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Paper Authors

*** GOLLAPALLI NOOKARATNAM, DR. DUMPA VENKATESWARLU, J.L.SUDHA.**

* Dept of Civil Engineering, Godavari Institute of Engineering &Technology (Autonomous).

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ANALYSIS AND DESIGN OF MULTI-STOREYED BUILDING WITH FLAT SLAB UNDER SEISMIC ZONE USING ETABS AND SAFE SOFTWARES

[1] GOLLAPALLI NOOKARATNAM, [2]DR. DUMPA VENKATESWARLU, [3]J.L.SUDHA

[1]PG Scholar, Dept of Civil Engineering, Godavari Institute of Engineering &Technology (Autonomous), Rajahmundry, A.P, India.

[2]Professor & Head of The Department of Civil Engineering, Godavari Institute of Engineering & Technology (Autonomous), Rajahmundry, A.P, India .

[3]Assistant Professor, Dept of Civil Engineering, Godavari Institute of Engineering &Technology (Autonomous), Rajahmundry, A.P, India .

ABSTRACT:

The demand for HOUSING is increasing at a peak rate due to increase in population and development of civilization. The demand is very high, especially in towns due to rapid industrialization. Adapting the construction of Multistoried Building not only matches with demand but also decreases the price of the single house. Hence an engineer to be knowledgeable about the planning and designing of such Multistoried Buildings. Advancements of computer packages have given many tools to the designer towards achieving the best and accuracy in their work. An attempt is made in this project to utilize the computer packages and comparing the results with manual procedures. In our project, a G+5 Structure with flat slab is analyzed and designed for live loads, dead load, seismic loads and wind loads. The complete process of Modeling, Analysis and design of whole structure is carried by using ETABS Packages. The typical flat slab is designed in SAFE by using finite element method. The structural responses are comparing with seismic zone II and III, prepared data base for responses. To increase the strength and deformation capacity of flat slabs Punching shear reinforcement is an efficient method. To preventing a total collapse of the structure in the case of the occurrence of a local failure, the increase in deformation capacity is desired so that the load can be distributed to other supports.

Key words: ETABS, SAFE, Flat slab, punching shear.

INTRODUCTION

1.1 General

Now days, there is a growth in housing requirement with multiplied population and urbanization. Therefore, constructing zone has won increasing prominence. However, the fact that the precise lands for constructing constructions especially inside the areas wherein human beings live intensively are restrained and high priced shows that there is a need for optimal evaluation of these lands. Additionally, continuously increasing fees results in boom in building fees; so, both dimensional and value optimization turns into vital or even essential.

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When a building is projected, geometrical dimensions of elements belonging to carrier system of the structure are usually determined by using engineering capability and experiences gained over time. In sizing, the tensile forces to which the material to be subjected to should comply with the specifications. In the building design, the pre-sizing details provided are generally not changed much; sizes obtained in second or – at most third solution are taken as carrier system sizes. In fact, carrier system can be sized in infinite possibilities in a manner to ensure all the necessary conditions; and the cost of each carrier system alternative can be different from each other. The basic aim in the engineering is to find a design having lowest cost, and ensuring predicted limitations.

1.2 Flat slab

Flat slabs system of construction is one in which the beams used in the traditional methods of structures are carried out away with. The slab directly rests on the column and load from the slab is transferred to the columns. Absence of beam results in plain ceiling and better architectural appearance and as a consequence much less vulnerability in case of fire than in ordinary cases where beams are used.

Basic definition of flat slab: Flat slab is a reinforced concrete slab which is supported directly on the concrete columns without the use of beams.Normal frame construction uses columns, slabs & beams. But it is possible to take construction without providing beams, in this type of case the frame system would consist of slab and column without beams and those types of slabs are called flat slab, since their behavior look like the bending of flat plates.

Fig.1 Slab with columns

1.3 COMPONENTS OF FLAT SLABS

1.3.1 DROPS:

To help heavy loads the thickness of slab near the support with the column is increased and those are referred to as drops. The drop dimension should be more than one - third of panel length because it has to resist the punching shear which is predominant at the contact of slab and column support.

1.3.2 COLUMN HEADS

Columns are commonly supplied with enlarged heads and these are referred to as column heads or capitals. By providing column heads we can increase the area at the support which helps in resisting the negative moment that is transferred from the slab to the column.

Flat slabs are acceptable for irregular column layouts, curved floor shapes, ramps and also for most floor situations etc. If we choose flat slabs there are some other uses like it includes minimum depth solution, a flat soffit (clean finishes and freedom of layout of services), fast track construction, flexibility in the plan layout (both in terms of the shape and column layout and scope and space for the use of flying forms.

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Flexibility of flat slab construction allows the architect great freedom of form and leads to high economy.

Examples: Solid flat slab, solid flat slab with drop panel, solid flat slab with column head, coffered flat slab, banded coffered flat slab , coffered flat slab with solid panels.

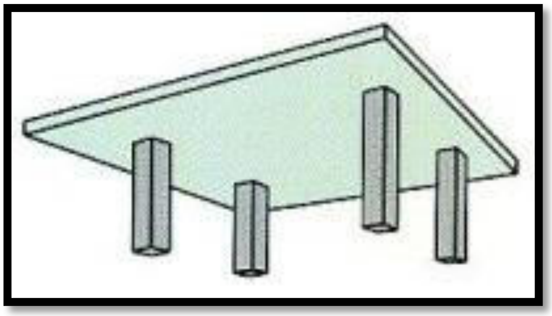

FIG.2 Solid Flat Slab

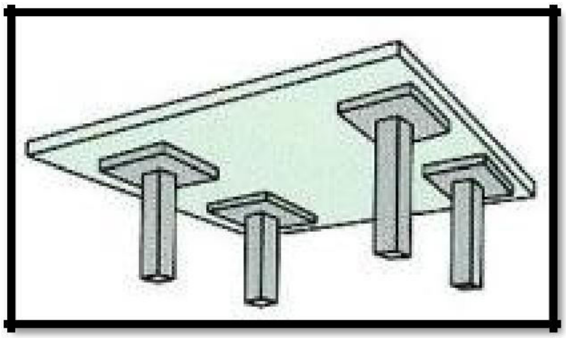

FIG.3 Solid Flat slab with Drop Panels

A flat slab is a flat section made of concrete. Though these flat slabs are classically used in foundations, they can also be used in the construction of roadways, paths, and other structures. The flat slab may need to be designed by an engineer who is familiar with the limitations and needs of slabs and the design should be based on the size and complexity of a flat slab.

Typically, a flat slab is made up of reinforced concrete. To provide support and reinforcement the rebar is criss-crossed in the forms once the concrete is poured and hardened. To withstand stresses due to earthquakes, frost etc the slab design is designed to be reinforced in several directions. If we fail to fail to fully reinforce a flat slab , it causes instability by crack or it gives along weak lines in the concrete.

A flat slab is poured in situ for some sites. In this case, the site is prepared, forms for the concrete set up, and the materials like reinforcing rebar are laid down. Then, the concrete is mixed, poured, and allowed to cure before moving on to the next stage of construction. The time required can vary considerably, with size being a major factor; the bigger the slab, the more complex reinforcement needs can get, which in turn adds to the amount of time required for set up. Once poured, the slab also has to be examined and tested to confirm that the pour was good, without air pockets or other problems which could contribute to a decline in quality.

When conditions at the site do not facilitate an easy pour, or when the conditions for the slab's construction need to be carefully controlled then a flat slab may be prefabricated off site and transported to a site when it is needed. If it is especially large transportation of the slab can be a challenge. It is required to successfully move barges, cranes, and flatbed trucks from the fabrication site to the site of the installation.

There are some problems in flat slab foundation. For example as structures tend to lose heat through the concrete, a flat slab can become a major source of energy inefficiency and allows the structure to settle as well. It can settle on uneven ground. If the soils are subjected to liquefaction, a slab foundation cannot hold up during seismic activity.

Concerning to the earthquake resistance there are some widely known advantages of flat-slab reinforced concrete structures but there are also known the disadvantages. Reinforced Concrete Code, Greek codes and Seismic Code provide specific compliance criteria in order such structures to be acceptable however both Codes do not forbid the use of such structural systems.

1.4 Advantages of flat slab

The advantages of these systems are:

1. The ease of the construction of formwork.
2. The ease of casting concrete
3. The ease of placement of flexural reinforcement.
4. The free placing of walls in ground plan
5. The free space for water, air pipes, etc between slab and a possible furred ceiling.
6. The reduction of building height in multi-storey structures by saving one storey height in every six storey's thanks to the elimination of the beam height.
7. The use of cost effective pre-stressing methods for long spans in order to reduce slab thickness and deflections as also the time needed to remove the formwork.

Due to their advantages mainly in countries in which the seismicity is low these structural systems seems to attract global interest. There is a belief that such structures are susceptible to seismic actions so the application of flat-slab structures is restrained. Moreover, it is known that flat-slab structures displayed serious problems during earthquake actions in Central America, at the beginning of 1960's.

1.5 BUILDING

A building is a man-made structure with a roof and walls standing more or less permanently in one place. Buildings come in a variety of shapes, sizes and functions, and have been adapted throughout history for a wide number of factors, from building materials available, to weather conditions, to land prices, ground conditions, specific uses and aesthetic reasons. To better understand the term building compares the list of nonbinding.

Buildings serve several needs of society – primarily as shelter from weather, security, living space, privacy, to store belongings, and to comfortably live and work. A building as a shelter represents a physical division of the human habitat (a place of comfort and safety) and the outside (a place that at times may be harsh and harmful).

1.6 Objective

The main objective of this study is to identify various parameters that affected the flat slabs. Using ETABS & SAFE software's Analysis and design of a multi storey building with flat slab is done. The ETABS stands for extended 3D (Three-Dimensional) Analysis of Building Systems. This is based on the finite element method and stiffness matrix based software. To satisfy all the checks as per Indian standards the analysis and design is done. Finally for various structural responses data base is prepared

1.7 Scope of work

Using ETABS & SAFE software the analysis is implemented for Flat slab and framed system. The structure is analyzed for both gravity loads and lateral loads. Under worst load combinations the individual structural elements are designed.

ETABS

ETABS have set the international standards in structural analysis and design in the last 30 years. The characteristic properties of a building's mathematical model are considered first, and then the graphical creation of a building's model in the same sequence that will actually be constructed (slab by slab, floor by floor) are allowed. Worldwide, ETABS is considered as the most popular analysis and design software as it is established as the innovator in structural analysis and design and the reference point for the entire market. It is the Top Seismic Product of the 20th Century‖ (2006) and —Honor Award in Engineering Software‖ (2002) awards.

Contrary to the common civil engineering programs ETABS uses the terms such as nodes, members etc but the latest version of ETABS incorporating structural element terminology that is used on a daily basis (Columns, Beams, Bracings, Shear Walls etc.), Additionally, it is the efficient, fast and easy way as it offers many automatic functions for the formation, analysis and design of the structural system. The user can easily create a model, apply any kind of load to it and then take advantage of the superior capabilities of ETABS to perform a start or analysis and design. Whether you are designing a simple 2D frame or performing a dynamic analysis of a complex high-rise building that utilizes non-linear dampers for inter-story drift control, ETABS is the solution.

2.1 Areas of Application

- ❖ Different materials can be assigned to the structural elements within the same model such as steel, RC, composite or any other user-defined material
- ❖ Easy and automatic generation of gravity and lateral loads (seismic and wind loads) when compared with other FE general analysis programs
- ❖ Analysis and design of building structures with a structural system consisting of beams, slabs, columns, shear walls and bracings.

2.2 Advantages of ETABS software

- ➢ Graphic input and editing for easy and fast model generation
- ➢ 3D generation of the model through plan views and elevations Fast model generation using the concept of Similar stories
- ➢ Easy editing through the Move, Merge, Mirror and Copy commands
- ➢ Accuracy in dimensions by using Snaps (end, perpendicular, middle etc.)
- ➢ Fast object creation with one click of the mouse

LITERATURE SURVEY

➢ BASKARAN (2007) has worked on irregular flat slabs designed according to structural membrane approach. Flat slabs simplify the installation of services and can accommodate more floors within restricted heights and also these are less labor intensive. They require more steel compared to two-way slabs as the span influencing their design is the longest. Vulnerability to punching shear failure and higher deflections are the other drawbacks

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of flat slabs. Drop panels, column heads or shear reinforcement are used to avoid punching shear failure. Both deflection and punching shear problems can be avoided if span in flat slabs is reduced. However, architects prefer to have few exposed columns in usable areas. This inevitably leads to columns in an irregular layout, hidden inside partitions or walls. To satisfy the functional requirements of constructing buildings in urban environments, flat slab construction with columns in an irregular layout is a viable solution.

➢ Hisabe has worked on Fatigue Life Extension of Damaged RC Slabs by Strengthening with Carbon Fiber Sheets Attaching Method. A series of wheel trucking fatigue tests were conducted on the intentionally damaged reinforced concrete slabs of highway bridges strengthened with carbon fiber sheets attached by the grid bonding method.

➢ Conclusions obtained in this study are RC slabs were strengthened with grid bonding where carbon fiber sheets were bonded with intervals on the bottom surface of concrete decks, have sufficient fatigue durability for practical use and it was roughly 10 times higher than that of a non-strengthened RC slab, and there was no problem in adhesiveness in grid bonding parts. Grid bonding specimens were observed in the shape of punching shear failure of slab concrete as well as the full-surface bonding.

➢ Graf (1992) has worked on analysis and testing of a flat slab concrete building. A 14-storey reinforced concrete flat slab concrete building in southern California was assessed for earthquake risk. The mid-1960's design uses frame action between the slab and columns for lateral resistance. Unlike other flat slab buildings damaged in past earthquakes, this building has large, deep, pyramid-shaped drop panel to reinforce the critical slab-column joint. Preliminary linear analysis identified probable structural weakness and seismic demands on structure, but the earthquake performance of the drop panel could not assessed. Tests at the university of California, Gerkelty campus investigated the ductility of the slab-column connection, and provided data for analytical model refinement. Results showed stiffness degradation as excepted, but loss of strength with in anticipated maximum drifts was negligible.

LOADS AND LOAD COMBINATION

GRAVITY LOADS

4.1 DEAD LOAD (DL):-

Self weight of the structure or own weight of the structure is known as dead load. All permanent constructions of the structure form the dead loads. The dead load comprises of the permanent constructions, weights of walls, partitions, floor finishes in the buildings In accordance with IS. 875(part -1)

Material Density

Brick masonry	19.0 KN/m^3
Plain concrete	24.0 KN/m^3
Reinforced	25.0 KN/m^3

DEAD LOAD CALCULATION:

MAIN WALL LOAD should be the cross sectional area of the wall multiplied by unit weight of the brick.

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(Main wall load is considered from above plinth area to below the roof.

According to the IS-CODE Main wall load should be double the plinth load. And plinth load should be double the internal plinth load

Parapet load should be the cross sectional is multiplied by unit weight.

SLAB LOAD: Slab load plus floor finishes together gives slab load. It can be calculated as the thickness of slab multiplied by unit weight of concrete.

(according to IS-CODE unit weight of concrete is taken as 25 kn/m^3).and FLOOR FINISHES taken as .1.5 kn/m2.

4.2 LIVE LOAD (LL):

Movable loads are simply known as Live Loads or Imposed Loads. Live loads include weights of furniture, distributed and concentrated loads , weight of movable partitions , load due to vibration and impact and dust loads.

LIVE LOAD CALCULATION:

According to the type of building, the value of live load varies.

Example : For a Residential building the live load is taken as 2kn/m2

LIVE LOADS: In accordance with IS 875(part -2)

i) Live load on slabs = 2.0 KN/m^3

ii) Live load on passage= 3.0 KN/m^3

iii) Live load on stairs = 3.0 KN/m^3

4.3. WIND LOAD:

Wind load is a lateral load caused by the movement of air relative to earth. The wind generally blows horizontal to the ground at high wind speeds. The term ‘wind’ denotes almost exclusively the horizontal wind since vertical components of atmospheric motion are relatively small. Against a building wind builds up a positive pressure on the windward side and a negative pressure on the leeward side. Anemometers or anemographs are used to measure the wind speed and these are installed at heights generally varying from 10 to 30 metres above ground at meteorological observatories. There are some factors which affect the wind load like building height and size, geographical location, degree of exposure, relationship to nearby structures, elevation, velocity of prevailing winds and positive or negative pressures due to architectural design features and direction of prevailing winds. Example for a structure especially designed to resist a high wind load is The Eiffel Tower.

The code book used for design purpose is IS 1893(Part 3).
In limit state method
If wind load is considered then Design load is 1.2(DL+LL+WL)
If wind load is not considered then Design load is 1.5(DL+LL+WL)

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4.3.1DESIGN WIND SPEED (Vz)

To get design wind speed at any height (V_z) for the chosen structure, the basic wind speed (V_b) shall be modified to include the following effects

Local topography

- Risk level and
- Terrain roughness, height and size of structure

It can be mathematically expressed as follows:

$$V_z = V_b K_1 K_2 K_3$$

Where

V_Z = design wind speed at any height z in m/s

V_b=Basic wind speed in m/s

K_1 = Risk coefficient (Probability factor)=0.91=1

K_2 = THS factor (Terrain, Height and Structure size factor)=1.02

and

K_3 = Topography factor=1

NOTE: Design wind speed up to 10m height from mean ground level shall be considered constant.

4.3.2DESIGN WIND PRESSURE

The relationship between wind pressure and wind velocity gives the design wind pressure at any height above mean ground level.

$$p_z = 0.6\, V_z^{\,2}$$

Where

P_z = Design wind pressure in N/m^2 at height z, and

V_z=design wind velocity in m/s at height 2.

NOTE - The coefficient 0.6 (in SI units) chosen corresponds to the average appropriate Indian atmospheric conditions. This value depends on a number of factors mainly on the atmospheric pressure and air temperature.

4.3.3.Wind Load on Individual Members

It is essential to take account of the pressure difference between opposite faces of such elements or units when we calculate the wind load on individual structural elements such as roofs and walls, and individual cladding units and their fittings. Therefore it is necessary to know the internal pressure as well as the external pressure for clad structures. Then the wind load, **F,** acting in a direction normal to the individual structural element or cladding unit is

$$F = \left(C_{pe} - C_{pi}\right) A P_d$$

C_{pe} = external pressure coefficient,

C_{pi} = internal pressure- coefficient,
A = surface area of structural or cladding unit, and
P_d = design wind pressure element

4.4 SEISMIC LOAD

Seismic loads are another lateral live loads caused by earthquakes and these are evaluated by using the code IS 1893. These loads are

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potentially more damaging than wind loads, very complex and uncertain. The earthquakes creates ground movements and that can be categorized as a 'shake', 'rattle' and 'roll'. During earthquakes, only the horizontal components of the movement are usually considered critical in a structural analysis though the ground under structure may shift in any direction. To design small and moderate sized buildings the "static equivalent load" method is used. Earthquake load or seismic load is considered almost as instantaneous where as wind load is considered as constant force. The magnitude of earthquake load depends on acceleration of the surface of the earth, stiffness of structural system and mass of the structure.

DESIGNSPECTRUM CALCULATIONS

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

$A_h = \frac{ZIS_a}{2Rg}$Where

Z = Zone factor

I= Importance factor,

R=Response reduction factor.

Sa /g =Average response acceleration coefficient.

However, the ratio (I/R) shall not be greater than 1.0.

Once the gravity loads and lateral loads are analysed, then the structural responses are analysed.

LOAD COMBINATIONS

The load combinations are considered as per the Indian standards.

All load combinations are considered while designing a structure. But only for critical combinations the structure is designed.

4.5 LOAD CASES AND LOAD COMBINATIONS

We consider both gravity and lateral load to design this structure. The primary load cases and the load

combinations are shown in table respectively. The present structure is modeled and analyzed using

ETABS. For the analysis of gravity loads, live load of the structure is considered 3kN/m^2.

Wind load is not considered up to 10m height of a building and the elements are required to be designed for critical combination of dead load and live load only.

We are required to use maximum and minimum loads to decide the critical load arrangements

For this code prescribes different load factors as given below :

Maximum load = *Wmax* = 1.5(DL + LL)

Minimum load = *Wmin* = DL

When the deflection is maximum or curvature producing concavity upwards is maximum, the maximum positive moments producing tension at the bottom will occur. This condition will occur when minimum load (i.e. only DL) is on adjacent spans while maximum load (i.e. both DL and LL) covers the whole span.

Table: 3Load combinations

4.6 MATERIAL PROPERTIES

The materials used in this structure are Concrete (M20) and Rebar(Fe 500)

PROPERTIES OF CONCRETE

Grade of concrete :-

M15, M20, M25 etc, are different types of grades in concrete in which letter M refers to concrete mix and the number 15, 20, 25 etc. denotes the specified compressive strength ($f$ck) of 150mm size cube at 28 days, expressed in *N/mm2*. Thus, concrete is known by its compressive strength. In Reinforced concrete works higher grades of concrete should be used for severe and very severe and extreme environment where as M20, M25 grades of concrete are common used for normal structures.

Compressive strength:-

The compressive strength of concrete varies considerably for the same concrete mix. Therefore a single representative value known as characteristic strength , is arrived at using statistical probabilistic principles.

Characteristic strength :-

The value of the strength below which not more than 5% of the test results are suspected to fall,(i.e., there is 95% probability of achieving this value, or only 5% probability of not achieving the same) is defined as characteristic strength of concrete.

Characteristic strength of concrete in flexural member :-

It may be noted that the strength of concrete cube does not truly represent the strength of concrete in flexural member because factors namely, the shape effect, the prism effect, state of stress in a member and casting and curing conditions for concrete in the member. Taking this into consideration the characteristic strength of concrete in a flexural member is taken as 0.67times2.6 the strength of concrete cube.

Design strength (fd) and partial safety factor(γd) for material strength :-

The strength to be taken for the purpose of design is known as design strength and is given by

Design strength *(fd)* = characteristic strength($f$ck)

Partial safety factor for material

Strength (γm)

The value of γm depends upon the type of material and upon the type of limit state. According to I.S. code,

γm = 1.5 for concrete and γm = 1.15 for steel.

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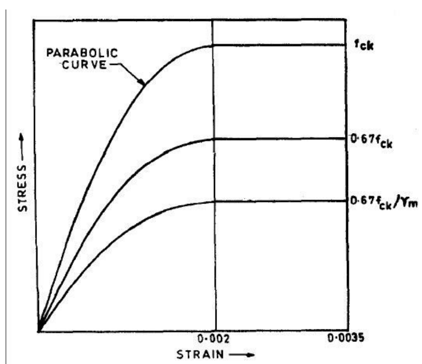
Design strength of concrete in member = 0.67𝑓ck / 1.5 = 0.446 𝑓ck ≈ 0.45 𝑓ck

In compression, concretes is very strong and in tension it is very weak (almost zero). To resist the tension and to counteract the moment which can't resist by the concrete, reinforced (steel bars) are provided. Due to non-uniform compaction and inadequate curing, the partial safety factor for concrete generally taken as 1.5 and partial safety factor for steel is taken as 1.15. For the design work, the maximum strength of the concrete is taken as - 0.67fck/1.5=0.45fck and for steel is fy/1.15=0.87 fy



STRESS-STRAIN CURVE FOR CONCRETE

Fig.4

BEAM

Effective depth of a beam is the distance between centroid of area the tension member to the maximum compression member. Generally the span length to effective depth ratio is taken as followings for different beams.

CANTILEVER-7

SIMPLY SUPPORTED-20

CONTINUOUS-26

The Reinforcement should be given both transversally and longitudinally. Transverse reinforcement is provided to hold the longitudinal bar in its position. Maximum reinforcement for beam shouldn't be more than 6percent.

The minimum shear reinforcement for a beam should be .75d or 300mm which is lesser.

COLUMN:-

Basically column can be defined as the member which takes compressional load is known as column. It is also known as strut.

According to the L/D ratio, column can be classified as Long, medium or Short.

If lex /B or ley/D more than or equal to 12 then that is called long column

If lex /B or ley/D less than or equal to 12 then that is called short column.

Where

lex is the effective length in X-axis.

ley is the effective length in Y-axis.

D is the effective depth of member

B is the breadth of member.

Generally in site maximum 2.5% reinforcement are taken but code permits reinforcement up to 6% in column. More sizes are provided at the middle portion of columns because it took more load than other.

ANALYSIS AND DESIGN

General

Flat slab structure having G+5 storey is

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analysed for gravity loads and lateral loads. The effect of axial force, moments, shear force, storey drift, storey shear and tensile force are observed for different stories. The analysis is carried out using ETABS& SAFE .

5.1GEOMETRIC DATA (Table.4)

S.NO	ITEM	DIMENSSION
1	Plan dimensions	16.08mx8.69m
2	Length in X- direction	16.08 m
3	Length in Y- direction	8.69 m
4	Floor to floor height	3m
5	No. of Stories	7
6	Total Height of the building	20
7	Thickness of the slab	115 mm
8	Thickness of the drop	175 mm
9	Width of the drop	2100 mm
10	Beam	230x420 mm
11	Size of the column	230x380 mm
12	Grade of the concrete	M20
13	Grade of the steel	Fe 500

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ELEVATION OF THE STRUCTURE

5.2 SUPPORT REACTIONS

To prevent translations in vertical and horizontal directions and also rotation, fixed support is provided. Hence in that direction a couple moment is provide

5.3 STRUCTURAL RESPONSES

5.3.1 MAXIMUM STOREY DRIFT

Inter-story drift is one of the particularly useful engineering response quantity and indicator of structural performance, especially for high-rise buildings. However, many researchers and engineers do not notice the difference between inter-story drift and harmful inter-story drift. Also, few rogrammers have considered the harmful inter-story drift in their structural analysis procedure. So they may unreasonably use the inter-story drift as unique standard for structural behavior judgment, which may eventually lead to unacceptable results and relatively conservative conclusions.

5.3.2 SHEAR FORCE

Parallel forces or unaligned forces are called shearing forces pushing one part of a body in one direction, and another part the body in the opposite direction. William A. Nash defines shear force thus: "If a plane is passed through a body, a force acting along this plane is called shear force or shearing force.

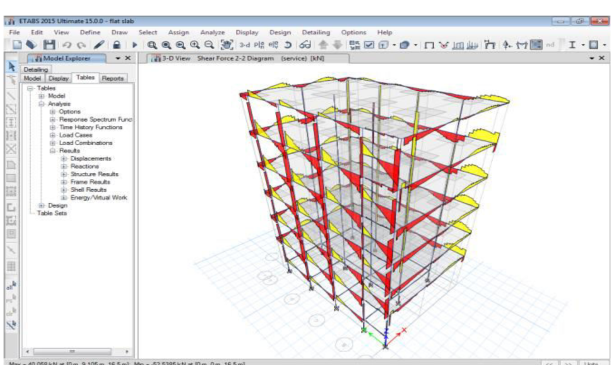

FIG.9Shear force

5.3.3 MOMENTS

When an external force is applied causing the element to bend, then the moment is measured by the average internal stress induced in a structural element. The internal stresses can be resolved into a resultant force and a resultant couple. For equilibrium, the moment created by external forces (and external moments) must be balanced by the couple induced by the internal stresses.

The resultant internal couple is called the bending moment while the resultant internal force is called the shear force (if it is transverse to the plane of element) or the normal force (if it is along the plane

COLUMN DESIGN

6.1 Column Design

Procedure to design column in ETABS

1. Go to Select → Select → Object type → Columns → Select → Close.
2. Go to Design → Concrete frame design → View/Revise overwrites→ Effective length=1
3. Go to Design →Concrete frame design → Start design/Check.

   We get area of steel. If we get red color, it indicates that the column is failed. We no need to re-design/check again if it indicates pink color.

6.2 Design Reports

To get Design Reports of the column

1. Go to Display
2. Then click on the show tables at the bottom.
3. Select design option.
4. From the design , click on Concrete Design .
5. Concrete Column PMM envelop

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will be developed.

Then export it into excel. Now design of column reinforcement is done for the highest value in the area of steel.

6.3 Cross Section Property

To change the cross section property

1. Select the elevation view of required column and define the column of required size.
2. Again select the column
3. Go to Assign which is present in the tool bar .
4. Then go to assign frame and select section property and finally column size.
5. For clear view go to 3D View ,
6. Then analyze the structure by using Analysis and run Analysis.
7. To display it in the form tables
8. Select → Object type → Column → Apply → OK → Display → Show tables → Design concrete design.
9. To get the detailed result of one column, select column and then right click, go to envelope and then go to interactive.

Figure : Column Design

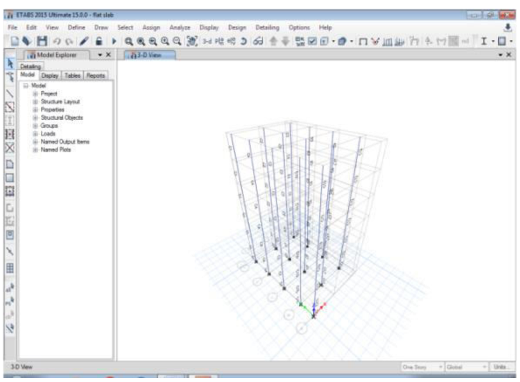

FIG.11 Structural Columns

COLUMN REINFORCEMENT

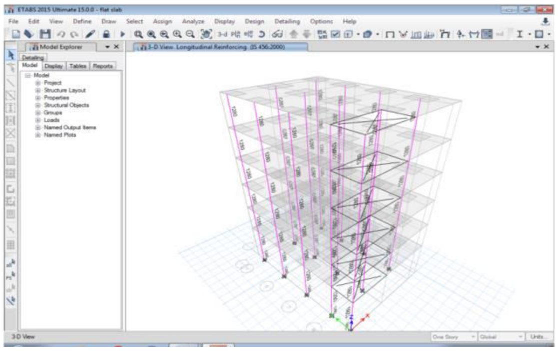

FIG.12 Column Reinforcement

COLUMNSUMMARY

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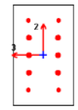
ETABS2015ConcreteFrameDesign

IS456:2000ColumnSectionDesign



Column Element Details Type: Non Sway Frame (Shear Details)

Level	Element	Section ID	Combo ID	Station Loc	Length(mm)	LLRF
5thslab	C3	Column230X380	Strength	2580	3000	1

Section Properties

b(mm)	h(mm)	dc(mm)	Cover(Torsion)(mm)
230	380	60	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt. Wt Factor (Unitless)	F_y (MPa)	F_{ys} (MPa)
22360.68	20	1	500	500

Design Code Parameters

γ_C	γ_S
1.5	1.15

Additional Moment Reduction Factor k (IS39.7.1.1)

A_g cm²	A_{sc} cm²	P_{uz} kN	P_b kN	P_u kN	K Unitless
874	7	1048.8	275.222	195.987	1

Additional Moment (IS39.7.1)

	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	0.86	380	6.789	12	No	0
Minor Bending(M_2)	Yes	0.86	230	11.217	12	No	0

Sep2.EDB Page1of2 9/2/2015

BEAM DESIGN

7.1 Beam Design

Procedure to design beams in ETABS

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1. Go to Design

2. Select Concrete frame design from the design

3. Click on the Start design check. Then we get area of steel values.

According to SP-34
Detailing of reinforcement in RC bars
Minimum 2bars @top
Minimum 2bars @bottom

Note:

After the design of beam, if the color on the beam turns out to be red, then it indicates that it may fail in bending or the combined effect of shear and torsion. If the area of steel shown on the screen, it indicates that the failure is in the combined effect of shear & torsion.
If the beam fails, select it then right click on it. We get O/S values under shear steel. To get detailed calculation go to shear at bottom.

BEAM DESIGN

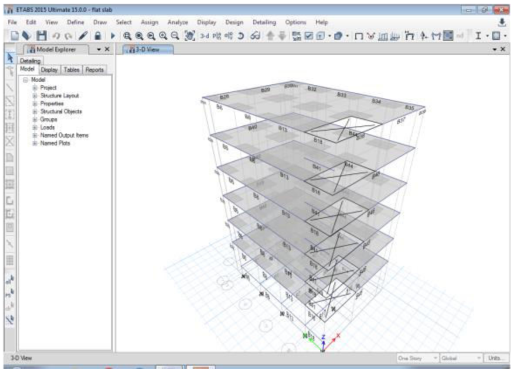

FIG.13 Structural Beams

Beam reinforcement

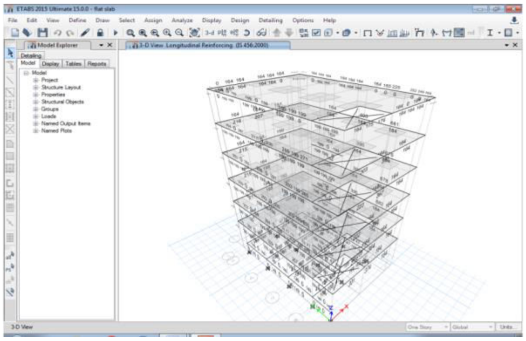

FIG.14 Beam reinforcement

7.2 Design Reports

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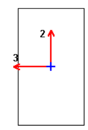
ETABS2015ConcreteFrameDesign

IS456:2000 Beam Section Design



Beam Element Details Type: Non Sway Frame (Summary)

Level	Element	Section ID	Combo ID	Station Loc	Length(mm)	LLRF
1stslab	B1	Beam230X420	Strength	3203	3393	1

Section Properties

b(mm)	h(mm)	bf(mm)	d_s(mm)	d_{ct}(mm)	d_{cb}(mm)
230	420	230	0	45	45

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt. Wt Factor (Unitless)	F_y (MPa)	F_{ys} (MPa)
22360.68	20	1	500	500

Design Code Parameters

γ_C	γ_S
1.5	1.15

Factored Forces and Moments

Factored M_{u3} kN-m	Factored T_u kN-m	Factored V_{u2} Kn	Factored P_u kN
-13.9486	1.7987	40.8908	-0.9347

Design Moments, M_{u3} & M_t

Factored Moment kN-m	Factored M_t kN-m	Positive Moment kN-m	Negative Moment kN-m
-13.9486	2.9902	0	-16.9388

Sep2.EDB Page1of2 9/2/2015

SLAB DESIGN

8.1 PUNCHING SHEAR DATA

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Flat slab exhibits higher stress at the column connection .They are most likely to fail due to punching shear which will occur due to the concentration of shear forces and the unbalanced bending and twisting moments . It has to be noted that the punching shear failure is rather more critical than the flexural failure. Such a concentration of shear force and moments leads to unsymmetrical stress distribution around the slab-column connections. The local and brittle nature of the punching shear failure is in the form of crushing of concrete in the column periphery before the steel reinforcement reaches the yield strain. The observed angle of failure surface is found to vary between 26° and 36°. Thus the punching shear capacity of a slab (in absence of shear reinforcement) depends on the strength of concrete, the area of tension reinforcement, the depth of the slab and the column size. The sudden disaster effect of the punching shear is a critical problem for any designer. Punching shear is a type of failure of reinforced concrete slabs subjected to high localized forces. In flat slab structures this occurs at column support points. The failure is due to shear.

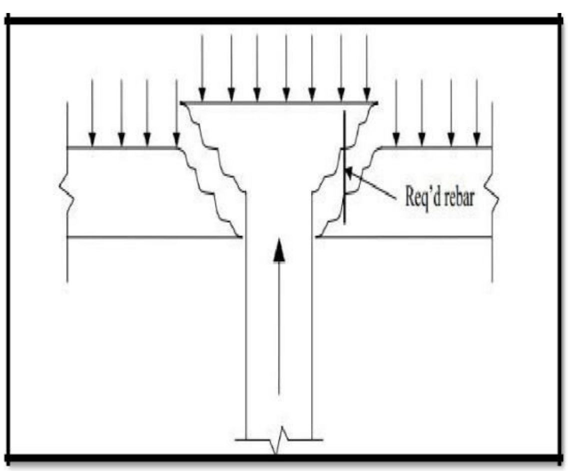

Fig.15 Punching Shear failure

Fig.16 Global collapse of the structure

The effect on the slab is referred to punching shear when the flat slab is exposed to a concentrated load larger than the capacity. The shear force per unit length can become high close to the area of loading in these slabs. Punching shear failure may occur within the discontinuity regions (D-region) of the flat slab if the capacity for punching in the slab is exceeded. This is a brittle failure mechanism, and may cause a global failure of the structure. For slab-column connection, punching shear failure is a typical failure. The above figure shows an example of a global failure of a structure due to punching shear.

PUNCHING SHEAR

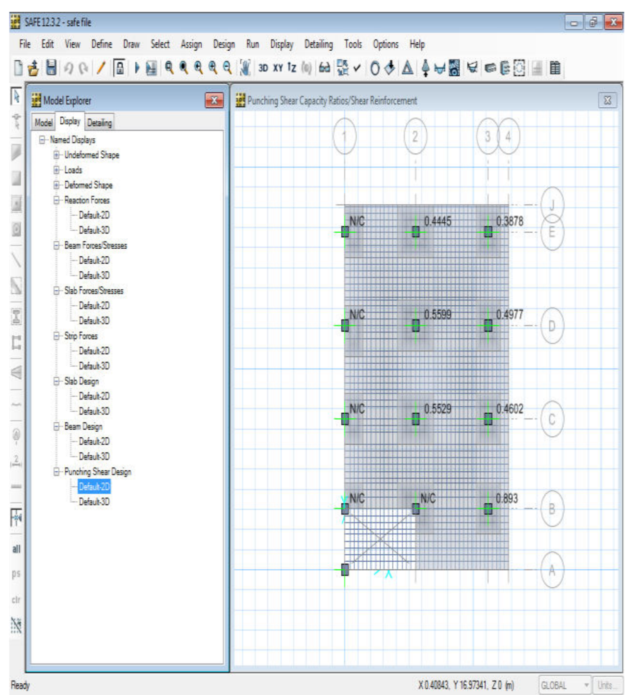

Fig. 17 Punching Shear Results

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TABLE: Concrete Slab Design 02 - Punching Shear Data									
Point	GlobalX	GlobalY	ReinfType	Status	Ratio	NumRails	StudPerRail	Combo	ShrStrMax
Text	m	m	Text	Text	Unitless	Unitless	Unitless	Text	N/mm2
6	0	12.591	None	Not Calculated					
14	4.145	12.591	None	OK	0.44446			1DL+1LL	0.496921
22	8.381	12.591	None	OK	0.387788			1DL+1LL	0.433561
30	0	9.105	None	Not Calculated					
38	4.145	9.105	None	OK	0.559855			1DL+1LL	0.625937
46	8.381	9.105	None	OK	0.497703			1DL+1LL	0.556449
54	0	5.619	None	Not Calculated					
62	4.145	5.619	None	OK	0.552905			1DL+1LL	0.618166
70	8.381	5.619	None	OK	0.460154			1DL+1LL	0.514467
78	0	2.267	None	Not Calculated					
86	4.145	2.267	None	Not Calculated					
94	8.381	2.267	None	OK	0.893033			1DL+1LL	0.998441
102	0	0	None	Not Calculated					

Table.7 Punching Shear Data

8.2 DROPS:

To help heavy loads the thickness of slab near the support with the column is increased and those are referred to as drops .The drop dimension should be more than one -third of panel length because it has to resist the punching shear which is predominant at the contact of slab and column support.

To assign a drop

Go to draw and then select draw floor/wall objects. Now click on draw rectangular floor/wall. A page will be displayed at the bottom. Then select drop in the property and assign their values. Now click on the centre of column at the required location.

To remove excess portion

Go to draw option and then click on reshape object and select required drop and adjust according to the required(Make all the line ends, perpendicular intersections, mid points etc are visible).

DROPS:

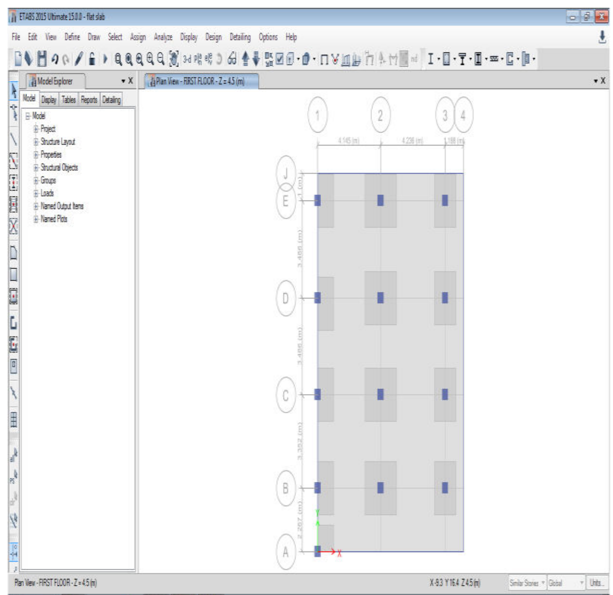

Fig.18 Slab with Drops

8.3 MESHING:

Meshing is done for monolithic existence and structural integrity is done in between columns, slabs and drops. Slabs acts in single direction. Columns and Drops acts in different directions. So we go for meshing.

To mesh the slab

Go to Draw and then go to draw beam/column/brace objects and start drawing from one corner to the other end. To replicate select any line, go to edit option and then click on replicate option.

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TABLE: Concrete Slab Design Summary 01 - Flexural And Shear Data								
Strip	SpanID	Location	FTopComb	FTopMome	FTopArea	FBotComb	FBotMome	FBotArea
Text	Text	Text	Text	kN-m	mm2	Text	kN-m	mm2
CSA1	Span 1	Start	1DL+1LL	-12.3373	295.963	1DL+1LL	2.1394	50.824
CSA1	Span 1	Middle	1DL+1LL	-3.1868	75.742	1DL+1LL	19.9577	482.586
CSA1	Span 1	End	1DL+1LL	-40.3547	997.737	1DL+1LL	0.0243	0
CSA1	Span 2	Start	1DL+1LL	-33.6992	827.762	1DL+1LL	9.3192	222.872
CSA1	Span 2	Middle		0	0	1DL+1LL	15.1028	363.342
CSA1	Span 2	End	1DL+1LL	-34.7091	852.757	1DL+1LL	1.3676	32.445
CSA1	Span 3	Start	1DL+1LL	-27.6087	683.392	1DL+1LL	0	0
CSA1	Span 3	Middle	1DL+1LL	-11.4584	278.471	1DL+1LL	1.2342	35.036
CSA1	Span 3	End	1DL+1LL	-4.371	107.088	1DL+1LL	5.8247	141.876
CSA2	Span 1	Start	1DL+1LL	-17.5201	422.56	1DL+1LL	1.8797	44.641
CSA2	Span 1	Middle	1DL+1LL	-3.8231	90.923	1DL+1LL	27.9417	681.428
CSA2	Span 1	End	1DL+1LL	-53.7097	1348.587	1DL+1LL	0.03	0
CSA2	Span 2	Start	1DL+1LL	-46.3898	1154.873	1DL+1LL	11.9144	285.692
CSA2	Span 2	Middle		0	0	1DL+1LL	22.3046	540.676
CSA2	Span 2	End	1DL+1LL	-48.3023	1205.149	1DL+1LL	1.0716	25.416
CSA2	Span 3	Start	1DL+1LL	-39.6036	989.815	1DL+1LL	0	0
CSA2	Span 3	Middle	1DL+1LL	-16.1878	394.215	1DL+1LL	0.4835	17.941
CSA2	Span 3	End	1DL+1LL	-5.3689	131.149	1DL+1LL	6.2432	152.101
CSA3	Span 1	Start	1DL+1LL	-17.2276	415.378	1DL+1LL	2.2545	53.566
CSA3	Span 1	Middle	1DL+1LL	-3.581	85.144	1DL+1LL	26.9977	657.735
CSA3	Span 1	End	1DL+1LL	-50.47	1262.419	1DL+1LL	0.0291	0
CSA3	Span 2	Start	1DL+1LL	-41.8552	1039.548	1DL+1LL	11.211	268.632
CSA3	Span 2	Middle		0	0	1DL+1LL	20.5806	497.975
CSA3	Span 2	End	1DL+1LL	-37.9282	935.192	1DL+1LL	1.3236	31.4
CSA3	Span 3	Start	1DL+1LL	-25.5631	637.369	1DL+1LL	0	0
CSA3	Span 3	Middle	1DL+1LL	-9.5404	234.011	1DL+1LL	0.7824	26.729
CSA3	Span 3	End	1DL+1LL	-3.2326	81.053	1DL+1LL	3.875	96.376
CSA4	Span 1	Start	1DL+1LL	-7.5566	184.191	1DL+1LL	1.5797	49.096
CSA4	Span 1	Middle	1DL+1LL	-4.3292	115.035	1DL+1LL	11.4207	281.89
CSA4	Span 1	End	1DL+1LL	-33.2357	865.346	1DL+1LL	0.0081	18.121
CSA4	Span 2	Start	1DL+1LL	-50.7114	1272.794	1DL+1LL	16.3184	393.083
CSA4	Span 2	Middle		0	0	1DL+1LL	22.6472	553.955
CSA4	Span 2	End	1DL+1LL	-71.1449	1837.419	1DL+1LL	1.2282	29.133
CSA4	Span 3	Start	1DL+1LL	-58.076	1484.455	1DL+1LL	0	18.313
CSA4	Span 3	Middle	1DL+1LL	-23.648	580.086	1DL+1LL	0.8597	32.634
CSA4	Span 3	End	1DL+1LL	-7.2297	177.031	1DL+1LL	5.8348	143.557
CSA5	Span 1	Start	1DL+1LL	-9.346	224.035	1DL+1LL	7.9163	189.918
CSA5	Span 1	Middle		0	0		0	0
CSA5	Span 1	End	1DL+1LL	-40.8653	1009.032	1DL+1LL	0.0212	0
CSA5	Span 2	Start	1DL+1LL	-37.0842	919.452	1DL+1LL	0	0

TABLE.8 Flexural and shear data

License

#*1B9B7JQJSK98HES

Models may be imported from ETABS into SAFE by specifying exporting option, story to be exported, load cases and combinations.

To import the data from ETABS, go to file and click on the import option. Then select the required exported file(in safe.f2k format) and then click on OK.

9.1 Procedure

Steps to be followed in safe software

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1. Model geometry
2. Material properties
3. Model assignments
4. Model loading
5. Design summary

Model geometry

This section provides model geometry information, including items such as joint coordinates, joint restraints, and element connectivity.

Model properties

This section provides model properties, including items such as material properties, section properties, and support properties.

Material properties:

To check the materials go to define and click on materials and then check for the required materials like concrete and rebar.

9.2. SECTION PROPERTIES

3. Model assignments

This section provides model assignments, including assignments to slabs, beams, and joints.

4. Model loading

This section provides model loading information, including load patterns, load cases, and load combinations.

5. Design summary

This section provides design information for beams, strips, and punching checks.

9.3. FLAT SLAB DESIGN

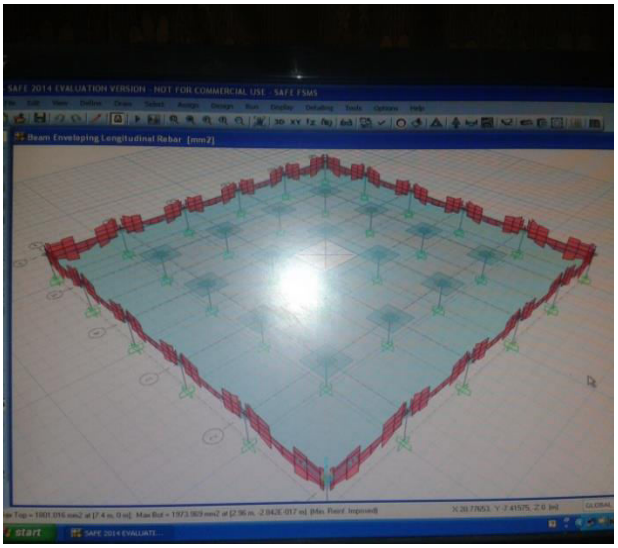

Fig. 21 Flat slab

9.4 Concrete Strip Design:

The strip of the column is designed under the guide lines of code IS 456-2000 and procedure to design is as follows.

1. To draw the design strip go to draw and then draw design strips.
2. To show the width of the strip, go to set display option and click on show width in design strip object.
3. To assign the grade of steel for the strips go to select and click on labels.
4. To design go to design and click on slab design over writes and then assign the rebar material.

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STRIP MOMENTS

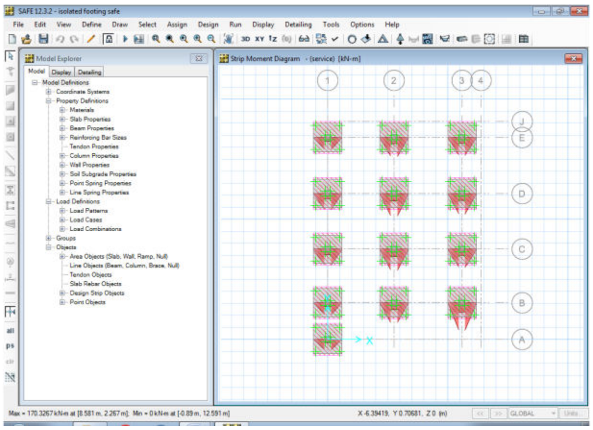


Fig.22 Strip moment along A

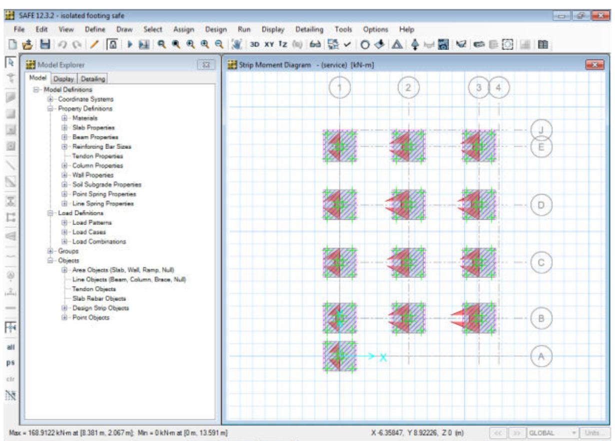


Fig.23 Strip moment along B

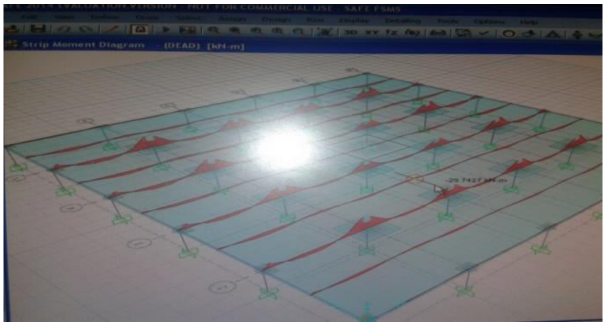


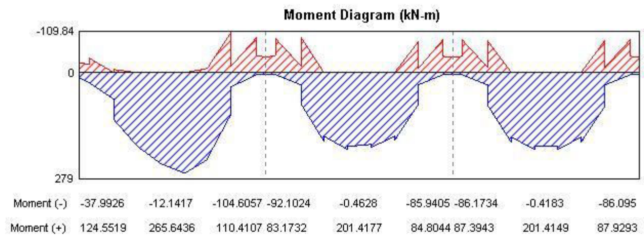
Fig.24 Bending Moment in a Column strip

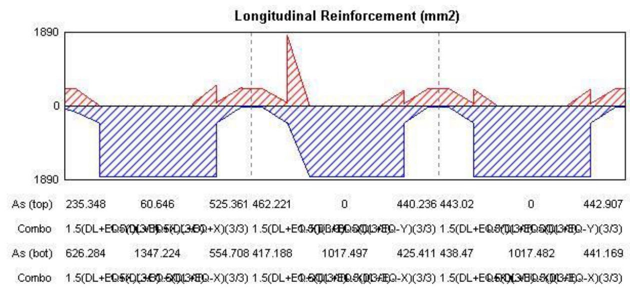
Geometric Properties

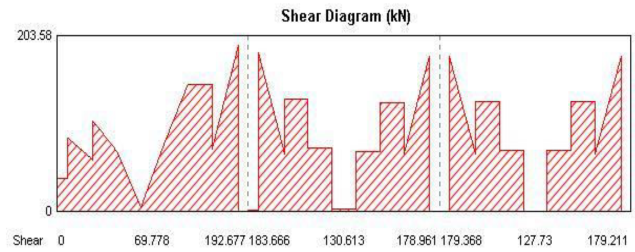
Combination = Overall Envelope
Strip Label = SA1
Length = 40 m
Distance to Top Rebar Center = 24 mm
Distance to Bottom Rebar Center = 24 mm

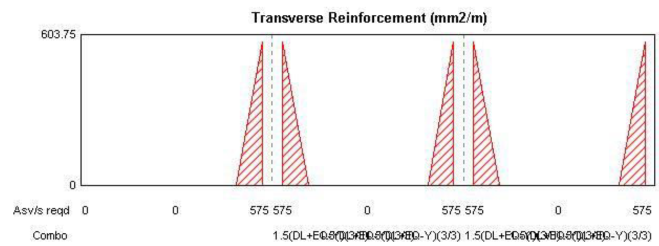
Material Properties

Concrete Comp. Strength = 20 N/mm2
Longitudinal Rebar Yield = 500 N/mm









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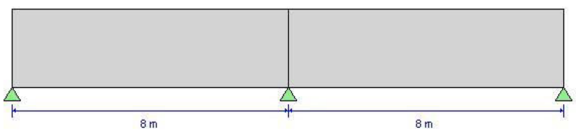

FOOTING DESIGN

There are two types of foundation.

1. Rigid foundation
2. Elastic foundation

In rigid foundation SBC(safe bearing capacity) is taken as input and it can be analyzed by using STAAD-PRO. In elastic foundation, stiffness is taken as input and it is used in theory of plates.

10.1 Footing Design

To design a footing

-

10.3 SOIL PRESSURE

To define soil sub grade modulus i.e 'k' value, go to define then select sol sub grade properties and click on the modify/show property. And then assign k=12500Kn/m3

Soil pressure summary

To display soil pressure go to display and then click on show reaction forces.

Then select Service in the load combo. Finally select soil pressure.

SHEAR WALL

A shear wall is a structural system composed of shear panels to counter the effects of lateral load(wind load and seismic load) acting on a structure are the most common loads that shear walls are designed to carry. Depending on the size of building some interior walls must be braced as well.

To define shear wall

Go to Define and then select section properties. And then wall section and go to modify walls

- Go to define and then select slab properties and click on modify option.
- Then select the required column and place it by giving the material properties like M20 and section properties like 450mm thickness.

To draw foundation

- Go to draw and then click on Quick draw areas around points.
- Then select footing in the property and gives their sectional properties.
- Finally place them in the requiredposition.

into shear wall. Then specify material as M20. Click on shell thin in the modeling type and it's thickness as 230mm.

Location of shear wall gives depends on trial and error method. Whichever the location gives the optimum moments on the column that will be the finalized location of the structure.

To draw the shear wall

Go to draw then select draw floor/wall objects and then click on draw walls. Select shear wall in the property and pier in the type of area. Now analyze the structure.

To see the reactions at the base

Go to display option and then select force/stress diagram and click on support /spring reactions. Select case in EQX.

DESIGN

Go to Define and select pier /labels and add some piers. Select shear wall in all the floors and go to design and click on the select shear wall design then click on view/revise preferences and assign the required material like rebar(HYSD500). Now go to Design and then shear wall design and then start analyzing by click on start design check.

CONCLUSIONS:

1. Lateral load resisting system should be coupled with slab column frame and or stiffness of column should be increases to improve drift conditions of flat slab in higher seismic zones.
2. To resist the larger of two interior negative design moments for the span framing into common supports, the negative moment's section shall be designed.
3. To increase the shear strength of the slab, drops are important criteria.
4. The negative moment is highly concentrated within the critical perimeter of the column; positive moment is much more uniform with maximum at column center line.
5. The maximum axial force is 293003.2 KN
6. The maximum storey drift in between zone II and III is 36%.
7. The difference in maximum shear force between seismic zone II and zone III is 36 %.
8. The difference in maximum storey shear between seismic zone II and zone III is 37%.
9. The difference in maximum moments between seismic zone II and zone III is 5%
10. The difference in maximum tensile force between seismic zone II and zone III is 33%.
11. The time period for mode-I in the structure is 2.031 sec for zone-II