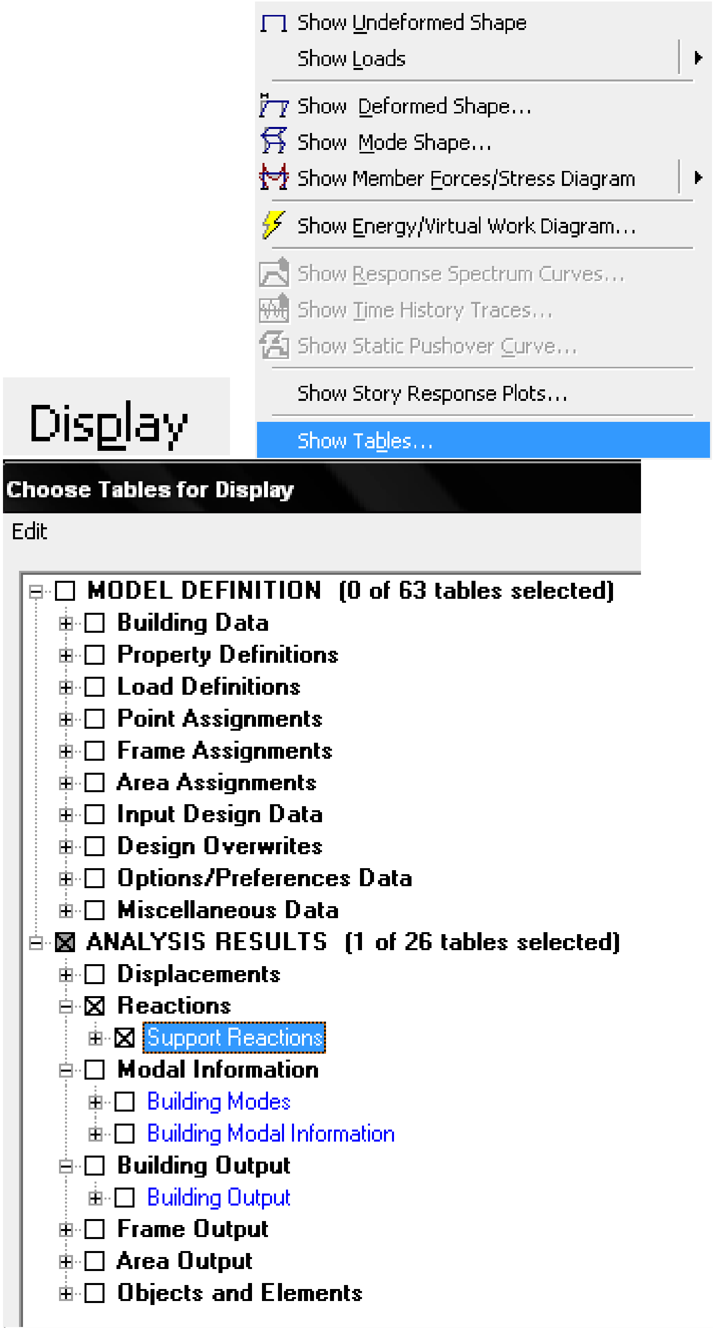
The structural evaluation and design process results in a design model that looks like the one shown below.

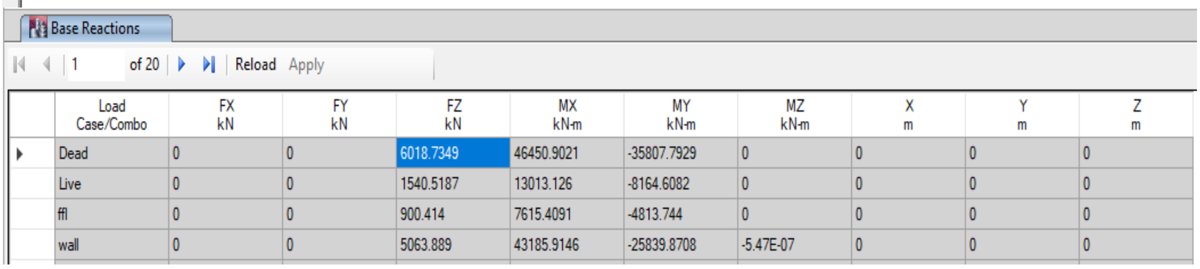


Design > Concrete Frame Design > Display Design Information shows steel percentages and column beam steel areas.




Elevation View - 4 Rebar Percentage (IS 456:2000)
G F E C B A
4 4 4 4 4 4
MUMTY LVL
TERRACE
3RD FL LVL
2ND FL LVL
FIRST FL LVL
PLINTH FL LVL
Base
0.80%
0.87%
0.31% 0.24% 0.24%
0.24% 0.24% 0.28%
0.24% 0.24% 0.24%
0.24% 0.24% 0.24%
0.35% 0.24% 0.28%
0.43% 0.24% 0.42%
0.24% 0.24% 0.24%
0.24% 0.34% 0.24%
0.34% 0.24% 0.28%
0.44% 0.24% 0.45%
0.24% 0.24% 0.24%
0.24% 0.34% 0.24%
0.29% 0.24% 0.29%
0.43% 0.24% 0.44%
0.24% 0.24% 0.24%
0.24% 0.34% 0.24%
0.24% 0.24% 0.34%
0.42% 0.24% 0.30%
0.24% 0.24% 0.24%
0.24% 0.27% 0.24%
Z
Y





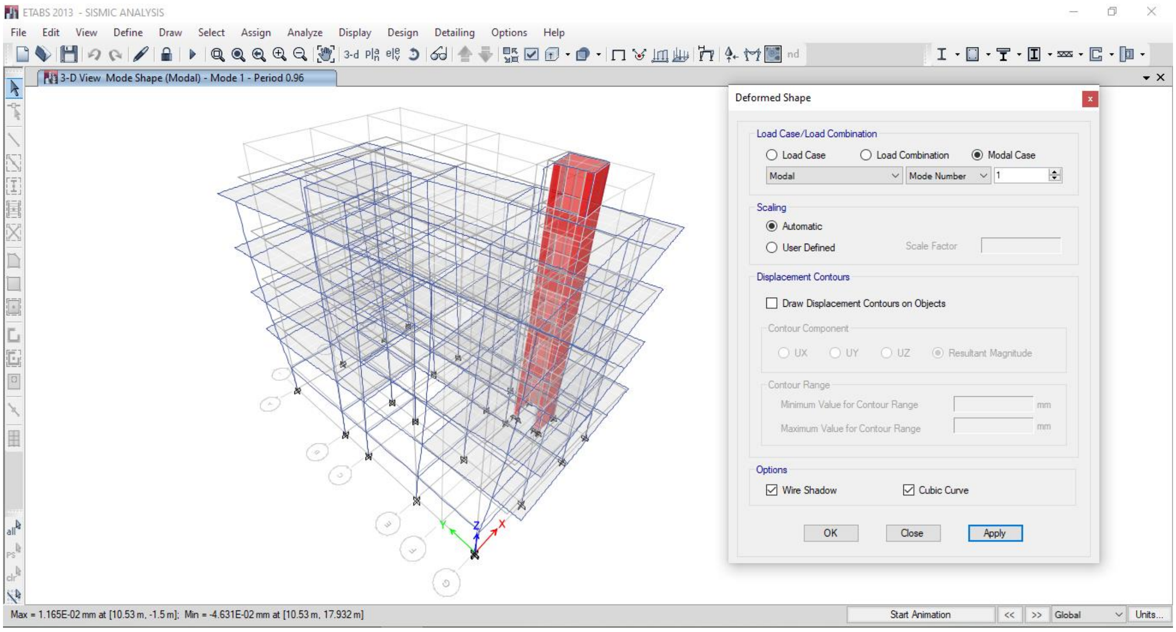
Load Case/Combo	FX kN	FY kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m	X m	Y m	Z m
Dead	0	0	6018.7349	46450.9021	-35807.7929	0	0	0	0
Live	0	0	1540.5187	13013.126	-8164.6082	0	0	0	0
ffl	0	0	900.414	7615.4091	-4813.744	0	0	0	0
wall	0	0	5063.889	43185.9146	-25839.8708	-5.47E-07	0	0	0

The above figure shows total load acting on buling .

19) Dimensions of time and the mode of occupancy in the X and Y axes of the structure.

• According to the IS 1893, the time period is 0.075H0.75, which is equal to 0.34 seconds in the X-direction and 0.46 seconds in the Y-direction.

Select Display > Show Mode Shape to see the time period in ETABS.



Your are able to see the proportion of the total population that is actively participating in the model by choosing Display > Show Table > Model Information > Building Model Information > Model Participating Ratio from the drop-down menu.

Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	UZ	Sum UX	Sum UY	Sum UZ	RX	RY	RZ	Sum RX
Modal	1	0.96	0.2041	0.2866	0	0.2041	0.2866	0	0.0663	0.0459	0.3389	0.0663
Modal	2	0.67	0.4838	0.2375	0	0.688	0.5241	0	0.0859	0.1991	0.0104	0.1522
Modal	3	0.503	0.0487	0.2272	0	0.7366	0.7512	0	0.1211	0.0436	0.4435	0.2734
Modal	4	0.308	0.0296	0.0441	0	0.7662	0.7953	0	0.1583	0.1158	0.0199	0.4317
Modal	5	0.18	0.0032	0.0074	0	0.7694	0.8027	0	0.0157	0.0045	0.0169	0.4474
Modal	6	0.174	0.0998	0.07	0	0.8693	0.8726	0	0.1987	0.244	3.526E-06	0.6461
Modal	7	0.135	0.015	0.0078	0	0.8843	0.8804	0	0.0274	0.039	0.0028	0.6735
Modal	8	0.127	0.02	0.0587	0	0.9042	0.9391	0	0.135	0.0406	0.0779	0.8084
Modal	9	0.126	0.0005	0	0	0.9047	0.9391	0	0.0001	0.0001	0.0178	0.8085
Modal	10	0.116	0.0081	0.0011	0	0.9128	0.9402	0	0.0041	0.0218	0.0001	0.8126
Modal	11	0.112	0.0053	0.0065	0	0.9182	0.9467	0	0.0192	0.0094	0.0049	0.8318
Modal	12	0.111	0.0019	0.0051	0	0.9201	0.9517	0	0.0201	0.0027	0.0001	0.8519
Modal	13	0.099	0.0019	0.0003	0	0.922	0.952	0	0.0014	0.0029	3.164E-05	0.8533

20) Design check

The sixth step is to build a model and load combinations and envelope. Analyze results

Seventh, verify the aforementioned outcomes

The greatest possible drift between floors is 0.004, or 0.004 times the floor height.

You should use the Equivalent Static/Linear Static Method if your Base Reaction FZ is more than the Maximum.

Third, the total mass participation in the x and y modalities must equal at least 90 percent of the lateral loads in order for this condition to be met.

Fourth, verify the mode shapes or distorted forms; the first three should represent x or y changes.

If the following requirements hold true in the response spectrum analysis, the model may be considered stable and unaltered.

Additional Points and Notes :-

1. The limitations of storey drift are specified in IS 1893-2002. (Part-1) Clause 7.11.1

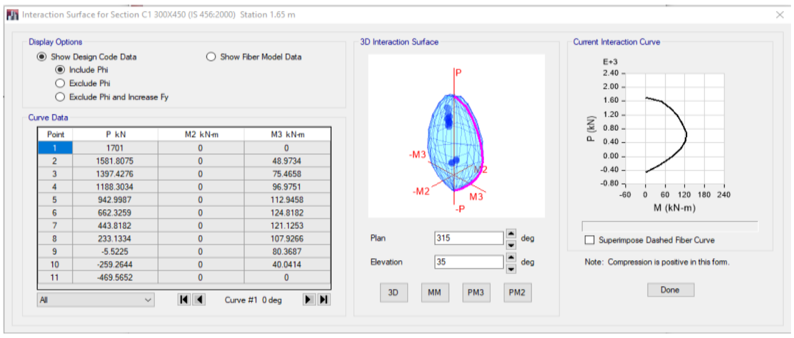
Time periods must be manually determined for determining the load pattern in comparable static analysis; the method for doing so varies depending on the kind of building being analysed.

Page 24 of IS 1893-2002, Part-1, Clauses 7.6.1 and 7.6.2.

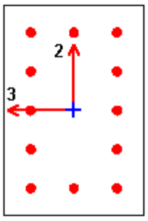
Page 25 of IS 1893-2002, Part-1, contains the comparative information of the base reactions. 4. For information on accommodating soft storeys, please see Clause 7.10.1 on Page 27 of IS 1893-2002.

21)Left-click any beam member to see below figure.

The figure illustrates the Pu-Mu interaction curve as well as shear, flexural, and beam/column features.



ETABS 2013 Concrete Frame Design
IS 456:2000 Column Section Design



Column Element Details Type: Ductile Frame (Flexural Details)

Level	Element	Section ID	Combo ID	Station Loc	Length (mm)	LLRF
PLINTH FL LVL	C6	C1 300X450	DCon2	1650	2100	0.534

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
300	450	58	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
25000	25	1	500	500

Axial Force and Biaxial Moment Design For P_u , M_{u2} , M_{u3}

Design P_u kN	Design M_{u2} kN-m	Design M_{u3} kN-m	Minimum M_2 kN-m	Minimum M_3 kN-m	Rebar Area mm²	Rebar % %
1456.7401	1.1705	-29.1348	29.1348	29.1348	1080	0.8

Factored & Minimum Biaxial Moments

	NonSway M_{ns} kN-m	Sway M_s kN-m	Factored M_u kN-m
Major Bending(M_{u3})	-9.4361	0	-9.4361
Minor Bending(M_{u2})	1.1705	0	1.1705

Slenderness Effects (IS 39.7.1) and Minimum Biaxial Moments (IS 39.2, 25.4)

	End Moment M_{u1} (kN-m)	End Moment M_{u2} (kN-m)	Initial Moment (kN-m)	k*M_a Moment (kN-m)	Minimum Moment (kN-m)	Minimum Eccentricity (mm)
Major Bending (M_3)	1.7434	-9.4361	-4.9643	0	29.1348	20

Effective Length Factors (IS 25.2, Annex E)

	K Sway	K Non-Sway	Framing Type	P-Delta Done?	Q Factor	K Used
Major Bend(M_3)	1.603615	0.72758	Ductile Frame	No	0.006397	0.72758
Minor Bend(M_2)	1.529941	0.708686	Ductile Frame	No	0.007429	0.708686

Additional Moment Reduction Factor k (IS 39.7.1.1)

A_g cm²	A_{sc} cm²	P_{uz} kN	P_b kN	P_u kN	k Unitless
1350	10.8	1923.75	599.0777	1456.7401	0.352548

Additional Moment (IS 39.7.1)

	Consider M_a	Length Factor	Section Depth (mm)	KL/Depth Ratio	KL/Depth Limit	KL/Depth Exceeded	M_a Moment (kN-m)
Major Bending (M_3)	Yes	7.857E-07	0.0005	2.668E-06	1.2E-05	No	0
Minor Bending (M_2)	Yes	7.857E-07	0.0003	3.898E-06	1.2E-05	No	0

Column Element Details Type: Ductile Frame (Shear Details)

Level	Element	Section ID	Combo ID	Station Loc	Length (mm)	LLRF
PLINTH FL LVL	C6	C1 300X450	DCon2	1650	2100	0.534

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
300	450	58	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
25000	25	1	500	500

Design Code Parameters

γ_C	γ_S
1.5	1.15

Additional Moment Reduction Factor k (IS 39.7.1.1)

A_g cm²	A_{sc} cm²	P_{uz} kN	P_b kN	P_u kN	k Unitless
1350	10.8	1923.75	599.0777	1456.7401	0.352548

Additional Moment (IS 39.7.1)

	Consider M_a	Length Factor	Section Depth (mm)	KL/Depth Ratio	KL/Depth Limit	KL/Depth Exceeded	M_a Moment (kN-m)
Major Bending (M_3)	Yes	7.857E-07	0.0005	2.668E-06	1.2E-05	No	0
Minor Bending (M_2)	Yes	7.857E-07	0.0003	3.898E-06	1.2E-05	No	0

Shear Design for V_{u2}, V_{u3}

	Rebar A_v /s mm²/m	Design V_u kN	Design P_u kN	Design M_u kN-m	V_c kN	V_s kN	V_p kN
Major Shear(V_2)	0	0	0	0	0	0	0
Minor Shear(V_3)	498.8	1.7395	1456.7401	1.1705	79.69	43.5594	123.2494

Design Forces

	Factored V_u kN	Factored P_u kN	Factored M_u kN-m
Major Shear(V_2)	6.7755	1456.7401	-9.4361
Minor Shear(V_3)	1.7395	1456.7401	1.1705

Design Basis

Shr Reduc Factor Unitless	Strength f_{ys} MPa	Strength f_{ck} MPa	Area A_g cm²
1	415	25	1350

Concrete Shear Capacity

Major Shear(V_2)	Conc.Area A_c cm²	A_{st} %	Allowable Tau_c MPa	CompFactor Delta Unitless	DepthFactr k Unitless	Strengh Factor Unitless
Major Shear(V_2)	0	0	0	0	0	0
Minor Shear(V3)	1089	0.496	0.488	1.5	1	1

Shear Rebar Design

	Design V_u kN	Stress Tau MPa	Conc.Cpcty Tau_{cd} MPa	Allowable $Tau_{c,max}$ MPa	Rebar Area A_{sv} /s mm²/m
Major Shear(V_2)	0	0	0	0	0
Minor Shear(V_3)	1.7395	0.02	0.73	3.1	498.8

ETABS 2013 Concrete Frame Design
IS 456:2000 Beam Section Design

Beam Element Details Type: Ductile Frame (Flexural Details)

Level	Element	Section ID	Combo ID	Station Loc	Length (mm)	LLRF
PLINTH FL LVL	B25	PB 230X450	DCon2	4822	4972	1

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
230	450	230	0	30	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
25000	25	1	500	500

Design Code Parameters

γ_C	γ_S
1.5	1.15

Flexural Reinforcement for Moment, M_{u3} & T_u

	Required Rebar mm²	+Moment Rebar mm²	-Moment Rebar mm²	Regular Minimum Rebar mm²	Seismic Minimum Rebar mm²
Top (+2 Axis)	248	0	203	176	248
Bottom (-2 Axis)	101	0	0	0	101

Design Moments, M_{u3} & T_u

Design +Moment kN-m	Design -Moment kN-m	Factored M_{u3} kN-m	Torsion T_u kN-m	Special M_t kN-m
0	-35.4346	-34.6646	0.4427	0.77

Beam Element Details Type: Ductile Frame (Shear Details)

Level	Element	Section ID	Combo ID	Station Loc	Length (mm)	LLRF
PLINTH FL LVL	B25	PB 230X450	DCon2	4822	4972	1

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
230	450	230	0	30	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
25000	25	1	500	500

Design Code Parameters

γ_C	γ_S
1.5	1.15

Shear/Torsion Design for V_{u2} & T_u

Rbar A_{sv} /s mm²/m	Rbar A_{svt} /s mm²/m	Design V_{u2} kN	Design T_u kN-m	Design P_u kN
254.94	221.69	43.0429	0.4427	0

Design Forces

Factored V_{u2} kN	Factored T_u kN-m	Equivalent V_e kN
43.0429	0.4427	46.1229

Design Basis

Design V_{u2} kN	Conc.Area A_c cm²	Area A_g cm²	Tensn.Reinf A_{st} mm²	Strength f_{ys} MPa	Strength f_{ck} MPa	LtWt.Reduc Factor Unitless
43.0429	966	1035	263	415	25	1

Concrete Capacity

Conc.Area A_c cm²	Tensn.Rein A_{st} mm²	A_{st} %	Allowable $Tau_{c.max}$ MPa	Strength f_{ys} MPa	CompFactor Delta Unitless	DepthFactr k Unitless	Strengh Factor Unitless
966	263	0.272	0.371	415	1	1	1

Shear Rebar Design

Design V_e kN	Stress Tau MPa	Conc.Cpcty Tau_{cd} MPa	Allowable $Tau_{c.max}$ MPa	Rebar Area A_{sv} /s mm²/m	Shear V_c kN	Shear V_s kN	Shear V_0 kN
46.1229	0.48	0.37	3.1	254.94	35.8804	38.64	74.5204

Torsion Capacity

Rebar A_{svt} /s mm²/m	Torsion T_u kN-m	Shear V_u kN	Core b_1 mm	Core d_1 mm
221.69	0.4427	43.0429	190	410

VIII. STRUCTURAL ANALYSIS AND DESIGN

8.1 General

Structural engineering researches, plans, designs, builds, inspects, monitors, maintains, rehabs, and demolishes permanent and temporary structures, structural systems, and their components. Structural design evaluates stability, strength, and stiffness. Structural analysis and design create structures that can sustain all loads over their lifetime. Structures bear loads. If the structure is poorly designed or built, or if the applied loads exceed the design constraints, the device may fail to fulfil its intended purpose, which might be devastating.

8.2 IMPORTANT POINTS FOR BEAMS

- For grades Fe 415 and Fe 500, maximum tension bar spacing is 180 mm and 150 mm, respectively.
- Ast = 0.85bd/fy for beam tension reinforcement. Maximum tension and compression reinforcement in beams is Ast < 0.04bd.
- The clear span between lateral supports of a simply supported or continuous beam should be no more than 60 b or 250 b2/d.
- Cantilevers must have a clear space of 25 b or 100 b2/d from the free end to the lateral constraint.
- For vertical stirrups, shear reinforcement must not exceed 0.75d along the member's axis, where d is the section's effective depth. Never surpass 300mm.
- Asv/b.Sv < 0.4/fy must be given by stirrups.

Where,
Asv = total cross sectional area of stirrup legs effective in shear
Sv = stirrup spacing along the length of the member
b = width of the beam
fy = should not be more than 415 N/mm²

• **Positive moment reinforcement**

i. Simple members require Ld/3 of the positive moment reinforcement along the same face into the support, whereas continuous members need Ld/4.

ii. The positive reinforcement that must be extended into the support in accordance with (a) must be anchored such that it produces its design stress in tension at the support face when the flexural member is part of the principal system for withstanding lateral loads.

iii. At inflection points and simple supports, reinforcing positive moment tension must be less than M1/V + Lo.
Where, M1 = moment of resistance if all reinforcement is strained to fd
fd = 0.87 fy in the case of limit state design and the permissible stress in the case of working stress design σst
V = shear force at the section due to design loads
Lo = sum of the anchoring beyond the centre of the support and the support provided by any hook or mechanical attachment. At inflection, Lo cannot exceed 12 or the effective depth of the members, whichever is larger. Crushing the reinforcing ends increases the bar's diameter by 30% to the M1/V ratio.

• **Negative moment reinforcement**

i. At the point of inflection, one-third of the negative moment reinforcement at the support must extend outward for a distance equal to or more than the effective depth of the member by 12, which is one sixteenth of the clear span.

• **Curtailment of tension reinforcement in flexural members**

i. Except for the simple support or cantilever end, reinforcement must continue beyond the point at which it no longer resists flexure for the effective depth of the member or 12 times the bar diameter, whichever is larger. This criteria does not applicable when the reinforcement cannot withstand flexure.

ii. Any of the following in a stress zone requires flexural reinforcement removal.

a. At the cutoff point, shear strength is two-thirds of the maximum allowed (this includes the web reinforcement). Web reinforcement limits shear at the cutoff point.

b. Each terminated bar has stirrup area greater than shear and torsion for three fourths the member's effective depth from the cutoff point. The extra stirrup area must be at least 0.4bs/fy, where b is beam width, s is spacing, and fy is reinforcing strength in N/mm2. The spacing must not exceed d/8βb, where βb is the ratio of bars chopped off to total bars at the section and d is the effective depth.

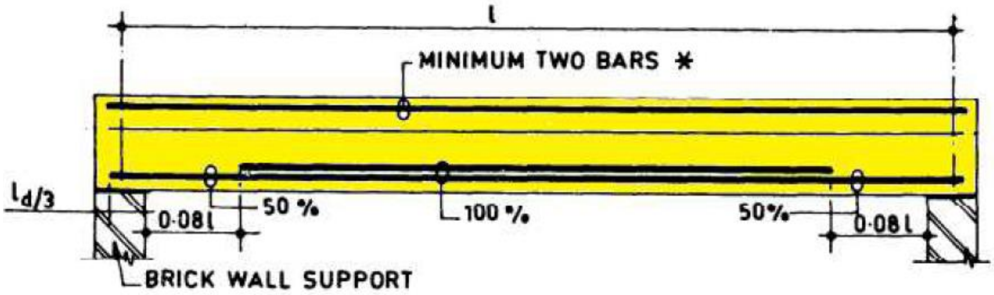
c. For bars with a diameter of 36 millimetres or less, continuing bars offer twice as much room as needed for flexure at the point where they are cut off, and the shear does not exceed three quarters of what is allowed.

• **Lap splices**

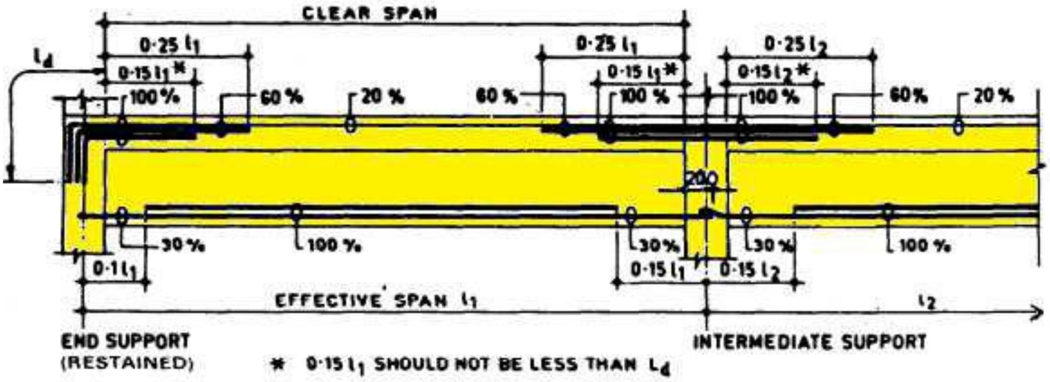
i. In order to join bars larger than 32mm, welding or mechanical splicing is required.

ii. For bars in flexure tension, the lap length is Ld or 30, whichever is bigger; for bars in direct tension, the lap length is 2Ld or 30, whichever is greater. The minimum length of the lap is 15 inches (or 200mm).
iii. Compression lap length should equal development lap length (as calculated in 26.2.1), but not be less than 24.
iv. Joining 2-inch-gap bars. The shorter bar's diameter determines lap length.

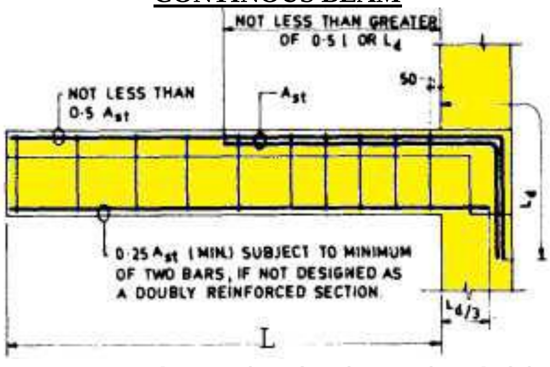
• Temperature, creep, and shrinkage after drywall and finishes are completed shouldn't be more than span/350, or 20 mm.
• Most of the time, the ultimate deflection owing to all loads (temperature, creep, and shrinkage) should not exceed effective span/250, measured from the floor supports' as cast level.



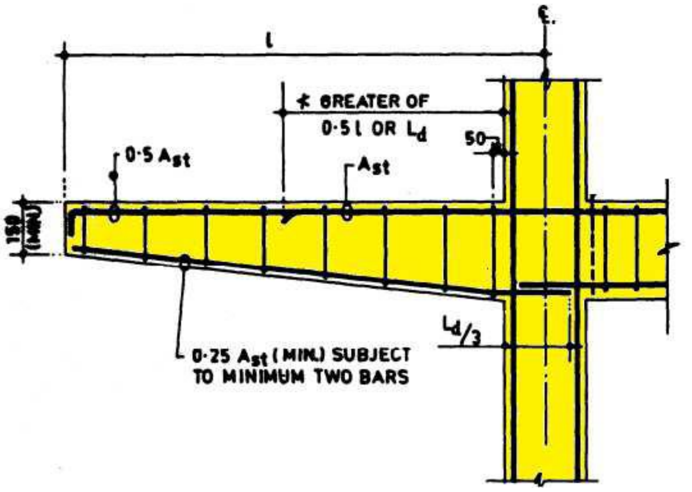
SIMPLY SUPPORTED BEAM



CONTINOUS BEAM



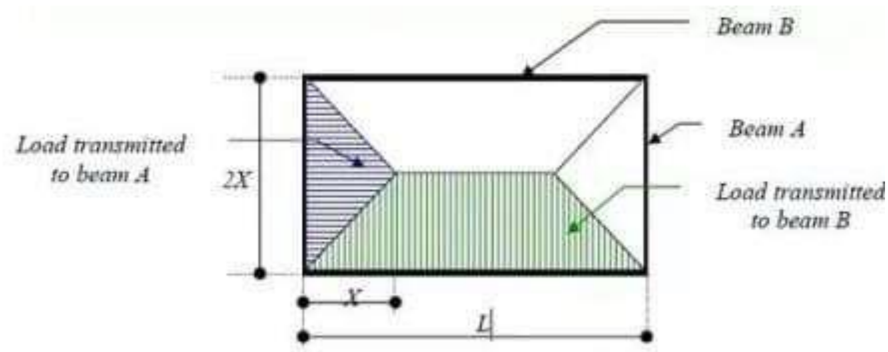
CANTILEVER BEAM PROJECTION FROM A COLUMN



CANTILEVER BEAM PROJECTION FROM A BEAM OVER COLUMN

8.2 IMPORTANT POINTS FOR SLABS

• If a slab extends in many directions, choose the shortest route to calculate its span-to-effective depth ratio.
• The span-to-depth ratio below should meet vertical deflection requirements for loads up to 3 kN/m2 in two-way slabs reinforced with mild steel and shorter spans (up to 3.5 m).Continuity 35, Structures That Are Supported By Slabs Simply multiplying by 0.8 will provide you the high strength Fe 415 warped bars you need.
The figure takes into account loads that are equally distributed when depicting beams that support solid slabs that span in two different directions at right angles. below.



• Major reinforcing bar spacing on the horizontal plane must not exceed 300 mm or three times the effective depth of the solid slab.
• Shrinkage and temperature impacts need minimum strengthening of slabs. Mild steel reinforcement at the rate of 0.15 percent in both directions is required for slabs. When using high-strength bent bars, that percentage drops to 0.12%.
• Reinforcing bars cannot exceed 1/8 of the slab's thickness.
• Slabs have maximum bending moments per unit width.
equations:
$Mx = \alpha x. \ w. \ lx^2$
$My = \alpha y. \ w. \ lx^2$
Where, αx and αy are coefficient given in table 26.
w = total design load per unit area
Mx and My = moments on strips of unit width spanning lx and ly respectively.
lx and ly = • In accordance with figure 25 of IS code 456, slabs are divided into central strips and edge strips in both directions. The central strip is three quarters the slab's width, while the outer strip is one eighth.

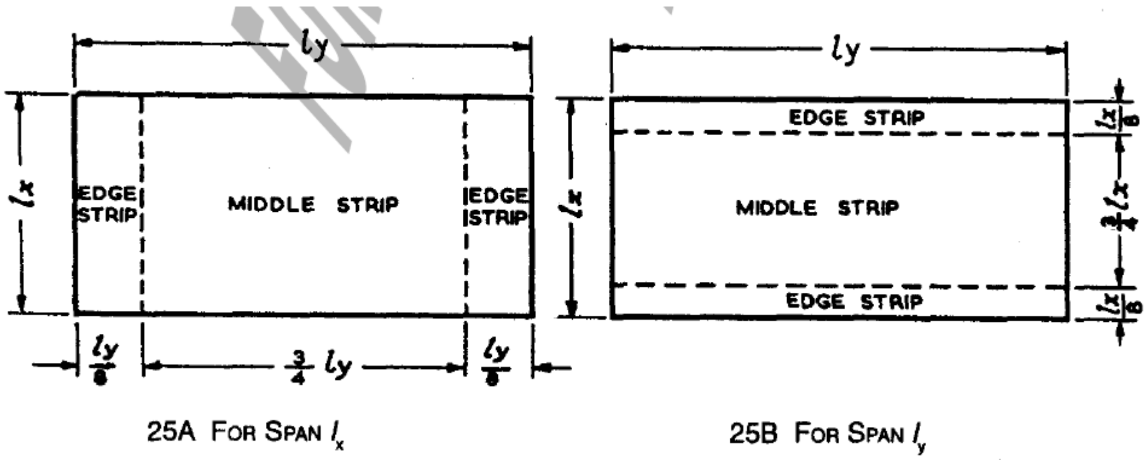


FIG. 25 DIVISION OF SLAB INTO MIDDLE AND EDGE STRIPS

D-1.1 does not disperse centre strip maximum moments (IS 456).

• At least half of the tension reinforcement must reach 0.3l from the support in the top section of the slab over the continuous borders of a middle strip.

Edges that don't quite connect might have negative moments. Tension reinforcement equal to 50% of the mid span and 0.1 times l into the span is usually adequate.

The minimum requirements of Section 3 and the torsion criteria of D-1.8 through D-1.10 must be met by the reinforcing strips installed parallel to the edge.

When a slab is supported on two sides, it is essential that torsional reinforcement be provided to each corner. Bars running parallel to the slab's edges and outward for at least a quarter of the shorter span will be used for top and bottom reinforcement. Three-quarters of the slab's mid-span moment reinforcement will be distributed between these four layers.

• In a corner with a single continuous slab edge, half the D-1.8 torque reinforcement is required.

Torsion reinforcements are unnecessary in the corners of a slab with a continuous edge at the corner.

If torsion ly/lx is more than 2, slabs should span only in one direction.

• For slabs that are simply supported, the maximum moment per unit width is given by the following equation, assuming no special measures are taken to prevent twisting at corners or lifting.

$Mx = \alpha x.\ w.\ lx^2$

$My = \alpha y.\ w.\ lx^2$

Where, αx and αy are coefficient given in table 27.

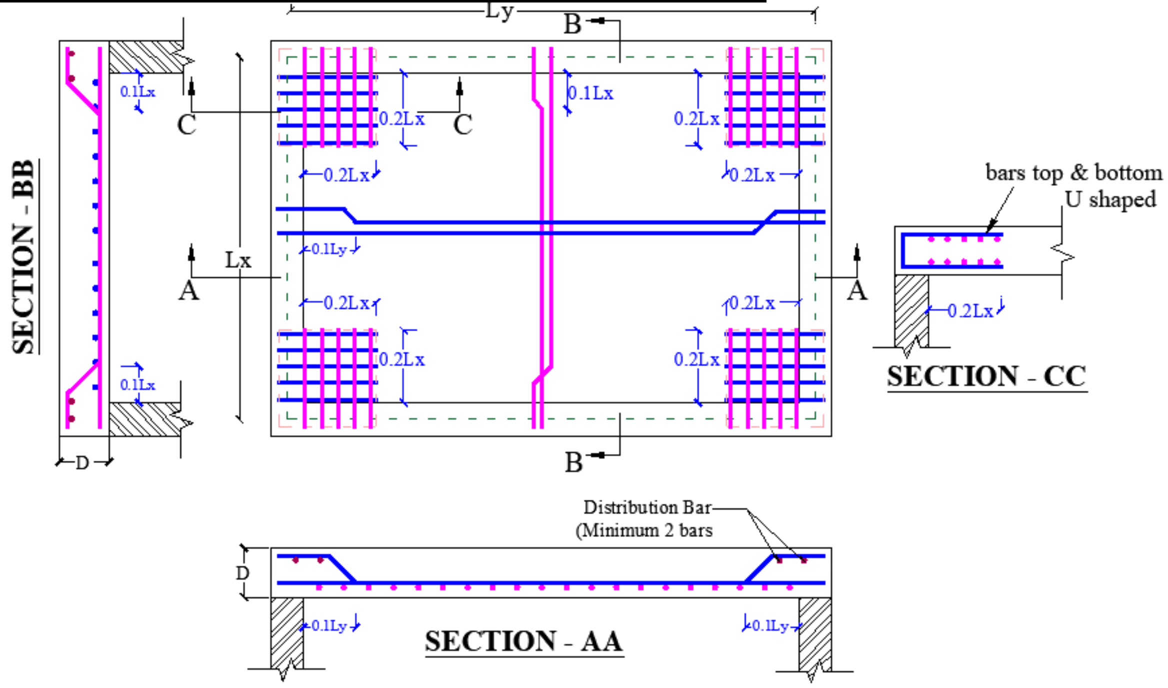
w = total design load per unit area

Mx and My = moments on strips of unit width spanning lx and ly respectively.

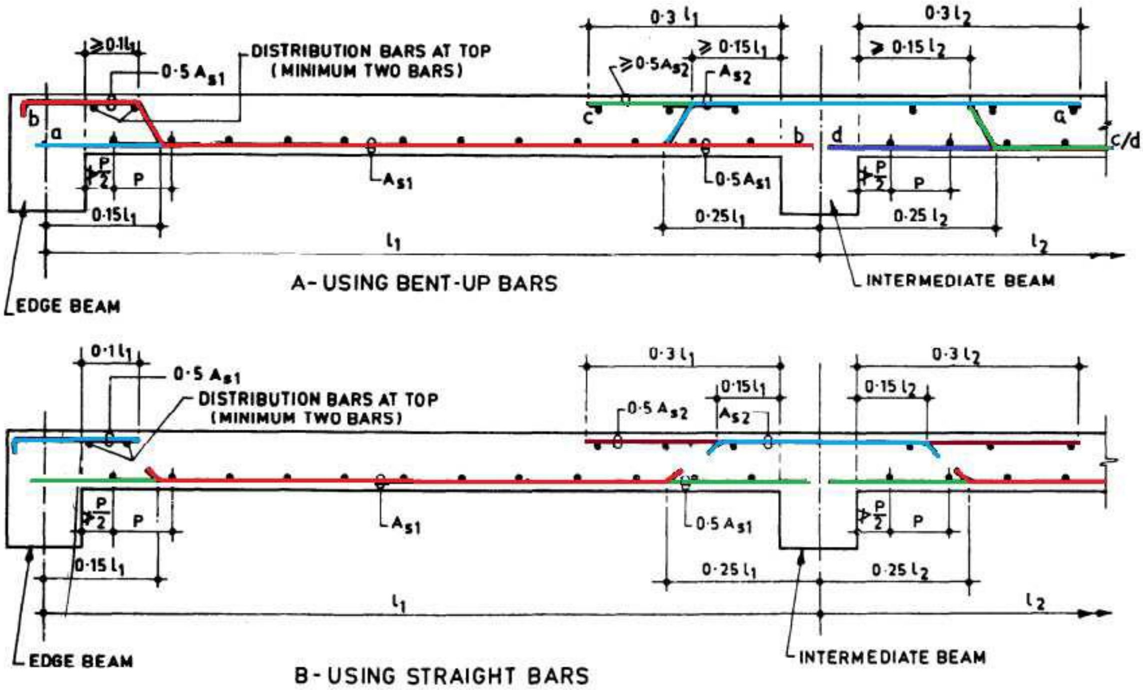
lx and ly = lengths of the shorter span and longer span respectively.

• A minimum of fifty percent of the tension reinforcement that is given at the midpoint of the span should extend to the supports. The remaining fifty percent need to stretch to within 0.1lx or 0.1ly of the support, depending on the circumstance.

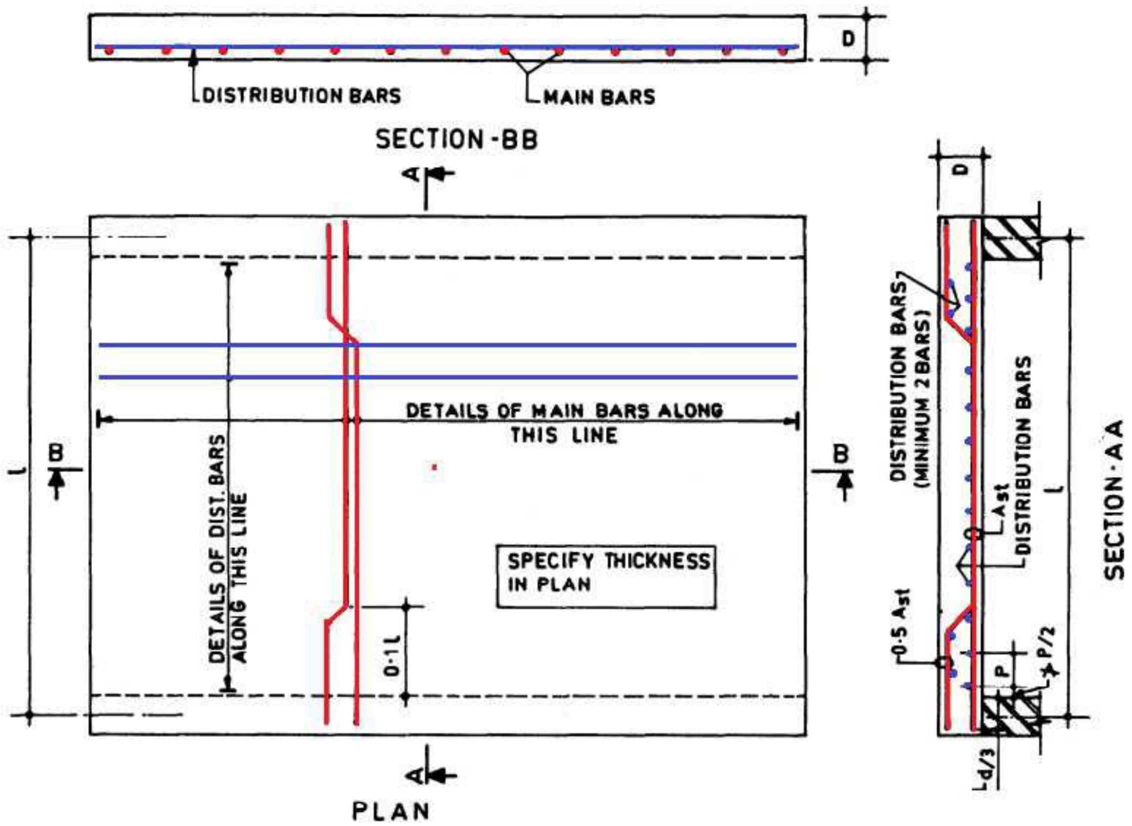
TYPICAL DETAILS OF TWO WAY SLAB (RESTRAINED SLAB)



DETAILING OF ONEWAY CONTINUOUS SLAB AS PER SP 34 (PG:127)



TYPICAL DEAILS OF ONE WAY SLAB AS PER SP34:1987 (#CL.9.3.1)



8.3 IMPORTANT POINTS FOR COLUMNS

• Columns and struts have effective lengths over three times the least lateral dimension. Pedestal if less than three.
• The lex/D and lex/b ratios of a compression member must be less than 12 for it to be considered short.
• The apparent gap between the compression members and the restraints is referred to as the unsupported length, which is denoted by the letter l.
The distance between end restraints must be no more than 60 times the smallest lateral dimension of the column.
• The unsupported length, l, of a column must be less than or equal to 100b2/D.
There can be no quirkiness in the columns.
Minimum allowed dimension (emin) = unsupported length (lun) 500 + side length (dx) 30 or 20 mm.
The gross column cross section must be between 0.8 and 6% of the longitudinal reinforcement cross section. Use less reinforcing as 6 percent may hinder concrete laying and compacting. Lapping bars from lower columns with those in the column under consideration should employ no more than 4% steel. The minimal steel percentage should be computed on the concrete area that must sustain direct stress in columns with a larger cross sectional area than needed. Instead of basing the proportion on area, do this. The minimum diameter for a bar is 12mm; four longitudinal bars are needed for rectangular columns and six for circular ones.

8.4 IMPORTANT POINTS FOR FOOTINGS

• Reinforced and plain concrete footings on soils need 150mm edge thickness.
• The greatest bending moment at a section must be determined for a freestanding concrete base supporting a column, pedestal, or wall.
i.e., foundations for a single column or wall.
Footings for masonry walls should be placed midway between the centre line and the wall's edge.
iii) For footings beneath gusseted bases, midway between the column or pedestal and the base.
• Footings are vulnerable to shear failures in both directions (punching shear)
The effective depth of a footing, denoted by the symbol d, is what establishes the minimum distance that a critical section must be from the face of a column or wall in the case of one-way shear.
There is a critical region that is d/2 distant from the face of the column in two-way shear. where d refers to the depth of the foundation that may be used.
A bearing transfers concrete compressive stress from the base of a column or pedestal to the top of the footing or pedestal. The loaded zone bearing pressure must not exceed the bearing stress limit in direct compression times (A1/A2) up to 2.

Where A1 is the supporting area for footing bearing, which in sloped or stepped footing may be taken as the area of the lower base of the largest frustum of a pyramid or cone contained entirely within the footing, and having for its upper base, the area actually loaded, and side slopes of one vertical to two horizontal; and where A2 is the area of the upper base.
A2 = Loaded area at the column base

8.5 WORKING STRESS METHOD (WSM)
The lower base of the biggest frustum of a pyramid or cone wholly enclosed within a sloping or stepped footing determines its bearing area. This base should have a heavy top base and side slopes from one vertical to two horizontal.

8.6 LIMIT STATES METHOD (LSM)
The LSM, or limit states approach, enhances conventional design practises. In contrast to WLM and ULM, LSM takes into account both safety at ultimate loads and serviceability at working loads. LSM uses a multiple safety factor framework to provide safety at ultimate loads and serviceability at all service loads by considering all "Limit states" (limit state of collapse, limit state of serviceability). Probabilistic safety factor selection should include failure mechanisms, material attributes, and loads.

8.7 LIMIT STATE METHOD Vs WORKING STRESS METHOD

Sr. No.	LSM	WSM
1.	LSM considers safety at ultimate loads and serviceability at working loads.	Calculations in WSM are based on service load conditions alone.
2.	It gives an idea about the excess load which a structure can carry beyond the working load without collapse.	It does not give any idea about margin of safety available for loads to access the extent of overloading without collapse.
3.	It takes into account nonlinear stress strain behavior of concrete and steel.	This method follows linear stress strain behavior for both materials.
4.	Material strength is fully utilized in designing the member.	Material strength is not fully utilized in designing the member.
5.	It is a somewhat complicated method involving more calculations.	It is a simple method.
6.	This method is still evolving for the design of more complex structures.	Due to its simplicity, it is still used for design of some complex structures water tank, bunker, silos etc.
7.	It results in smaller section size in comparison to that obtained from WSM, thus gives economical section.	It results in bigger section size in comparison to that obtained from LSM, thus gives uneconomical section.
8.	It is a more rational method which not only takes into account safety and economy but also fitness of the structure by controlling serviceability limits	It is an old conservative method which mainly concentrates on safety aspect.

.

IX. Design of Two-way slab for Residential building

Design steps: -

a) **Data:**

live load =3 KN/m^2, floor finishes=1.2 KN/m^2 ,fck=20 N/mm^2 , fy=500N/mm^2

Miscellaneous= 2 KN/m^2

Lx=3.91m, Ly=5.59m

b) **Depth of slab:**

As per IS 456:2000, Clause 24.1,

Assuming thickness of slab 125mm

Assume 20mm cover and 8mm diameter bars

Effective depth, d = 125 – 20 – 8/2 = 101mm

c) **Effective span**

As per IS 456: 2000 clause 22.2

Eff. Span along short and long spans is computed as:

a) L_{ex1}= centre to centre of support = 3.91m

b) L_{ex2} = clear span+ effective depth = 3.91+0.101 =4.011m

c) L_{ex1}= centre to centre of support = 5.59m

d) Lex2 = clear span+ effective depth = 5.59+0.101 =5.691m

Eff. span along short span, Lex= 4.011m

Eff. span along long span, Ley= 5.691m

d) Loads Calculations:

Self wt of the slab = D* density= 0.125* 25 = 3.125 KN/m^2

Floor Finishes = 1.2 KN/m^2

Live load =2 KN/m^2

Total Load (W) = 8.33 KN/m^2

Ultimate Load (Wu) =12.49 KN/m^2

Type of slab

Eff. span along short span, Lex= 4.011m

Eff. span along long span, Ley= 5.691m

Ly/Lx=1.4<2

Hence slab has to design two way slab,

Hence, design as two-way slab.

Ultimate design moment coefficients

= 1.4 one long edge is discontinuous.

e) Moment and shear forces

Referring to IS 456-2000 code B.M co-efficient are as follows,
From table 26, page no.91

	Shorter span, αx	longer span, αy
-ve moment at continuous edge	0.063	0.037
+ve moment at mid span	0.047	0.028

Calculation of maximum bending moment:
-ve moment at continuous edge:

For shorter span =$\alpha x w u l x^2$
= 0.063x12.49x(4.011)2
= 12.65 kN-m
For longer span = $\alpha y w u l x^2$
= 0.037x12.49x(4.011)2
= 7.4 kN-m
+ve moment at mid span:

For shorter span = $\alpha x w u l x^2$
=0.047x12.49x(4.011)2
= 9.44 kN-m
For longer span = $\alpha y w u l x^2$
= 0.028x12.49x(4.011)2
= 5.62kN-m

f) Check for depth Equating the Mu lim to maximum B.M

Mulim =0.133fckbd²

12.65 x10^6=0.133x20x1000 d²

d_{req}= 68.98mm < 101 mm { d_{pr} is Hence ok}

Hence the effective depth selected is sufficient to resist the design ultimate moment.Say the slab thickness is 125mm

g) Area of steel required

Reinforcements along Short and long span directions

As per IS: 456 Annex G Clause. G.1

X_u / d =0.47 is less than limiting value (0.46) for fe-500

The area of reinforcement is calculated using the relation:

$$Mu = 0.87 * A_{st} * d * Fy * [1 - \frac{Ast*Fy}{B*d*Fck}]$$

SPAN	DIRECTION	MOMENTS	Area (mm2)
Short span	+ve moment(kNm)	9.44 kN-m	**201**
	-ve moment(kNm)	12.65 kN-m	**270**
Long span	+ve moment(kNm)	5.62kN-m	**180**
	-ve moment(kNm)	7.4 kN-m	**180**

f) Check for area of steel

As per IS 456 clause 26.5.2.1

Min.Ast = $\frac{0.12}{100} bD$

=0.012X1000X125=150mm²

g) Check for spacing

As per IS 456:2000 Clause. 26.3.3(b)

Short span: Assuming 8mm ϕ bar,

Spacing = $\frac{\frac{\pi}{4}(8)2}{201} * 1000$ =250mm

Spacing = $\frac{\frac{\pi}{4}(8)2}{270} * 1000$ =186mm

long span: Assuming 8mm ϕ bar,

Spacing = $\frac{\frac{\pi}{4}(8)2}{180} * 1000$ =280mm

Spacing = $\frac{\frac{\pi}{4}(8)2}{150} * 1000$ =335mm

Maximum spacing = 3d or 300mm, whichever is less
= 3 × 101 = 303mm (or) 300mm (take lesser value)
= 300 mm

Hence Provide 8mm ϕ bar at 125mm c/c. At (Along X-direction).
Provide 8mm ϕ bar at 150mm c/c. At (Along Y-direction

h) **Check for shear stress**

Vu = 0.5*Wu*Lx

= 0.5*(12.49)*(4.011)

Vu = 25KN

Considering slab width and shorter span.

$\tau_v = (\frac{Vu}{bd}) = \frac{(25*1000)}{1000*101}$ =0.24N/mm2

τ_v =0.24N/mm^2

$p_t = \frac{100ast}{bd}$ $= \frac{100*270}{1000*101}$ =0.25

Permissible shear stress, = 0.33N/mm^2 (IS 456:2000, Table19 Pg:73)

τ_c=0.36, k=1.3(IS 456:2000 Clause 40.2)

Design shear strength of concrete = kτ_C

= 1.3x 0.36 = 0.429 N/mm^2 τ_{cmax}=0.36, k=1.3

k τc=0.36*1.3=0.46 N/mm^2> τv

$\tau_v < \tau_c$ hence the shear stress are within the safe.

i) Check for deflection control

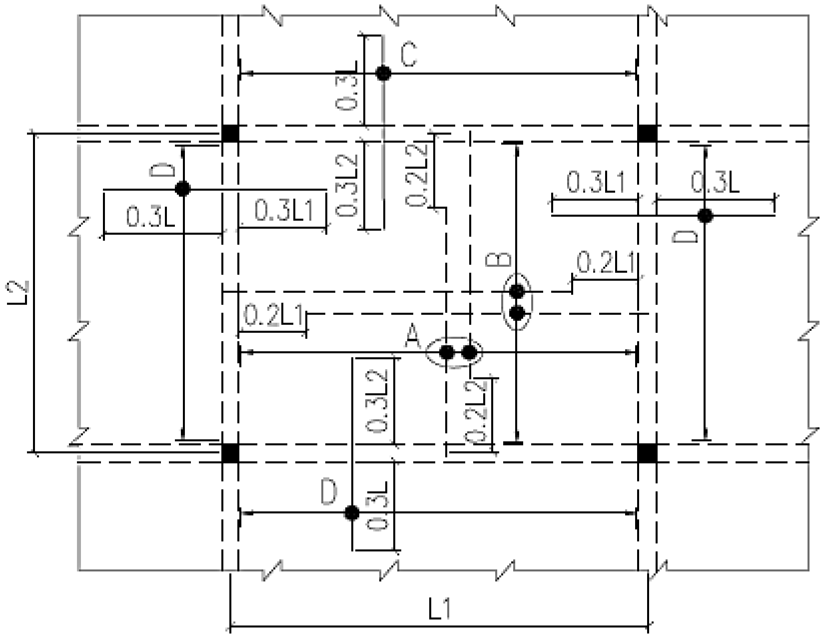
Ast prov = 180 mm^2
Ast req = 150 mm^2
Fs = 0.58 x fy (Ast $_{req}$/ Ast $_{prov}$) =244
$p_t = \frac{100ast}{bd}$=0.18
Modification factor = 2 (IS 456:2000, fig. 4)

Permissible *l/d* ratio = 32 × 2= 64

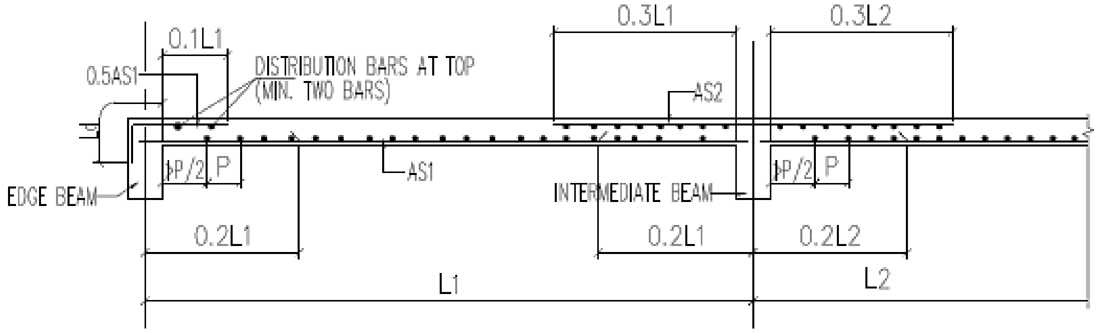
Actual *l/d* = (4011/101) = 40< 64

Therefore, deflection is safe with provided depth.

ii) Reinforcement details



PART PLAN

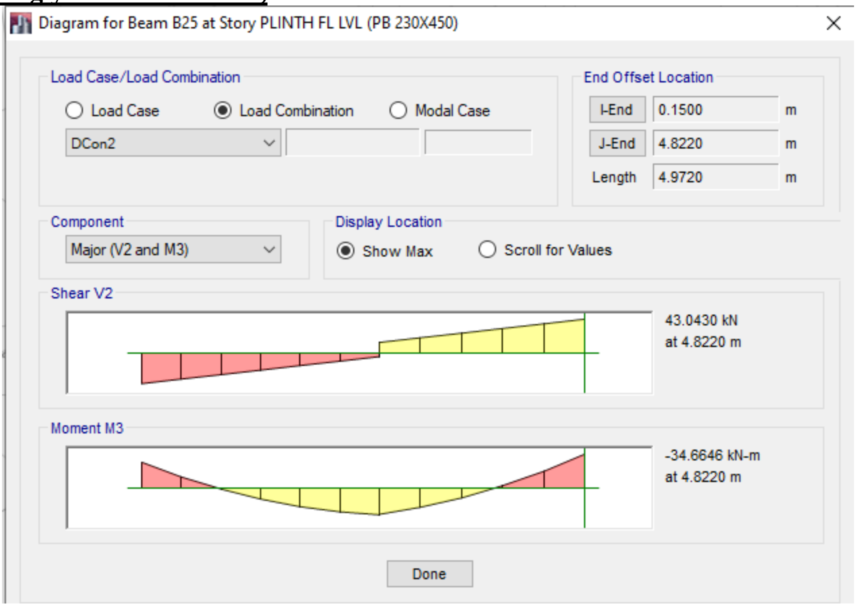


(TYP.) REINF. DETAIL OF SLAB
(SECTION THROUGH MIDDLE STRIP)

SLAB SCHEDULE						
MKD.	THK (mm)	REINFORCEMENT				REMARKS
		BOTTOM BAR		TOP BAR		
		SHORT BAR(A)	LONG BAR(B)	SHORT BAR(C)	LONG BAR(D)	
S1	125	8Φ@125 c/c	8Φ@150 c/c	8Φ@125 c/c	8Φ@150 c/c	

Fig. 9.1 Reinforcement details in Two way slab

9.2 Design of Singly reinforced Beam,



Design:

Data:

Fck=25N/mm2
Fy=500N/mm2
Length =4.822m, b=300mm, D=450mm
Max moment (Mu) = 34.665KN-m (from Etabs software)
Shear force (Vu) =43.043KN
Assuming 12mm dia bars with 30mm clear cover
d=450-30-12/2 = 414mm

Compare M_u and $M_{u,lim}$

$M_{u,lim}$ = 0.133Fckbd^2 For Fe=500Mpa
= 0.133*25*300*414^2
= 170kN-m >Mu

The section is under reinforced hence it is singly reinforced beam is design,.

Determine the value of Xu,max for given type of steel(#cl.38.1) and calculate Mulim of the section (Annex – G,#G1.1©)

Area of steel required(Annex - #G1.1(b)

$$Mu = 0.87 * A_{st} * d * Fy * \left[1 - \frac{Ast*Fy}{B*d*Fck}\right]$$

Ast,req=263mm^2

Xu, max/d=0.46 for fe 500MPa (cl 38.1 IS-456, Pg: 70)

Determine the depth of netutral axis from the following equation:

xu = 0.87 fY Ast
d 0.36 fck~b.d

=0.125

Xu/d < Xu,max/d hence the section is under reinforced
Ast,min =(0.85 b d/ fy)   (IS 456-200 Pg:47)
Ast,min = 161.874 mm^2
Ast,max= 0.04bd = 0.04 x 300 x 450 = 5400 mm^2
No of bars =Asc/area of single bar $=\frac{263}{\pi(12)2/4}$

=2.32=3

Provide 3 bars of 12mm diameter($A_{sc(provided)}$=339mm^2)

Check for shear:

Vu=43.0430KN

τ_v= V_u/bd

=(43.0430*10^3)/(300*414)

=0.35N/mm^2

τ_c=100*Ast/bd

=(100*339)/(300*414)

=0.27

from table-19 IS-456-2000

from table-19 IS-456-2000

τc=0.38N/mm2

τv > τc hence,Shear reinforcement required.

Vus=[Vu-(τcbd)]

=[43.043*1000-(0.38*300*414)

Vus=140.62KN

Using 8mm diameter bar 2LVS

Sv=$\frac{0.87*fyAsvd}{Vus}$

Sv=173.23=180mm

Sv>0.75d=(0.75*414)=310mm

Sv=200mm

Provide 8mm diameter 2LVS @ 200mm c/c.

Check for deflection:

(L/d) actual= (4.822/414) =13.73

(L/d) max=[(L/d) basic*Kt*Kc*Kf]

Pt=0.97, pc=0.31

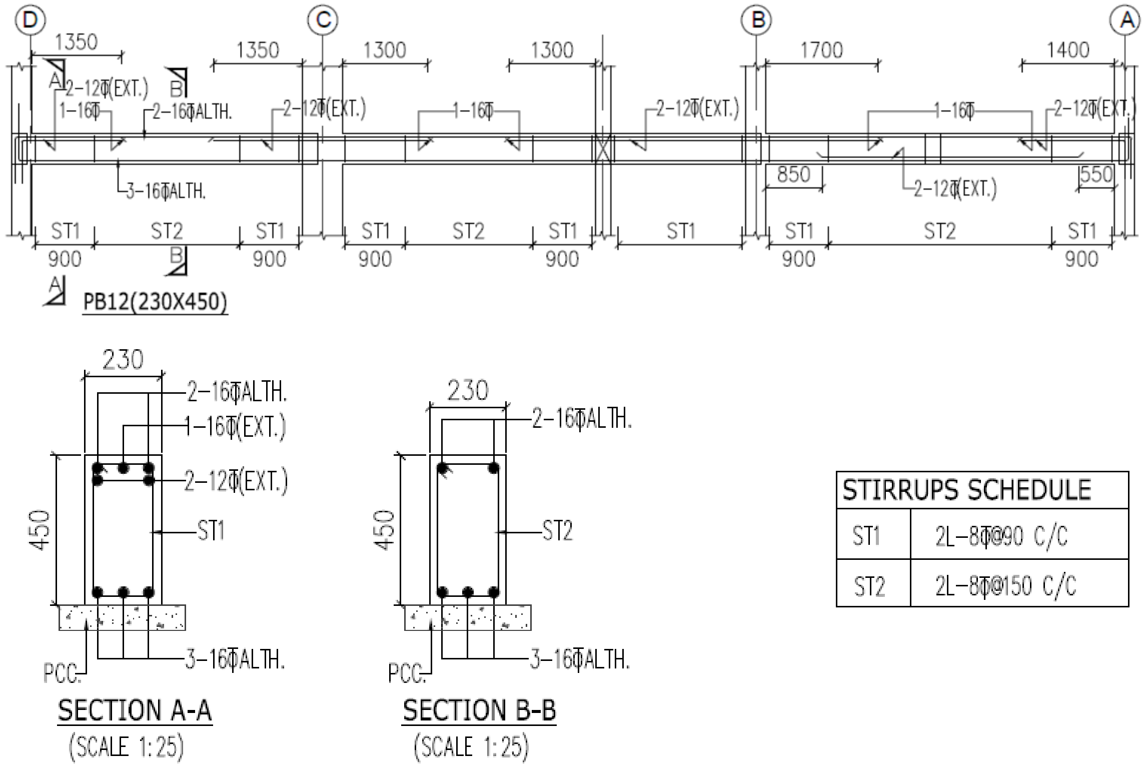
Refer fig. 8.1, 8.2, 8.3

(L/d)max=[20*0.83*1.10*1.0]

=18.26

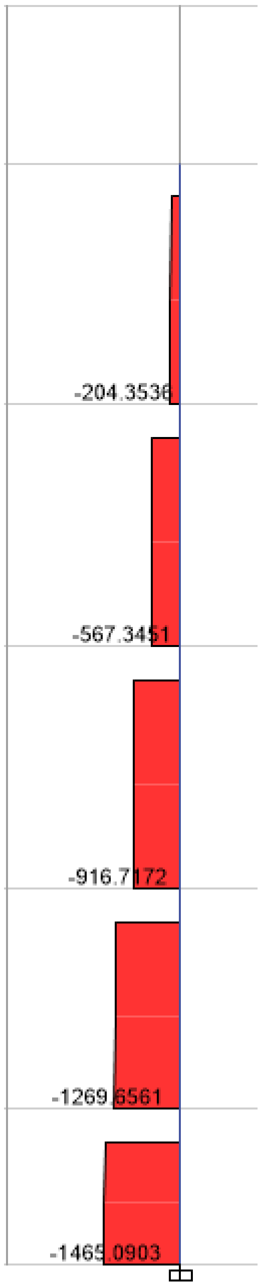
(L/d) act<(L/d) max, thereby satisfying deflection control.

Reinforcement Details



STIRRUPS SCHEDULE	
ST1	2L-8Φ@90 C/C
ST2	2L-8Φ@150 C/C

Fig. 9.2 Reinforcement details in Plinth beam



9.3 Design of short columns under compression and biaxial bending (C6).

Fig 9.3.1:- Bending moment, shear force and axial force.

Design of Column subjected to Axial load and Biaxial Bending (IS 456, 2000, SP:16, 1980)

Column

Depth(D, dim. || Z axis) = 450 mm	450	mm
Breadth (b, dim. || Y axis) = 300 mm	300	mm
Clear cover	40	mm
Main bar dia	16	mm
Effective cover(d)	48	mm
Effective depth	402	mm

Materials of Construction

Grade of concrete fck	25	N/mm2
Grade of steel fy	500	N/mm2

Design Forces

Axial load:(P) =		1456.7501	KN	
Moment about Z axis (Mz) =		9.4361	KN-m	
Moment about Y axis (My) =		1.1705	KN-m	
d'/D		0.10666667		
Mz/fckbD2		0.00621307		
P/fckbd		0.43162966		
Referring chart 45 of SP: 16	p/fck	0.02		
Assume a higher value of p/fck		0.06		
p		1.5	%	
As=(p*b*D)/100		2025	mm2	Required
Area of 16 mm bar		201.024	mm2	Provided
No of bars required		10.0734241		12 No.s
Area provided		2412.288	mm2	

Use 12 No.s 16 mm – 2211.264 mm2

Moment Capacities

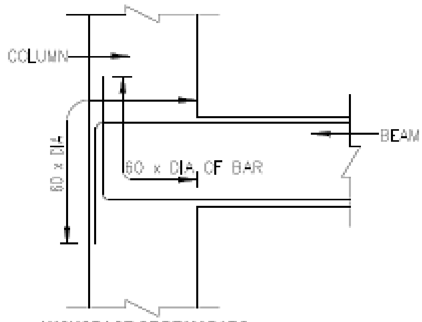
d'/D=0.15, P/fckbd=0.14,p/fck=0.06	Mz1/fckbD2	0.1	Referring chart 45 of SP: 16
	Mz1	151.875	KN-m
d'/D=0.2, P/fckbd=0.14,p/fck=0.06	My1/fckbD2	0.09	Referring chart 46 of SP: 16
	My1	136.6875	KN-m

Calculate αn

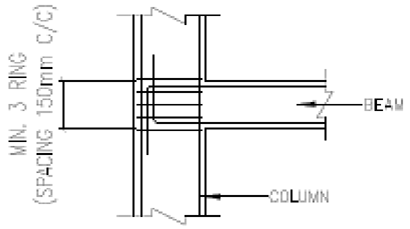
Pz=0.45fckAc+0.75fyAs	1594.134	KN
P/Pz	0.9138191	
αn(For values of P/Pu=0.2 to 0.8, values of αn vary linearly from 1 to 2.For values less than 0.2,αn is 1 for values greater than 0.8 αn is 2	1	Referring to IS:456, Clause 39.6

Criteria for Biaxial bending

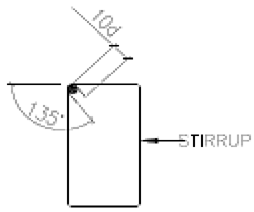
(Mz/Mz1)^αn+(My/My1)^αn <=1	0.07069403	<=1	SAFE OK



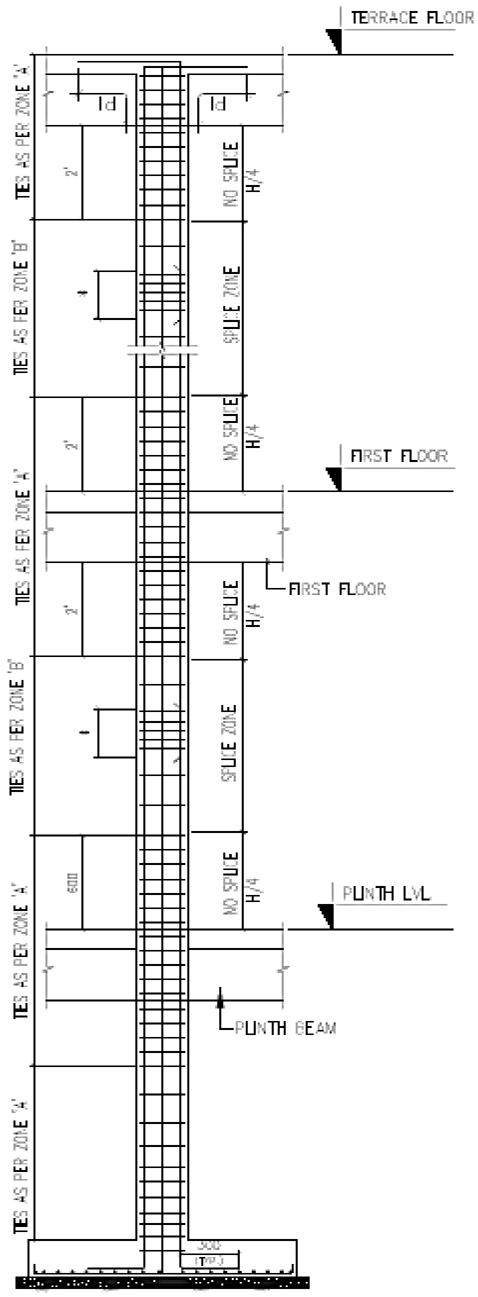
ANCHORAGE OF BEAM BARS
AT THE END COLUMNS



BEAM-COLUMN
JOINT DETAILING



TYPICAL DETAIL OF
STIRRUP BENDING



TYP. COL. ELEVATION

* TIES @ 150 C/C ALONG SPLICE LENGTH

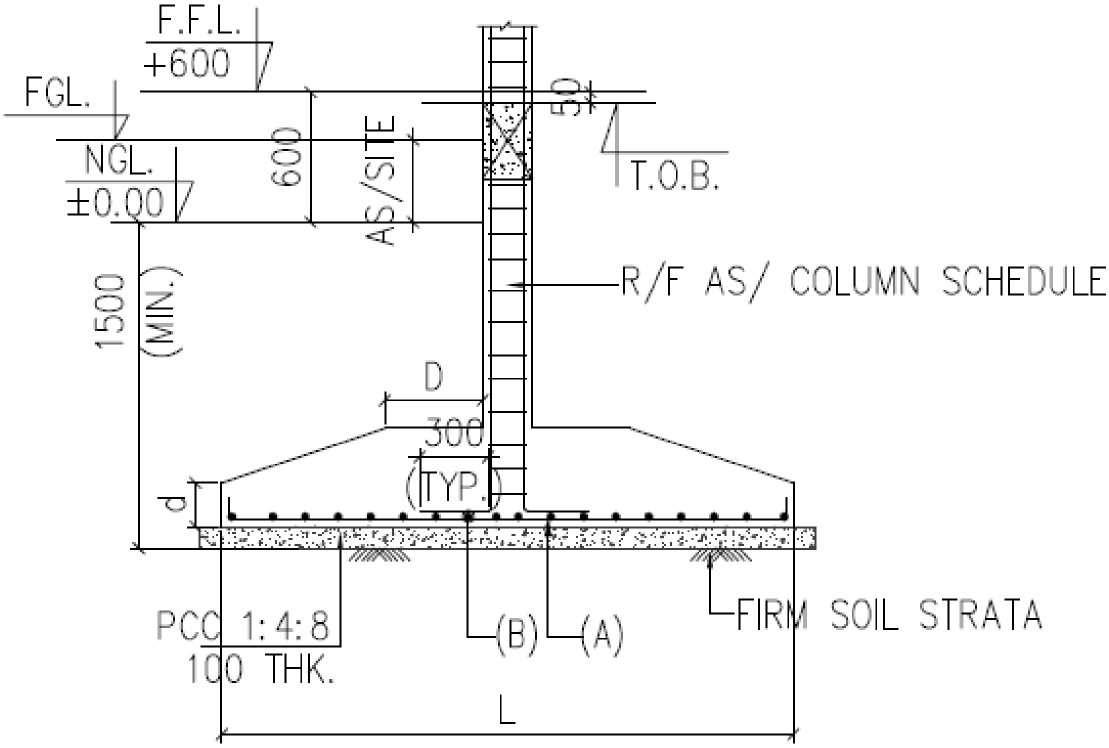
COLUMN SCHEDULE				
COL. MKD.	COLUMN SIZE	REINF.FOUNDATION LVL. TO 1st FLOOR ROOF LVL.	COLUMN SIZE	REINF.1st FLOOR ROOF LVL. TO TERRACE LVL.
C1	300, 450	REINF. 10-16T CONC. MIX M-25 TIES ZONE A 8T@100C/C ZONE B 8T@200C/C	300, 450	REINF. 6-16T+4-12T CONC. MIX M-25 TIES ZONE A 8T@100C/C ZONE B 8T@200C/C
C2	300, 450	REINF. 6-20T+6-16T CONC. MIX M-25 TIES ZONE A 8T@100C/C ZONE B 8T@200C/C	300, 450	REINF. 12-16T CONC. MIX M-25 TIES ZONE A 8T@100C/C ZONE B 8T@200C/C

Fig 9.3.1:- Reinforcement Details Of Column

9.4 Design of RCC Isolated Footing: (F7)

DESIGN OF FOOTING - 1		
GIVEN DATA		
Service Load	976.72	kN
Moment Mux (Unfactored)	19.42	kNm
Size of the column Bc	230	mm
Lc	450	mm
SBC of soil	180	kN/m²
fck	25	MPa
fy	500	MPa
1.Size of the footing		
Load on column	976.72	kN
wt. of footing and backfill at 10%	97.672	kN
Total load	1074.392	kN
Area of footing, Required	5.968844444	m²
Width of the footing: Bf (assume)	1.6	L=B
Length of the Footing: Lf (assume)	1.6	m
Area of the footing provided (Af)	2.56	m²
Section modulus, Zxx	0.682666667	
2.Calculation of depth of footing		
P, max	409.9785156	kN/m2
P, min	353.0839844	kN/m2
Comment:	Vary the dimension of Footing	
2	p,min is greater than zero. Safe	
Cantilver Projection from face of the column(along length)	0.575	m
Cantilver Projection from face of the column(along width)	0.685	m
Maximum Projection	0.685	m
Net Soil Reaction at the face of column(P')	389.5320435	kN/m2
Average Soil Reaction (Pavg)	399.7552795	kN/m2
3.Depth of the Footing		
Cantilever Projection of Footing(Max)	0.685	m
Moment at the face of column	140.6813783	kN-m
Effective depth required	205.6944067	mm

To be safe against One Way and Two Way Shear		
Depth Increase factor	2.1	mm
Increased effective depth	431.9582541	mm
Effective cover(d')	50	mm
Overall depth required	481.9582541	mm
Overall depth provided	500	mm
Effective Depth Provided	450	mm
RFT in bothways		
a	4.44444E-05	
b	-1	
c	718.6788163	
Ast1	21756.77051	mm^2
Ast2	743.229486	mm^2
Ast,Required	743.229486	mm^2
Provide#	12	mm
Spacing , required	152.1701408	mm
Spacing , provided	125	mm
Thus Ast	904.7786842	mm^2
pt, provided	0.20106193	%
4.Check for one way shear		
Shear at 'd' from face of column Vu	140.913736	N
τv	0.313141636	N/mm
Calculation of τc		
Ast at supports	904.7786842	mm^2
pt	0.20106193	%
pt, taken	0.20106193	%
β	14.43713199	
β, taken	14.43713199	
τc	0.331534149	
fck	25	N/mm^2
fck,taken	25	N/mm^2
Comment:	**τv < τc, Shear Reinforcement not Required**	
5) Check for two way shear		
Punching area	0.612	mm^2
Punching Perimeter	3.16	kN
Punching Shear	738.3263894	N/mm^2
Resting Shear	1137.6	kN
Comment:	**Hence safe**	



(TYP.) ISOLATED FOOTING SECTION (LXW)

SCALE 1:50

MKD.	SIZE (LXW)	THK. (d)	THK. (D)	REINFORCEMENT DETAILS	
				BOTTOM BAR	
				LONG BAR (A)	SHORT BAR (B)
F1	2500X2000	200	575	12Φ@150C/C	12Φ@175C/C

Fig. 9.4.1 Reinforcement details of Footing

X. RESULT AND CONCLUSION:

G+3-storey apartment building analysis and design. ETABS V13.2, a premium section analysis and design programme, is used. RCC frame, shear wall, and retaining walls. The soil investigation report gives an isolated footing. ETABS developed RCC beams and columns. Analysis and design were as conventional as possible. Recognized were the structural engineer's design problems.

Manual design and software analysis data for structures

Following conclusions are drawn:

ETABS was used to analyse and manually verify IS456.

2. Manual and computerised calculations provide similar results.
3. Results match when expanded to a 4-story structure.
4. ETABS is ideal for study and design of a four-story structure with identical levels.
5. ETABS reduces analysis and design time.

IS-CODE STANDARDS

Sl. No.	Code	Description
1.	IS-875 (Part 1) - 1987	Code of Practice for Design Loads (other than earthquake) for Buildings and structures – Unit weights of buildings and stored material.
2.	IS-875 (Part 2) - 1987	Code of Practice for Design Load (other than earthquake) for buildings and structures-imposed loads.
5.	IS-875 (Part 5) - 1987	Code of practice for design loads (other than earthquake) for buildings and structures – Special loadsand load combinations.
6.	IS:456 - 2000	Code of practice for plain and Reinforced Concrete.
7.	IS: 1893 - 2016	Criteria for Earthquake resistant design of structures.
8.	IS: 13920-2016	Ductile detailing of reinforced concrete structures subjected to seismic forced – Code of practice.
9.	IS: 1904- 1986	Indian Standard Codes of practice for design & construction foundations in Soil: General Requirements
12.	IS 4326	Code of practice for earthquake resistant design and Construction of buildings.
14.	SP-16	Structural use of concrete. Design charts for singly reinforced beams, doubly reinforced beams and columns.
15.	SP 34	Handbook on Concrete Reinforcement & detailing
17.	Handbook-by Reynolds & Steedman	Reinforced Concrete Designer's Handbook.

REFERENCES

[1]. Varalakshmi V, G shivakumar and R S Sarma (2014) "Designed and d G+5 residential building by ETABS", International Conference on Advance in Engineering and Technology.

[2]. Abhay Guleria (2014) "Structural Analysis of a Multi-Storey Building Using ETABS for different Plan Configurations",International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 5, ISSN: 2278-0181

[3]. Chandrashekar and Rajashekar (2015), "Analysis and Design of Multi Storied Building by Using ETABS Software",International journals of scientific and research vol.4: issue.7: ISSN no. 2277-8179.

[4]. Balaji and Selvarasan (2016), "Design and Analysis of multi-storeyed building under static and dynamic loading conditions using ETABS", International Journal of Technical Research and Applications e-ISSN: 2320-8163, www.ijtra.com Volume 4, Issue 4, PP. 1-5

[5]. Geethu S N, Depthi M, Abdul Nasir N A and Izzudeen K M(2016) "Comparative study on design and analysis of multi storied building by STAAD.Pro and ETABS software".

[6]. Mohith Y S, (2017) "Analysis and design of commercial building using Etabs" International Research Journal of Engineering and Technology (IRJET) e-ISSN:2395-0056Volume:04Issue:06.

[7]. D. Kornack and P. Rakic, "Cell Proliferation without Neurogenesis in Adult Primate Neocortex," Science, vol. 294, Dec. 2001, pp. 2127-2130,doi:10.1126/science.1065467.

[8]. M. Young, the Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.