Design Philosophy and Seismic Analysis of a Multi-Storey Building (B+G+10) with Flat Slabs in Seismic Zone II Using ETABS and SAFE Software

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Abstract:

This journal paper presents the design philosophy and seismic analysis of a multi-storey building (B+G+10) with flat slabs located in Seismic Zone II. With the growing population and limited resources, vertical expansion has become a necessity. The economy's development has attracted foreign companies and innovative entrepreneurs, requiring the construction of high-end, safe workplaces. High-rise structures face challenges from wind and seismic loads, making proper design and analysis crucial for safety.

The design philosophy emphasizes the use of reinforced concrete due to its versatility, durability, and fire resistance. Reinforced concrete, a composite material of concrete and steel reinforcement, ensures strain compatibility and load sharing between the materials.

The paper discusses various design loads, including dead loads, live loads, wind loads, and earthquake (seismic) loads. Dead loads encompass the self-weight and permanent attachments to the structure, while live loads consider dynamic factors due to occupancy. Wind loads are assessed based on the local wind conditions, and earthquake loads are determined using seismic codes.

Design principles for foundations, columns, and footings are addressed, with a focus on ensuring structural stability, safety, and uniform settlement. The depth of the foundation is calculated using Rankine's formula, considering soil properties.

Column design is crucial, with short and long column classifications, and minimum eccentricity requirements are detailed.

The seismic analysis of the building involves the use of ETABS and SAFE software, which enable engineers to model the structure and assess its response to seismic forces. The combination of a sound design philosophy and comprehensive seismic analysis tools ensures the building's ability to withstand various loads, thereby contributing to safety and sustainability.

1. INTRODUCTION

The population of our country is increasing at a faster rate and the demand for the various commodities is increasing as a result of it. The availability of resources is limited and that too is diminishing day by day with its continuous use. Similarly, the need of land for construction purposes is also increasing day by day which is resulting in the conversion of agricultural land into dwellings. So it has become very important for the civil engineers to tackle with such problem. Thus, in spite of doing any further horizontal expansion, they are more of concentrating on vertical expansion.

Since our economy is a developing one, commerce sector is playing a very vital role. Various foreign companies are establishing their roots in our country. Even the young minds in our country are coming up with innovative ideas. For proper functioning of these enterprises and companies, they need a fully established place to operate within the country. Hence it becomes the duty of the civil engineers to provide them with a work place with high end facilities and safety.

High rise structures mainly face problem with loads pertaining to wind and earthquakes. Structures which have regular geometry, stiffness in plan and elevation and distribution of mass uniformly throughout the building suffer little damage than the irregular configurations.

Earthquakes are caused mainly due to release of strain-energy by faults movement, ground shaking occurs when a seismic waves travel inside the earth layer. These seismic waves will have differential level of energy, amplitudes and different time interval to reach the surface. Depending on the ground shaking severity during earthquake it is categorized based on the occurrence and size in to minor, moderate and strong/major. The damage of the earthquake is measured by magnitude (M) which is recorded on seismograms. There may be some variations in the level of performance when an earthquake occurs at different buildings located on same site

As we know earthquakes are the unpredictable natural disasters, from which it is very difficult for saving life and engineering properties against it. We want to identify the act of the building for seismic loads to overcome these issues by the various developmental analytical procedures, from which the structures can withstand for small earthquakes and enough warning has to be produced when subjected to strong earthquakes, this may save the possible number of lives.

Wind effects on the structures can be classified as static and dynamic. Static wind effect primarily causes elastic bending and twisting of the structure and for tall, long span structures a dynamic analysis of the structure is essential. Wind gusts cause fluctuating forces on the structure which includes large dynamic motions, including oscillations.

Thus, in modern days with more advancement and the rapid growth of urbanization and for aesthetic purpose buildings are constructed to fulfill the needs for the growing population. Hence it has become necessary to construct high rise buildings since the horizontal expansion is not economic and easier because of the limited availability of land.

SEISMIC ZONES OF INDIA

The varying geology at different locations vary the likelihood of damaging earthquake taking place at different locations is different. Thus seismic zone map is important to identify different regions. Based on the levels of intensities sustained during past earthquakes zones are classified as zone II, zone III, zone IV and zone V as on 2002 revision. For the purpose of determining seismic forces, the country is classified into four seismic zones. About 59% of the land area of India is liable to seismic hazard damage.

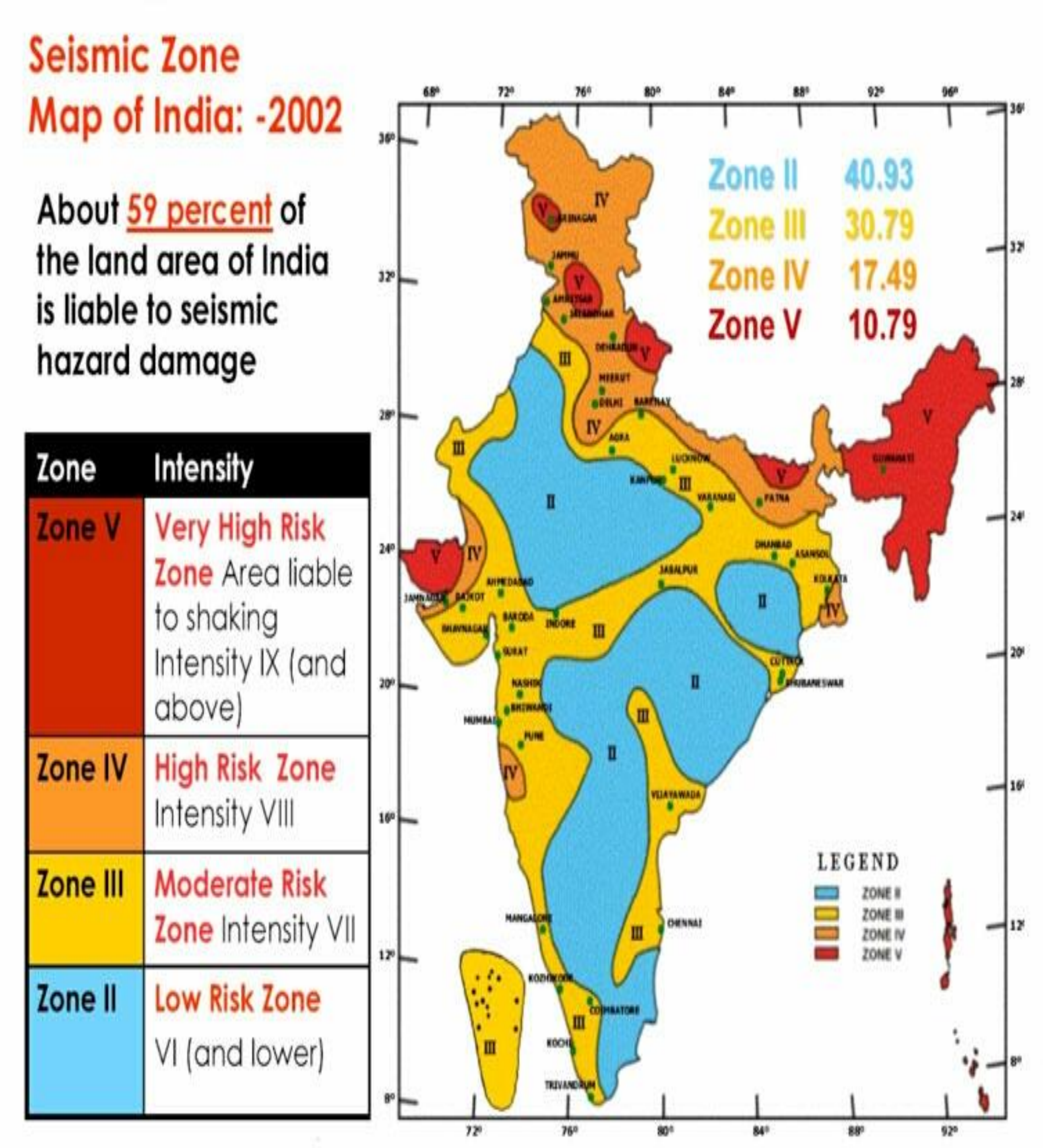

Fig SEISMIC ZONES OF INDIA

The different zones and their zone factor are given in the below table:

Seismic Zones	**II**	**III**	**IV**	**V**
Seismic Intensity	Low	Moderate	Severe	Very Severe
Zone Factor	0.10	0.16	0.24	0.36

Table 1 ZONE FACTOR, Z

Zone II	**Zone III**	**Zone IV**	**Zone V**
Ajmer	Agra	Ahnora	Bhuj
Allahabad	Ahmedabd	Amritsar	Darbhanga
Aurangabad	Belgaum	Barauni	Guwahati
Bangalore	Bhubaneshwar	Bulandshahar	Imphal
Bhilai	Bijapur	Chandigarh	Jorhat
Bhopal	Mangalore	Darjeeling	Kohima
Chitradurga	Pune	Debra Dun	Mandi

Gulbarga	Chennai	Delhi	Srinagar
Hyderabad	Coimbatore	Gangtok	Tezpur
Jaipur	Kolkata	Gorakhpur	Sadiya
Jamshedpur	Cuttack	Ludhiana	
Jhansi	Dharwad	Monghyr	
Jodhpur	Dharamapuri	Moradabad	
Kota	Goa	Nainital	
Kurnool	Gaya	Patna	
Madurai	Mumbai	Pilibhit	
Mysore	Kalapakkam	Roorkeea	
Nagpur	Kanchipuram	Shimla	
Nagarjunasagar	Kanpur		

Table 2 IMPORTANT CITIES IN DIFFERENT ZONES

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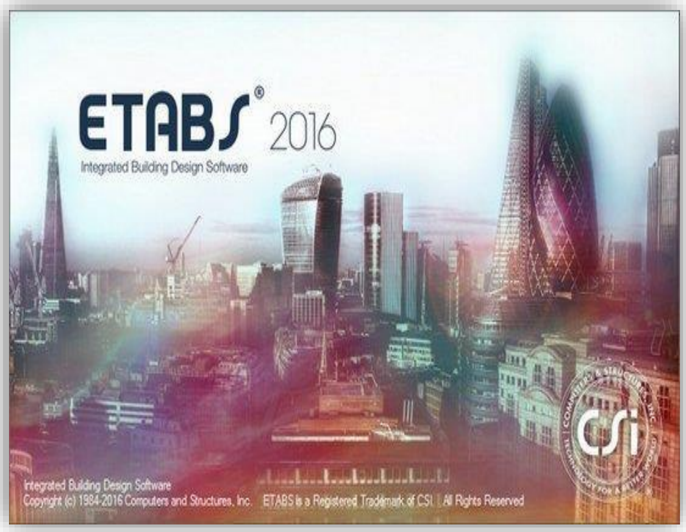
2 DRAFTING SOFTWARES, FLAT SLABS AND CODES USED

2.1 SOFTWARES

ETABS



For performing the seismic analysis, the software used in this work is ETABS. It is easy and sophisticated to use. The Special and new purpose design and analysis program are developed particularly for structural systems. It features an instinctive and high powered graphical interface integrated with the unmatched modelling, analytical and design operations, all using a common database.

Although ETABS is ease for simple structures, it handles even most complex building models, it includes a variety of nonlinear behaviours, makes a choice for the structural engineers worldwide in the building industry. Model creation is never been easier, instinctive drawing commands helps in the quick generation of floors/slabs and the elevation frames. Auto-CAD drawings are converted directly to ETABS models or else used as templates, where objects can be overlaid.

2.2. SAFE

For obtaining footing, column and slab value this software is used in this project. The model is imported from ETABS. As SAFE is the ultimate tool for designing concrete floor and foundation systems. From framing layout all the way through to detail drawing production, SAFE integrates every aspect of the engineering design process in one easy and intuitive environment. SAFE provides unmatched benefits to the engineer with its truly unique combination of power, comprehensive capabilities, and ease-of-use.

Post-tensioning may be included in both slabs and beams to balance a percentage of the self-weight. Suspended slabs can include flat, two-way, waffle, and ribbed framing systems. Models can have columns, braces, walls, and ramps connected from the floors above and below. Walls can be modeled as either straight or curved.

Mats and foundations can include nonlinear uplift from the soil springs, and a nonlinear cracked analysis is available for slabs. Generating pattern surface loads is easily done by SAFE with an automated option. Design strips can be generated by SAFE or drawn in a completely arbitrary manner by the user, with complete control provided for locating and sizing the calculated reinforcement. Finite element design without

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strips is also available and useful for slabs with complex geometries.

2.3. FLAT SLAB

Flat slab is a reinforced concrete slab supported directly by concrete columns without the use of beams. Flat slab is defined as one sided or two-sided support system with sheer load of the slab being concentrated on the supporting columns and a square slab called drop panels. Flat Slabs are considered suitable for most of the construction and for asymmetrical column layouts like floors with curved shapes and ramps etc.

2.4 TYPE OF FLAT SLAB CONSTRUCTION

Following are the types of flat slab construction

Simple flat slab

Flat slab with drop panels

Flat slab with column heads

Flat slab with both drop panels and column heads

USE OF COLUMN HEADS

It increase shear strength of slab

It reduce the moment in the slab by reducing the clear or effective span

USE OF DROP PANELS

It increase shear strength of slab

It increase negative moment capacity of slab

It stiffen the slab and hence reduce deflection

2.4.1 SIMPLE FLAT SLAB

It is such type of flat slab which does not content any type of additional construction between slab and column.

2.4.2 FLAT SLAB WITH DROP PANELS

It is such type of flat slab which content additional construction between slab and column called as drop panel.

2.4.3 FLAT SLAB WITH COLUMN HEADS

It is such type of flat slab which content additional construction between slab and column called as column heads.

2.4.4 FLAT SLAB WITH BOTH DROP PANEL AND COLUMN HEAD

It is such type of flat slab which content both drop panels and column head in additional construction between slab and column.

FIG.2.1.1. FLAT SLABS RESTING ON FIG.2.1.2. FLAT SLAB WITH COLUMNS DROP PANELS

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FIG.2.1.3. FLAT SLAB WITH COLUMN FIG.2.1.4. FLAT SLAB WITH. HEAD PANEL AND COLUMN HEAD

2.5 COMMERCIAL BUILDING

A commercial building design is considered in this project. Commercial building is a building that is used for commercial purposes, and includes office buildings, warehouses, and retail buildings (e.g. convenience stores, 'big box' stores, and shopping malls). In urban locations, a commercial building may combine functions, such as offices on levels 2-10, with retail on floor 1. When space allocated to multiple functions is significant, these buildings can be called multi-use. Local authorities commonly maintain strict regulations on commercial zoning, and have the authority to designate any zoned area as such; a business must be located in a commercial area or area zoned at least partially for commerce. Here in the project the building which we are designing and analyzing will be used fully for office purpose.

2.6 RRFERRED INDIAN STANDARD CODES

Civil engineers are working really hard and making efforts to get better results, whether they are casting a RCC column or constructing a wall. But, as a civil engineer how will you ensure optimal level of quality? How will you convince your client and non-engineering people that you have done 100 % quality construction work? For this you should have written documents which define the specific criteria of any job or task. These documents are especially being written to thoroughly analyze the subject with respect to test, design and experiments.

In India, Bureau of Indian standard (BIS) is the apex body which is responsible to set the guidelines for engineering design, materials and working procedures. For civil engineering activity it has been publishing the IS codes with the joint approval of civil engineering council. We ought to follow the IS guidelines while carrying out the construction activity. Below is a list of referred IS Codes which are useful for construction professionals, civil engineers and students.

- IS 456-2000 [PLAIN AND REINFORCED CONCRETE- CODE OF PRACTICE]
- IS 1893 (Part 1): 2002 [CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES]
- IS 875 (Part 1) 1987 [CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES (DEAD LOADS)]
- IS: 875 (Part 2) 1987 [CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES (IMPOSED LOADS)]
- IS: 875 (Part 3) – 1987 [CODE OF PRACTICE FOR DESIGN LOADS

(OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES (WIND LOADS)]

- IS : 875 (Part 5) – 1987 [CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES (SPECIAL LOADS AND COMBINATIONS]

3. DESIGN PHILOSOPHY

A structure is an assembly of members each of which is subjected to bending or to direct force (either tensile or compressive) or to a combination of bending or direct force. Concrete is arguably the most important building material, playing a part in all building structures. Its virtue is its versatility, i.e. its ability to be moulded to take up the shapes required for the various structural forms. It's also very durable and fire resistant when specification and construction procedures are correct.

Reinforced concrete is a composite material comprising concrete and steel reinforcement. The successful use of these materials in structural elements is attributed to the bond between steel and concrete which ensures strain compatibility so that the loads on the structural elements is shared between steel and concrete without disruption of the composite material.

3.1. DESIGN LOADS

For the analysis and design of structure, the forces are considered as the loads on the structure. The design of any reinforced concrete structural element requires knowledge of the various types of imposed loads, wind loads together with the dead loads of the materials. The different types of load acting on the structure are presented in the following section.

3.2. DEAD LOADS

It includes self-weight, weights of finishes, partitions, walls, grills etc. the load in a building shall comprise the weight of all walls, partitions, floors and roofs and shall include the weight of all other superimposed loads, which are permanently attached to the structure. For such loads, which don't change their position and so their magnitude don't vary. Dead loads are considered as per IS:875 (part 1) 1987.

3.3. LIVE LOADS (IMPOSED LOADS)

These are the loads assumed to be produced by the intended use or occupancy of a building including the weight of movable partitions, distributed, concentrated loads, load due to impact and vibration, and dust load but excluding wind, seismic, snow and other loads due to temperature changes, creep, shrinkage, differential settlement, etc. Live loads are considered as per IS:875(part 2)-1987.

3.4. WIND LOADS

Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and difference in terrestrial radiation. The wind generally blows horizontal to the ground at high wind speeds. The effect of wind on the structure as a whole cases, the calculated wind loads act normal to the surface to which they apply. Wind loads are considered as per IS:875(part 3)-1987.

3.5. EARTHQUAKE LOADS (SEISMIC LOADS)

Earthquake may be defined as a wave like motion generated by forces in constant turmoil under the surface layer of the earth, travelling through the earth's crust. The random motion of the ground caused by an earthquake causes inertia forces in a structure both in the horizontal and vertical directions. These design earthquake loads and their combinations are discussed in IS:1893(part 1)-2002.

3.6. FOOTING DESIGN

The foundation of a structure is a part of the structure which transfers the load to the soil on which it rests. It forms a very important part of the structure. The ground on which the foundation rests is called the sub grade or foundation soil. The purpose of foundation is to effectively support the superstructure by

Transmitting the applied load effects (reactions in the form of vertical and horizontal forces and moments) to the soil below, without exceeding the safe bearing capacity of the soil, and

Ensuring that the settlement of the structure is within tolerable limits, and as nearly uniform as possible.

The foundation should provide adequate safety against possible instability due to overturning and sliding and/or possible pullout

3.7. DEPTH OF FOUNDATION

The depth of foundation shall not be less than 500mm. The minimum depth of foundation is determined by Rankine's formula give below

Minimum depth of the foundation = $\mathbf{p/\gamma\,[(1-\sin\phi)/(1+\sin\phi)]^2}$

Where, p = Safe bearing capacity of the soil

γ = Specific weight of the soil

ϕ = Angle of repose of the soil

3.8. COLUMN DESIGN

Column forms a very important component of a structure. Column supports beams which in turn support walls and slabs. It should be realized that the failure of a column results in the collapse of the structure. A column is defined as a compression member, the effective length of which is exceeds three times its lateral dimension. Compression members whose lengths do not exceed three times their lateral dimension are classified as pedestals.

A column is considered as short, when the ratio of the effective length to its least lateral dimension is less than or equal to 12. When this ratio exceeds, the column will be considered as a long column. All columns shall be designed for minimum eccentricity, equal to the unsupported length of column/500 plus lateral dimensions/30, subject to a minimum of 20mm. where bi-axial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum about one axis at a time.

3.9. SHORT AXIALLY LOADED MEMBERS IN COMPRESSION

When the minimum eccentricity does not exceed 0.05 times the lateral dimension, the members may be designed by the following equation:

Pu = 0.4 fck Ac+0.67 fy Asc

Where, Pu = axial load on the member

fck = characteristic compressive strength of concrete

Ac = Area of concrete

fy = Characteristic strength of the compression reinforcement, and

Asc = Area of longitudinal reinforcement for columns

3.10. MEMBERS SUBJECTED TO COMBINED AXIAL LOAD AND BIAXIAL BENDING

Such members may be designed by the following equation

$$[(Mux/Mux1)]^{\alpha n} + [(Muy/Mux)]^{\alpha n} \leq 1.0$$

Where, Mux and Muy = moments about X and Y axes respectively

Mux1 and Muy1 = maximum uniaxial capacity for an axial load of Pu bending about X . and Y axes respectively

αn is related to Pu/Puz

Puz = 0.45 fck Ac+0.75 fy Asc

For values of Pu/Pz = 0.2 to 0.8, the values of αn vary linearly from 1 to 2. For values less than 0.2, αn is 1, for values greater than 0.8, the values of αn is 2.0.

3.11. BEAM DESIGN

A beam is one dimensional (normally horizontal) member, which provides support to the slab walls or secondary beams. A reinforced concrete beam should be able to resist tensile, compressive and shear stressed induced in it by the loads on the beam. Concrete is fairly strong in compression but weak in tension. Plain concrete beams are thus limited in carrying capacity due to the low tensile strength. Steel is very strong in tension. Thus, the tensile weakness of concrete is overcome by the provision of reinforcing steel in the tension zone in the concrete to make a reinforced concrete beam. The following are some of the recommendations given in IS 456-2000.

3.12. EFFECTIVE SPAN

For simply supported beam or slab the effective span shall be taken as clear span plus effective depth or the distance between the centers of bearing whichever is less.

In case of continuous beam or slab, if width of support is not less than 1/12 of clear span, the effective span shall be taken as mentioned above. If the supports are wider than 1/12 of clear span or 600mm whichever is less, the effective span shall be taken as follows

For end span with one end fixed and the other continuous, the effective span shall be the clear span between supports.

For end span with one end free and the other continuous, the effective span shall be equal to the clear span plus half the effective depth of the beam or slab or the clear span plus half the width of the discontinuous support, whichever is less;

In the case of spans with roller or rocket bearings, the effective span shall always be the distance between the centers of bearings.

In case of cantilever the effective length of a cantilever shall be taken as its length to the face of the support plus half the effective depth except where it forms the end of a continuous beam where the length to the center of support shall be taken.

3.13. MINIMUM TENSION REINFORCEMENT

The minimum area of tension reinforcement shall not be less than that given by the following

As/bd = 0.85/fy

Where,

As = Minimum area of tension reinforcement,

b = Breadth of beam or the breadth of the web of T-beam,

d = Effective depth

fy = Characteristic strength of reinforcement in N/mm²

3.14. MAXIMUM TENSION REINFORCEMENT

The maximum area of tension reinforcement shall not exceed 0.04 bD

3.15. COMPRESSION REINFORCEMENT

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The maximum area of compression reinforcement shall not exceed 0.04 bD. Compression reinforcement in beams shall be enclosed by stirrups for effective lateral restraint.

3.16. MAXIMUM SPACING OF SHEAR REINFORCEMENT

The maximum spacing of shear reinforcement measured along the axis of the member shall not exceed 0.75d for vertical stirrups and d for inclined stirrups at 45 degrees, where d is the effective depth of the section under consideration. In no case shall the spacing exceed 300mm.

3.17. MINIMUM SHEAR REINFORCEMENT

Minimum shear reinforcement in the form of stirrups shall be provided such that

Asv/bsv ≥ 0.4/0.87fy

Where,

Asv = total cross sectional area of stirrups leg effective in shear,

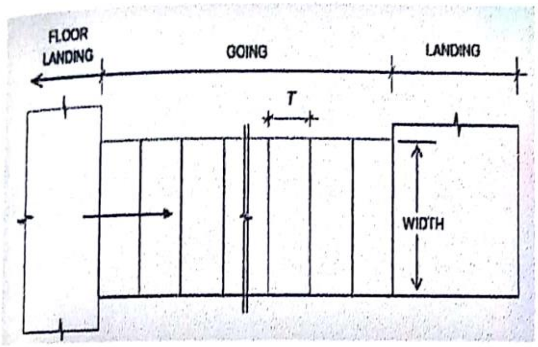
Sv = Stirrup spacing along the length of the member,

b = breadth of the beam or breadth of the web of flanged beam,

fy = Characteristic strength of the stirrup reinforcement in N/mm² which shall not be taken greater than 415N/mm²

3.18. STAIRCASE DESIGN

The staircase is an important component of a building, and often the only means of access between the various floors in the building. It consists of a flight of steps, usually with one or more intermediate landings (horizontal slab platforms) provided between the floor levels. The horizontal top portion of a step (where the foot rests) is termed tread and the vertical projection of the step (i.e. the vertical distance between two neighbouring steps) is called riser. The horizontal projection (plan) of an inclined flight of steps, between the first and last risers, is termed going.



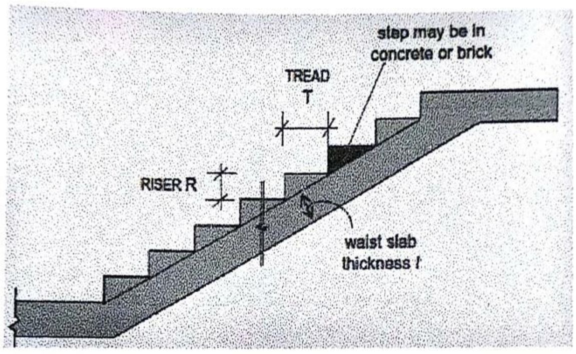


FIG 3.1 A TYPICAL FLIGHT IN A
FIG 3.2 A TYPICAL FLIGHT IN A STAIRCASE (PLAN)
STAIRCASE

3.19. EFFECTIVE SPAN OF STAIRS

The effective span of stairs without stringer beams shall be taken as the following horizontal distances:

Where supported at top and bottom risers by beams spanning parallel with the risers, the distance Centre to Centre of beams;

Where spanning on the edge of a landing slab, which spans parallel, with the risers, a distance equal to the going of the stairs plus at each end either half the width of the landing or one meter, whichever is smaller; and

Where the landing slab spans in the same direction as the stairs, they shall be considered as acting together to form a single slab and the span determined as the distance Centre-to-Centre of the supporting beams or walls, the going being measured horizontally.

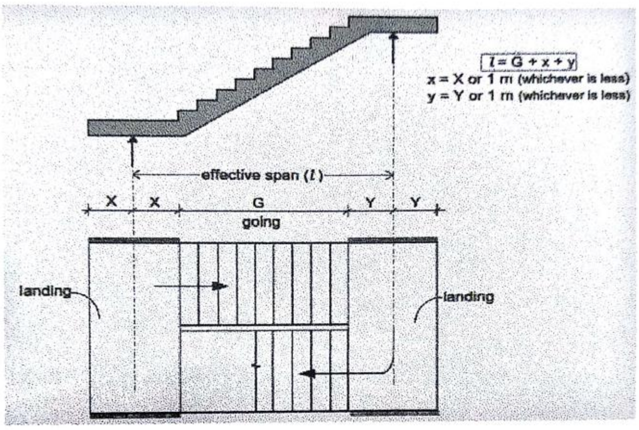


FIG 3.3 EFFECTIVE SPAN FOR STAIRS SUPPORTED AT EACH END BY LANDINGS SPANNING PARALLEL WITH THE RISERS

3.20. DISTRIBUTION OF LOADING ON STAIRS

In the case of stairs with open wells, where spans partly crossing at right angles occur, the load areas common to any two such spans may be taken as one-half in each direction as shown in figure. Where flights or landings are embedded into walls for a length of not less than 110mm are designed to span in the direction of the flight, a 150mm strip may be deducted from the loaded area and the effective breadth of the section increased by 75mm for purposes of design.

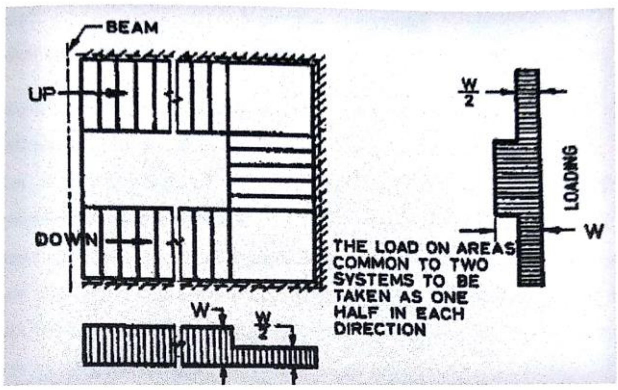


FIG 3.4 LOADING ON STAIRS WITH OPEN WELL

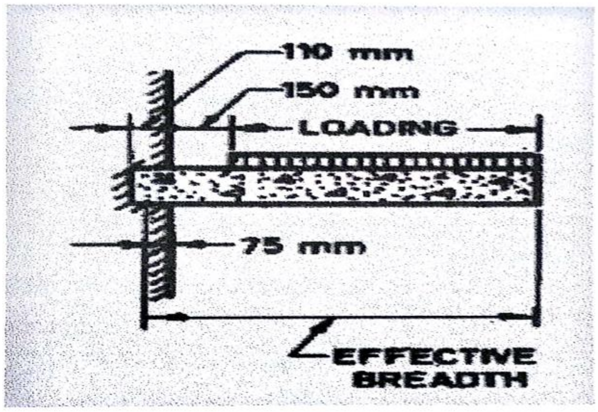


FIG 3.5 LOADING ON STAIR BUILT INTO WALL

3.21. TYPES OF FLAT SLAB DESIGN

Multitudes of process and methods are involved in designing flat slabs and evaluating these slabs in flexures. Some of these methods are as following:

The empirical method

The sub-frame method

The yield line method

Finite –element analysis

For smaller frames, **empirical methods** are used but **sub-frame method** is used in case of more irregular frames. The designs are conceptualized by employing appropriate software but the fact is using sub-frame methods for very complicated design can be very expensive. The most cost effective and homogenous installation of reinforcements can be achieved by applying the **yield line method**. A thorough visualization in terms of complete examination of separate cracking and deflection is required since this procedure utilises only collapse mechanism. Structures having floors with irregular supports, large openings or bears heavy loads, application of **finite- element analysis** is supposed to be very advantageous. Great thought is put into choosing material properties or installing loads on the structures. Deflections and cracked width can also be calculated using Finite- element analysis.

3.22 MANUAL DESIGN

3.22.1. COLUMN DESIGN

Pu	15220.76	Kn
Muz	256.68	kN-m
Muy	38.6	kN-m

Size of column

B	=	900	Mm	Fck =	30	N/mm2
D	=	900	Mm			
				Fy =	500	N/mm2
% of Steel Assumed		4.3	%			

Effective length of column

Ley	=	Floor to floor ht. - Beam depth x 0.8	=	-596.8	m
Lez	=	Floor to floor ht. - Beam depth x 0.8	=	-596.8	m
Floor to floor ht			=	4	m
Beam Depth		→	=	750	m

Ley / B	-663.11	→ column is short in Le y Direction
Lez / D	-663.11	→ column is short in Le z Direction

Minimum Eccentricity

e = (Effective length of column/500 +(B or D) / 30) OR 2cm whichever is max

Ex	-116.36	cm OR	2 cm	Whichever is maximum
Ey	-116.36	cm OR	2 cm	Whichever is maximum

Moment due to minimum eccentricity

Mz	304.42	kN-m	Moment due to minimum Eccentricity is max.
My	304.42	kN-m	Moment due to minimum Eccentricity is max.

Final forces for Column Design

Pu	15220.76	kN
Muz	304.4	kN-m
Muy	304.4	kN-m

Using Dia of Bar = 25 and Cover 40 mm

d' = 52.5

d' / D 0.058 → For major Dierection.

p/Fck = 0.143

Pu / (Fck x B x D) 0.63

Referring chart from SP-16 for Fy 500

Mux1 / (Fck x B x D^2) = 0.09

Mux1 = 1968.3 kN-m

Similaly

d' / B 0.058 → For minor Dierection.

p/Fck = 0.143

Pu / (Fck x B x D) 0.63

Referring chart from SP-16 for Fy 500

Muy1 / (Fck x B^2 x D) = 0.09

Muy1 = 1968.3 kN-m

Puz = 0.45 Fck Area of concrete + 0.75 Fy Area of steel

Puz = 23526.05 kN

Pu / Puz = 0.65

Alpha = 1.75

Ratio = $\left(\frac{Mux}{Mux1}\right)^{\alpha} + \left(\frac{Muy}{Muy1}\right)^{\alpha} \leq 1$

Ratio = 0.076 **Less than 1 hence OK.**

Area of Steel = 34830 mm^2 Manual **35171 softwae**

For Dia of Bar = 32 Mm

No. of bar required = 44 Nos.

No. of bar Provided =	45	Nos.	**Hence ok**

3.22.2. BEAM DESIGN

Factored Moment kNm	84.68	kN-m	
Factored Shear Force (kN)	102.46	kN	Ductile detailing
Torsion	4	kN-m	
Breadth (b) (mm)	300		
Overall Depth (D) (mm)	600		
Effective Cover (mm)	25		
Grade of Concrete (N/Sq mm)	30		
Grade of steel (N/Sq mm)	500	**Xumax/D=**	0.46
mulim/bdd	4.01		
Mu/(bdd)	0.92		

Min Dia of longitudinal bar	Dia of shear Rft	minimum spacing of stirrups
20	8	
143.75	300	**144**
160	192	

equivalent torsional moment	**7.059**
equivalent torsional Shear	**21.333**
Final moment	**91.739**
Final shear force	**123.793**

SINGLY REINFORCED

Singly Reinforced

Doubly Reinforced

For Factored Moment & Shear		-	**For Factored Moment & Shear**		
			mulim	397.562	
pt (%)	0.221		pt (%)	1.137	
Ast Reqd (Sq mm)	381		Ast1 Reqd (Sq mm)	1961	
Ast. Min	293		ASC	-1390	
Ast Reqd (Sq mm)	381		AS2	-1310	Asc
			TOTAL AST (AS1+AS2)	651	-1390
Diameter of bar in mm			Diameter of bar in mm		
32	0		32	0	
28			28	0	
25	0		25	2	
20	2		20	2	4
16	2		16	0	0
12	0		12	0	0
10	0		10	0	
8	0		8	0	
Ast Provided (Sq mm)	1030		Ast Provided (Sq mm)	1610	1257
pt Provided	0.60		pt Provided	0.93	
Tow V (N/Sq mm)	0.72		Tow V (N/Sq mm)	0.72	

Tow C (N/Sq mm)	0.53	Tow C (N/Sq mm)	0.64
Dia of shear Reinforcement	8	Dia of shear Reinforcement	10
No of Legs	2	No of Legs	2
Vus (kN)	31.581	Vus (kN)	0.001
Max Spacing of bar (mm)	660.87	Max Spacing of bar (mm)	32610320.79
Spacing of provided bar (mm)	100	Spacing of provided bar (mm)	100

.

d =	575.0	d =	575.0
Beta =	5.8	Beta =	3.7
Spacing reqd	660.9	Spacing reqd	32610320.8
Min shear spacing =	302.5	Max shear spacing =	472.6
Max shear spacing from depth =	431.3	Max shear spacing from depth =	431.3
Max shear spacing =	300.0	Max shear spacing =	300.0
min of 1,2,3	300.0	min of 1,2,3	300.0

4.22.3 DESIGN OF FLAT SLAB

Size of the office floor =25X25

Size of the panel =5mX5m

Load case =4KN/m^2

M25 Fe 500 HYSD

Column Size =500X500mm

Slab Thickness:

According to IS code 456

Thickness of slab =6000/32 =187.5mm

Provide 190mm thickness let the cover be 30mm

Let the drop be 50mm

Here, we have D=270mm d=240mm

Size of drop:

It should not be less than 1/3*6=2m

Let us provide 3mX3m so that the width of drop

Width of column strip=width of middle stripe=3000mm

Loads:

Self-weight =0.27*1*25=6.75KN/m^2

Floor finishing =1.5KN/m^2

Live load =4KN/m^2

Total load =12.25KN/m^2

Design factored load=12.23*1.5=18.375KN/m^2

Clear span =Lw=6-0.5=5.5m

Design load = Wp = Wu*L2*Lw =18.375*6*5.5=606.37KN

Design total moment:

Total moment

Mo=(WuLw/8) =606.37*5.50/8 =416.87KN-m

Total negative moment =0.65*416.87=271KN/m

Total positive moment =0.35*416.87=146KN/m

The above moments are to be distribution between column strip and middle strip

Moments	Column strip	Middle strip
-ve moment	0.75*217=203KN-m	0.25*271=68KN-m
+ve moment	0.6*416=87.6KN-m	0.4*416=59KN-m

Width of the column strip=width of the middle strip=3000mm

Mulim=0.138fckbd^2=q.138*25*3000*240=596.16*10^6N-mm

Thus Mulim>Mu hence the thickness selected is sufficient

Check for shear:

d/2 = 240/2=120mm from the face of column

Therefore, a square of size =500+240=740mm

V= total load-load on740*740 area=18.375*6*6-18.375*740*740=651.43KN

Nominal shear= τ_v = 651.43*1000/7*740*240=0.52N/mm^2

Shear strength =Kb*τ_c

Where=Kb=1+β_c

Here, β_c =L1/L2 =1

Kb=1, τ_c=0.25√25 =1.25N/mm^2

Design shear stress permitted =1.25N/mm2>ح$_v$

Design of Reinforcement:

1. for negative moment 203KN-m

And d=240mm

Mu=0.87*500*Ast*d (1-Ast.fy/b.d.fck)

$203*10^6$ = 0.87*500*Ast*240(1-Ast*500/3000*240*25)

Ast =2062.62 in 3000 mm width

Using 12mm bars and for spacing we have

S= $(3.14*12^2/2062.62)*3000$ =164.49mm

Provide 12mm bars of 160mm c/c

2. For negative moment =88KN-m, d=190mm

$88*10^6$= 0.87*500*Ast*190(1-Ast*500/3000*190*25)

Ast=1107.8mm

Using 10mm bars and fro spacing we have

S= $(3.14*10^2/1107.8)*3000$ =212.69mm

Provide 10mm bars at 220mm c/c

Now for the mid span we have

1. For negative moment =68KN-m d=240

Mu=0.87*500*Ast*d (1-Ast.fy/b.d.fck)

Ast=663.52mm

Again for spacing we have

S= $(3.14*12^2/663.52)*3000$=500mmc/c

2. For positive moment=59KN-m

Mu=0.87*500*Ast*d (1-Ast.fy/b.d.fck)

Ast=732.68mm and For spacing we have S= $(3.14*12^2/732.68)*3000$=320c/c

3.22.4 DESIGN OF STAIRCASE

Height of the floor = 4m

Step size 150mm rise 250mm tread

Imposed load or L load= 4KN/m

Dimension the staircase=5*8.2m

Arrangement of stairs

No of rises= floor to floor height/Rise =$4*10^3/150$ =26

No of rise for each flight= 26/2= 13

No of treads=13-1=12

Provide the width of flight=2.4m

Width of landing=width of flight= 2.4m

Load calculation(considering 1m strip)

Assume thickness of waist slab=150mm

Using 12mm diameter bar with 20mm clear cover

For going=d=150-30-13/2=114mm

Dead load of waist slab on slope =0.150*25=3.75

Load on horizontal plan=3.75√R^2+ح^2/T=3.75 (√$150^2+250^2/250$)=4.37KN/m^2

D.L of each step= (P/2)*ℓ =150/2*25=1.875KN/m^2

Floor finishing=1.5KN/m^2

Live load =Residential/As per IS875 part 2=4KN/m^2

Ultimate Load =17.61KN/m^2

For landing slab:

Landing slab thickness waist slab thickness=150mm

DL of landing =0.150*25=3.75KN/m^2

Floor finishing =1.5KN/m^2

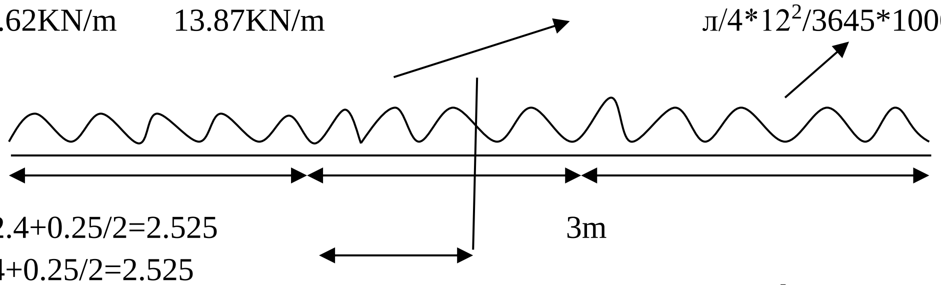
Live load =4KN/m^2

Total load=9.25 KN/m^2

Ultimate load =13.875KN /m^2

Bending Moment:

Consider the flight maximum span take flight 17.62KN/m 13.87KN/m



2.4+0.25/2=2.525 3m
2.4+0.25/2=2.525

Reaction: x

∑V=0 Rc+Rd

13.87*2.525+17.62*3+13.87*2.525=122.90KN

∑Mc=0

$13.87*2.525^2/2$+17.62*3*(3/2+2.529)+13.87*2.525(2.525/2+3+2.525)-Rd*8.05

Rd=61.835KN

Rc=61.835KN

The point where S.F=0 the beam is location of zero S.F

Vxx=0=61.835=13.87*2.525-17.60x =1.5m

Mxx=Mu=61.83(2.525+1.50)-13.87*2.525*(2.525/2+1.5)=152.11KN-m

Check for depth:

Mulim=152.11*10^6=0.36*0.48(1-0.42*0.48)*30*1000d^2

=191.70>d provided

Area of steel:

Mu=152.11*10^6=0.87*500*Ast*150(1-Ast*500/1000*150*30)

Ast=3645mm^2

Check for minimum steel:

Area=0.12% of gross area

0.12/100*1000*191.70=230mm^2

л/4*12^2/3645*1000=31mm #12mm

Provide #12 at 40mm spacing at c/c

Max=3d=3000mm

Distribution steel:

Area 0.12% of gross area =230mm^2

Spacing 8#230mm c/c

Check for shear:

Vu=61.85*10^3/1000*150=0.41N/mm^2

100*Ast/bd=100*3645/1000*150=2.43 hence, $ʓ_c > ʓ_v$ safe

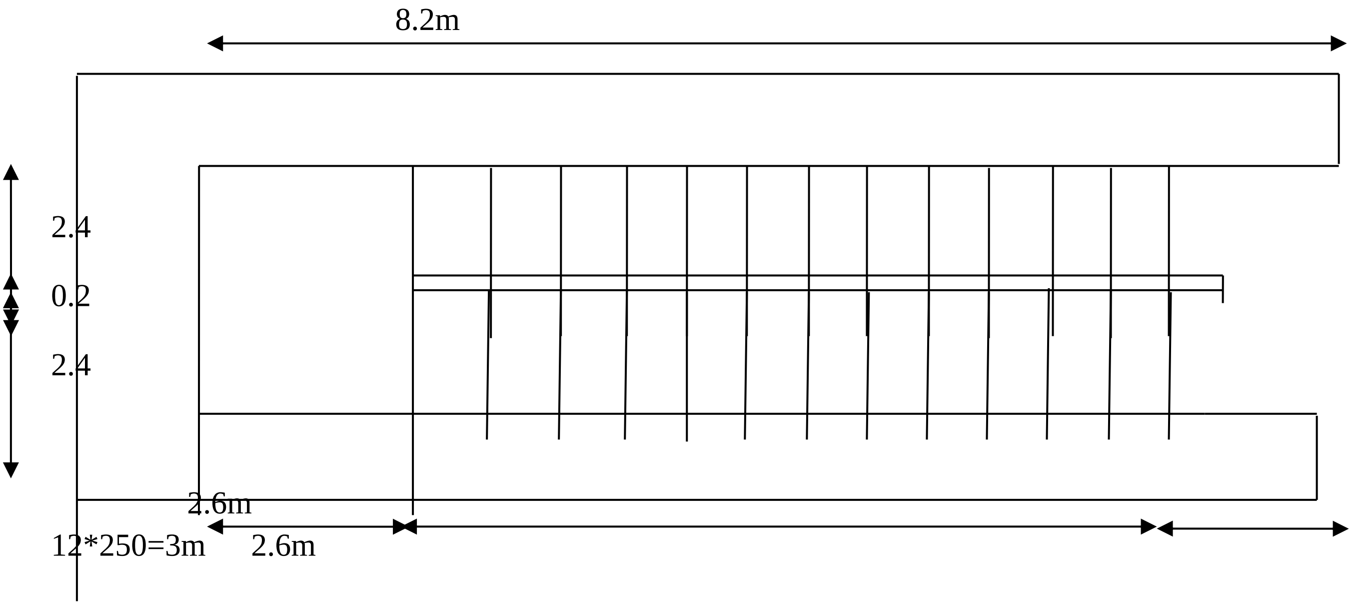


FIG 4.7.STAIRCASE

4.22.5. FOOTING

P = 1500 KN

SBC = 350 KN/m²

Fck = 25 N/m^2

Fy = 500 N/mm^2

a) Load calculation:

P = 1500 KN

10 % of load = 150 KN

Total = 1650 KN

Area required = 1650 / 350 = 4.71 m^2

Provide L x B = 2.17 x 2.17 = 2.2m x2.2m

Net upward pressure q_0 = load / area

= 1650 / 2.2 x 2.2

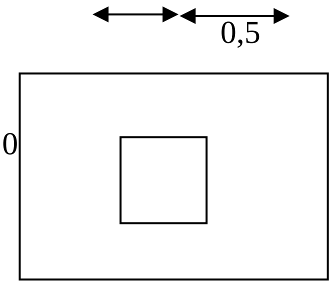
= 340.90 KN/m^2 < 350 KN/m^2

b) Thickness of footing:

the critical section for bending moment is at the

$M_{11} = wl^2/2$ = 340.90 x 0.85 x 0.85 / 2

= 123.15 KN/m^2



0.35

Mu = 1.5 x 123.15 0

Mu = 184.72 KN-m

Mu = 0.138 f_{ck} b d^2

= 0.138 x 25 x 1000 x d^2

d = 231 mm = 230 mm

D = 300 mm

From shear consideration we have to double the depth

d = 600 – 50

d = 550mm

D = 600 mm

Clear cover = 50 mm

Area of steel

Mu = 0.87 fy Ast d [1 – (Ast fy / b d fck)]

184.72 x 10^6 = 0.87 x 500 x 550 x Ast [1 – (Ast 415 / 1000 x 650 x 20)]

$184.72 \times 10^{6} = 239250\ Ast – 8.7\ Ast^2$

Ast = 795.06 mm^2

Provide 10mm dia = $[((\Pi / 2 \times 10^2) / 795.06) \times 1000]$

= 98.717mm

Provide 10 mm dia @ 100 mm c-c

Check for one way shear: d=550

Critical section for one way shear is at a distance d = 0.55 m 50

From column size

SFxx = 340.90 x 0.5 = 170.45 KN

Vu = 170.45 x 1.5 = 255.67 KN 340.90KN

τ_v = Vu / bd

= $(255.67 \times 10^3) / (1000 \times 550)$

= 0.46

τ_{cpcr} = (100 As A / b d)

= (100 x 930.37 / 1000 x 650)

= 0.14

$\tau_c < \tau_v$ safe

Check for two way shear (punching Shear):

d / 2 = 0.550 / 2

= 0.275 B=2.9m

b 1 = 0.4 + d / 2 + d / 2 from column face 2.2

b 1 = 0.4 + 0.275 + 0.275

= 0.95m

Perimeter of critical section:

$b_2 = (b_1 + b_1) = 2\ (0.95 + 0.95)$

= 3.8 m

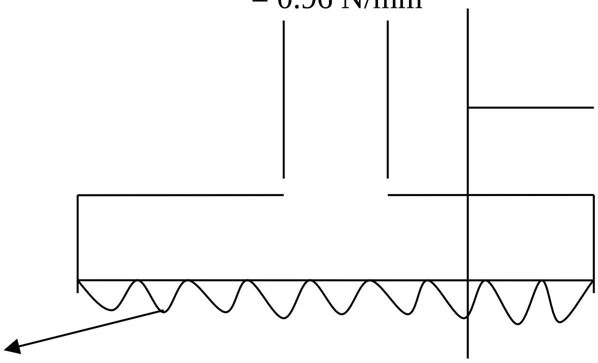
SF for punching = $q_0\ [(B \times B) – (b_1 \times b_1)]$

= 196.19 [(2.9 x 2.9) – (1.05 x 1.05)]

Vu = 1342.29 KN

τ_v = (Vu / b d) = $[(1342.29 \times 10^3 \times 1.5) / (3800 \times 550)]$ D=650

= 0.96 N/mm^2



Permissible shear stress Ks PCC

Ks = 0.5 + ßc

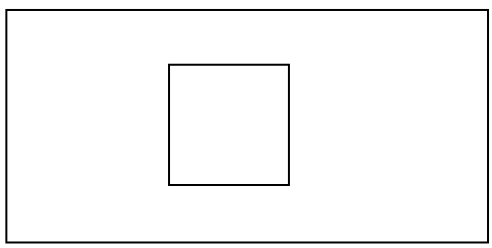
ßc = 900/900 = 1 10mm@90mmc/c

Ks = (0.5 + 1) = 1.5

$\tau_c = 0.25 \sqrt{Fck}$

$1.11 = \sqrt{Fck}$

Allowable shear stress = Ks x τ_c = 1 x 1.11 = 1.11 KN/ m^2 $\tau_v < \tau_c$ safe



Conclusion:

In light of the increasing population and the need for innovative and sustainable urban development, this journal paper has explored the design philosophy and seismic analysis of a multi-storey building in Seismic Zone II. The adoption of reinforced concrete as the primary building material, along with adherence to design principles and load considerations, is essential for constructing safe and durable high-rise structures.

The discussion on design loads, including dead loads, live loads, wind loads, and earthquake loads, highlights the need to account for various forces that can act on the structure. Proper assessment of these loads is fundamental to ensuring the building's integrity and safety, especially in seismic-prone areas.

Additionally, the paper delves into the critical aspects of foundation design, emphasizing the need for uniform settlement and structural stability. Column design is highlighted as a crucial element, with strict requirements to prevent failure. The use of ETABS and SAFE software for seismic analysis provides engineers with powerful tools to model the building's behavior under various loading conditions.

In conclusion, this paper serves as a valuable resource for civil engineers and stakeholders involved in the design and construction of multi-storey buildings in Seismic Zone II. It underscores the significance of a robust design philosophy and the use of advanced software tools in creating safe and resilient structures that meet the demands of our rapidly evolving urban landscape.

Scope of Study

The scope of this study extends to civil engineers, architects, and stakeholders involved in the design and construction of multi-storey buildings located in Seismic Zone II. The study focuses on the critical aspects of seismic analysis and design philosophy, emphasizing the use of reinforced concrete as a primary building material for high-rise structures.

The study's significance lies in providing a comprehensive understanding of the importance of design principles and load considerations. It highlights the need to account for various loads, including dead loads, live loads, wind loads, and earthquake loads, to ensure the structural integrity and safety of buildings, particularly in regions prone to seismic activity.

The study's scope also includes the critical components of foundation design and column design, with an emphasis on uniform settlement and structural stability. The utilization of advanced software tools such as ETABS and SAFE for seismic analysis is explored, providing engineers with the means to model and assess the building's behavior under different loading conditions.

Ultimately, this study serves as a valuable resource for professionals in the field, guiding them in the creation of safe, durable, and resilient structures that align with the evolving demands of urban development in Seismic Zone II. It contributes to the body of knowledge in structural engineering and offers practical insights into the design and analysis of multi-storey buildings.

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