DESIGN AND DETAILING OF VARIOUS TYPES OF BEAM BY USING SOFTWARE

Submitted in partial fulfilment of the requirements
for the degree of
Bachelor of Engineering
by

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CERTIFICATE

This is to certify that the project entitled **"DESIGN AND DETAILING OF VARIOUS TYPES OF BEAM BY USING SOFTWARE"** is a bonafide work of **Kazi Mohammed Ibrahim (15CE18), Siddiqui Faizan Ali (15CE54), Momin Arbaz (16DCE76), Khan Arbaz (16DCE67)** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

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APPROVAL SHEET

This dissertation report entitled **"DESIGN AND DETAILING OF VARIOUS TYPES OF BEAM BY USING SOFTWARE"** by **Kazi Mohammed Ibrahim (15CE18), Siddiqui Faizan Ali (15CE54), Momin Arbaz (16DCE76), Khan Arbaz (16DCE67)** is approved for the degree of "Civil Engineering"

Examiners

1. ……………………………

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Date:

Place: Panvel

DECLARATION

We declare that this written submission represents ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that, we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

A beam is a structural element that is capable of withstanding load primarily by resisting bending. The bending force induced into the material of the beam as a result of the external loads own weight span and external reactions of these loads is called a bending moment.

Beams are traditionally descriptions of a building or civil engineering structural elements but smaller structure such as a truck or automobile frames machine frame and other mechanical or structural systems contains beams structures that are designed and analysed similarly.

This project deals with design of various types of beam using ETABS software and detailing by using AutoCAD software along with other analytical details of beam under different type of loadings.

CONTENTS

LIST OF FIGURES

ABBREVIATION NOTATION AND NOMENCLATURE

RC	Reinforced Concrete
SF	Shear Force
BM	Bending Moment
ACI	American Concrete Institute

Chapter 1

Introduction

A reinforced concrete (RC) structure has several members in the form of beams, slabs, and walls that are rigidly connected to form a monolithic frame. Each individual member must be capable of resisting the forces acting on it. A beam is a structural element that primarily resists loads applied laterally to the beam's axis. Its mode of deflection is primarily by bending. The loads applied to the beam result in reaction forces at the beam's support points. The total effect of all the forces acting on the beam is to produce shear forces (S.F) and bending moments (B.M) within the beam, that in turn induce internal stresses, strains and deflections of the beam. The term girder is also used to represent beams but is usually a large beam that may support several beams. Beams support the loads applied on them by slabs and their own weight by internal moments and shears. Refer fig.1

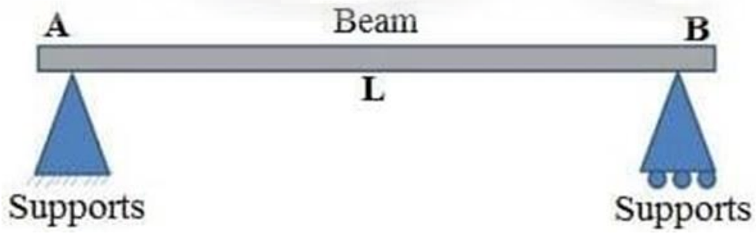


Fig. 1. Beam

Beams are traditionally descriptions of building or civil engineering structural elements, but any structures such as automotive automobile frames, aircraft components, machine frames, and other mechanical or structural systems contain beam structures that are designed to c arry lateral loads are analysed in a similar fashion.

1.1 Classification of Beams

1.1.1 Based on support conditions

1.1.1.1 Simply Supported Beam

A simply supported beam is a type of beam that has pinned support at one end and roller support at the other end. Depending on the load applied, it undergoes shearing and bending. It is the one of the simplest structural elements in existence. Refer fig 1.1

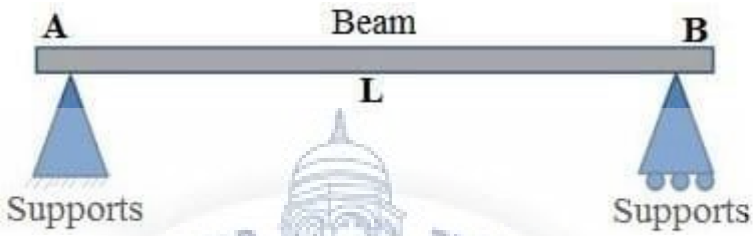


Fig. 1.1: Simply supported Beam

1.1.1.2 Continuous Beam

A continuous beam is a statically indeterminate multi-span beam on hinged support. The end spans may be cantilever, may be freely supported or fixed supported. At least one of the supports of a continuous beam must be able to develop a reaction along the beam axis. Refer fig 1.2

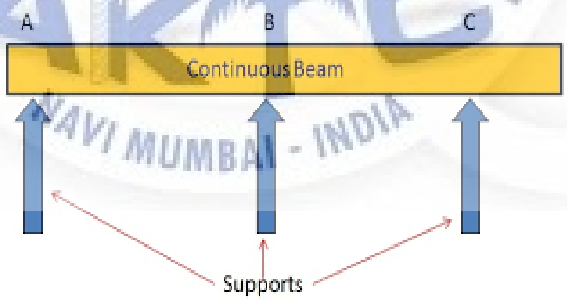


Fig. 1.2: Continuous Beam

1.1.1.3 Fixed Beam

A fixed beam is supported at both free ends and is restrained against rotation and vertical movement. It is also known as built-in beam. Structural beams resting at supports which get fixed and can’t rotate or free to move are fixed beams. They will generally design not to take any Bending Moments. Refer fig 1.3

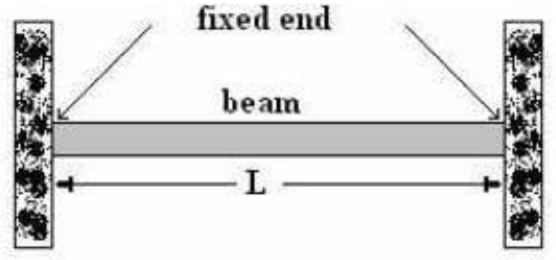


Fig. 1.3: Fixed Beam

1.1.1.4 Cantilever Beam

A beam which is fixed at one end and free at another end is known as Cantilever beam. Refer fig 1.4

Fig. 1.4: Cantilever Beam

1.1.2 Based on construction materials

1.1.2.1 Reinforced Concrete Beam

It is constructed from concrete and reinforcement. Refer fig 1.5

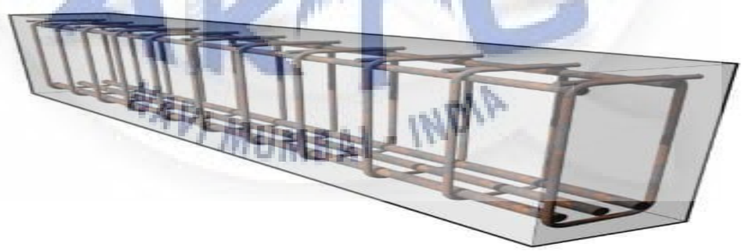


Fig. 1.5: Reinforced Concrete Beam

1.1.2.2 Steel Beam

It is constructed from steels and used in several applications. Refer fig 1.6

Fig. 1.6: Steel Beam

1.1.2.3 Timber Beam

This type of beam is constructed from timber and used in the past, but its application is significantly declined now. Refer fig 1.7

Fig. 1.7: Timber Beam

1.1.2.4 Composite Beam

Composite beams are constructed from two or more different types of materials such as concrete and steel, and various valid cross sections have been utilized. Refer fig 1.8

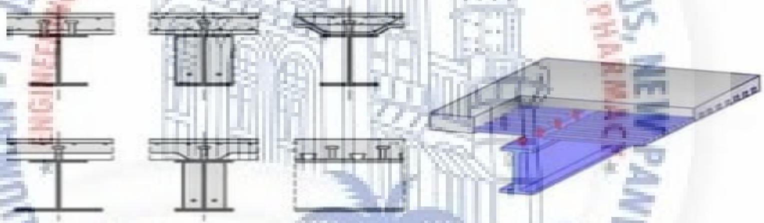


Fig. 1.8: Composite Beam

1.1.3 Based on Geometry

Several cross-sectional shapes of beams are available and used in different parts of structures. These beams can be constructed from reinforced concrete, steel, or composite materials:

1.1.3.1 Rectangular Beam

This type of beam is widely used in the construction of reinforced concrete buildings and other structures.

a. Singly Reinforced Beam

In RC beam of rectangular cross section, if the reinforcement is provided only in the tension zone, it is called a singly reinforced rectangular beam.

b. Doubly Reinforced Beam

When the reinforcement provided on both side i.e. in tension zone as well as compression zone then that beam is considered as doubly reinforced beam. The doubly reinforced beam is provided when the dimensions of cross-section and the grade of concrete and steel is restricted.

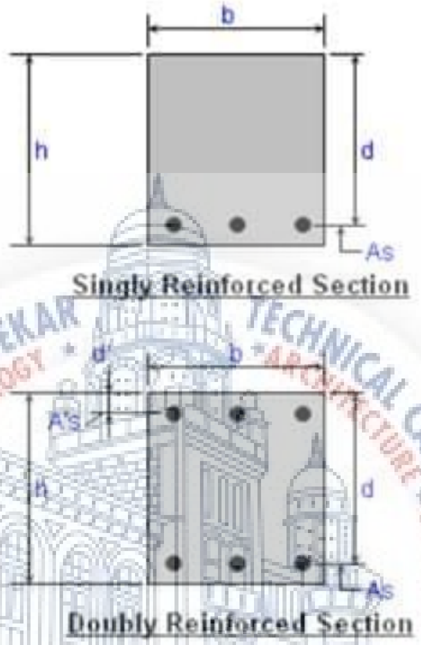


Fig. 1.9: Singly and Doubly Reinforced Beam

1.1.3.2 T Beam

This type of beam is mostly constructed monolithically with reinforced concrete slab. Sometimes, Isolated T-beam are constructed to increase the compression strength of concrete. Refer fig 1.10

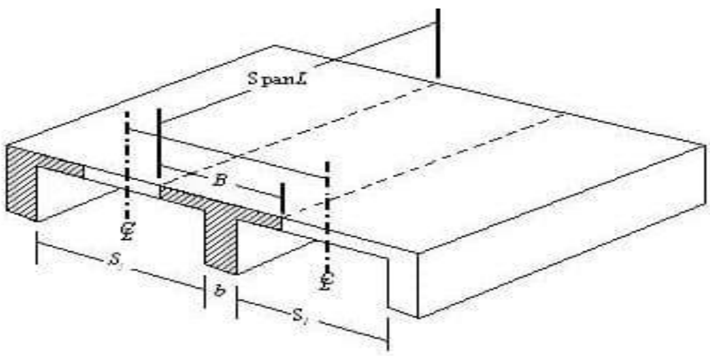


Fig. 1.10: T-beam and L-beam

1.1.3.3 L Beam

This type of beam is constructed monolithically with reinforced concrete slab at the perimeter of the structure, as shown in fig. above.

1.1.3.4 Deep Beam

The beams that have large depths, and its clear span to depth ratio is less than 4 according to ACI Code. Significant amount of the load is carried to the supports by a compression force combining the load and the reaction. Consequently, the strain distribution is no longer considered linear as in the case of conventional beams. Refer fig 1.11

Fig. 1.11

1.1.3.5 Straight Beam

Beam with straight profile is called as straight beam and majority of beams in structures are straight beam. Refer fig 1.12

Fig. 1.12: Straight Beam

1.1.3.6 Curved Beam

Beam with curved profile is called as curved beam, such as in case of circular buildings. Refer fig 1.13

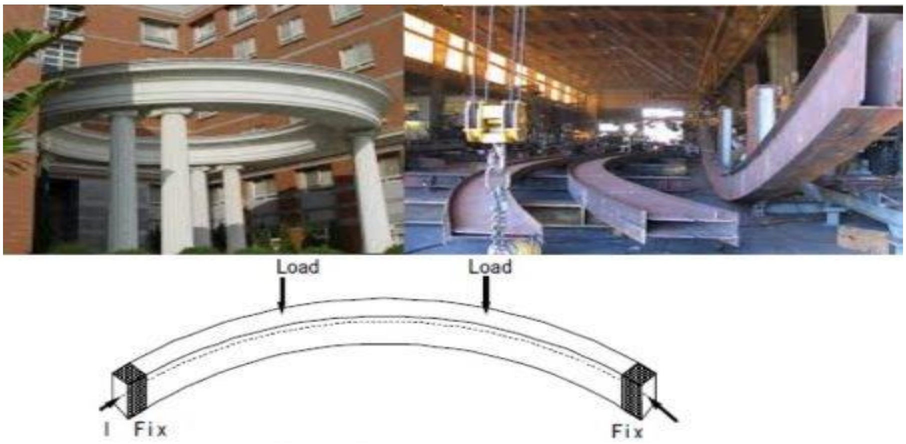


Fig. 1.13: Curved Beam

1.1.3.7 Tapered Beam

Beam with tapered cross section is called as tapered beam. Refer fig 1.14

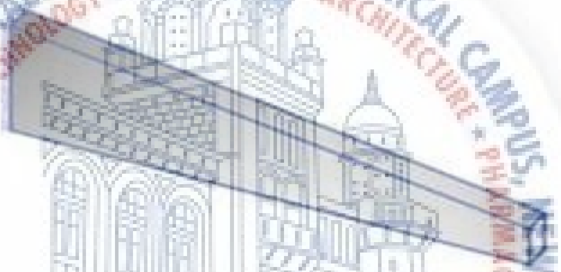


Fig. 1.14: Tapered Beam

1.1.4 Based on Equilibrium Condition

1.1.4.1 Statically Determinate Beam

For a statically determinate beam, equilibrium conditions alone can be used to solve reactions, i.e. the number of unknown reactions are equal to the number of equations. Refer fig 1.15

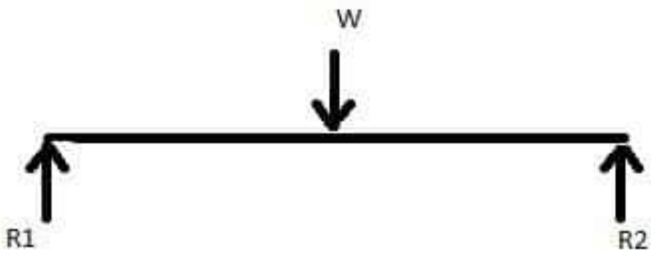


Fig. 1.15: Statically Determinate Beam

1.1.4.2 Statically Indeterminate Beam

For statically indeterminate beam, equilibrium conditions are not enough to solve reactions. So, the analysis of this type of beam is more complicated than that of statically determinate beams. Refer fig 1.16

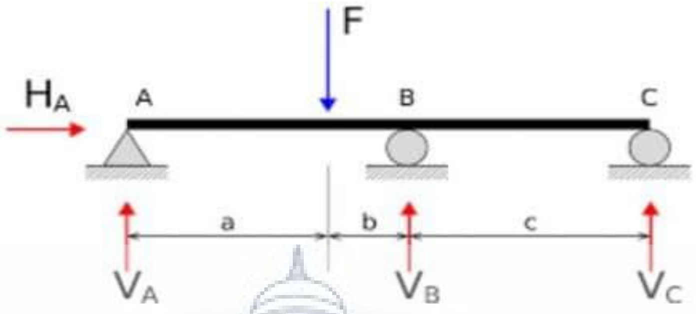


Fig. 1.16: Statically Indeterminate Beam

1.1.5 Based on Method of Construction

1.1.5.1 Cast In-situ Concrete Beam

This type of beam is constructed on project site. So, forms are initially fixed then fresh concrete is poured and allowed to be hardened. Then, loads will be imposed. Refer fig 1.17

Fig. 1.17: Cast In-Situ Beam

1.1.5.2 Precast Concrete Beam

This type of beam is manufactured in factories. So, the construction condition is more controllable compare with on-site construction. Consequently, the quality of concrete of the beam will be greater.

Various cross-sectional shapes can be manufactures such as T-beam, Double T-beam, inverted T-beam and many more. Refer fig 1.18

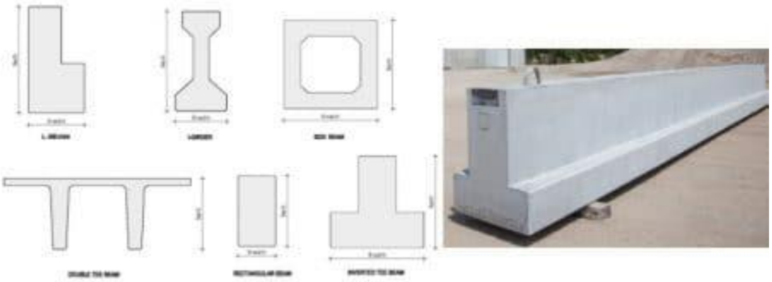


Fig. 1.18: Precast Concrete Beam

1.1.5.3 Pre-stressed Concrete Beam

This type of beam constructed by stressing strands prior to applying loads on the beam. Pre-tensioned Concrete Beam are variations of pre-stressed concrete beam. Refer fig 1.19

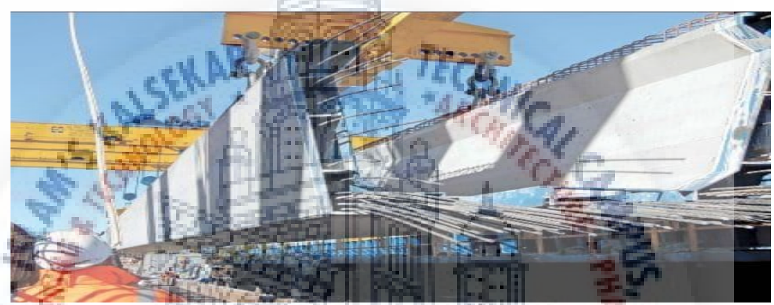


Fig. 1.19: Pre-Stressed Concrete Beam

1.1.6 Based on loading

1.1.6.1 Torsion Beam

Structural concrete members are often subjected to torsional moments in addition to bending moments and axial or shear forces. Torsion develops in structural members as result of symmetrical loadings, member geometry, or structural framing. In complex structures such as helical stairways, curved beams, and eccentrically loaded box girders, torsional effect dominates the structural behaviour. Torsional moment tends to twist the structural member around its longitudinal axis, including shear stresses. However structural members are rarely subjected to torsional moment alone. Usually torsional moments act concurrently with bending moment (B.M.) and shear or axial forces. As the torsional cracks spiral around the beams, it is necessary to provide closed stirrups as well as additional longitudinal reinforcement, especially at the corners of the faces of the beam.

1.1.6.2 Coupling Beam

Coupling beams are a very important member of a lateral force resisting system. It couples, or we can say combines two independent systems. Coupling beam is used effectively when two shear wall or any other elements that are used for withstanding lateral loads is combined. This consequently decrease overturning effect and improve overall stiffness of a system.

Moreover, if coupled beam proportioned properly above second floor of building, plastic hinges are developed and subjected to similar rotations at the beam end over structure height at the same time. This lead to distribute input energy dissipation over the height of the structure in the coupling beams instead of concentration mostly in the wall piers of the first story. Therefore, the main function of coupling beam is dissipation of energy and improving stiffness and strength of the lateral load system of the structure. Refer fig 1.20

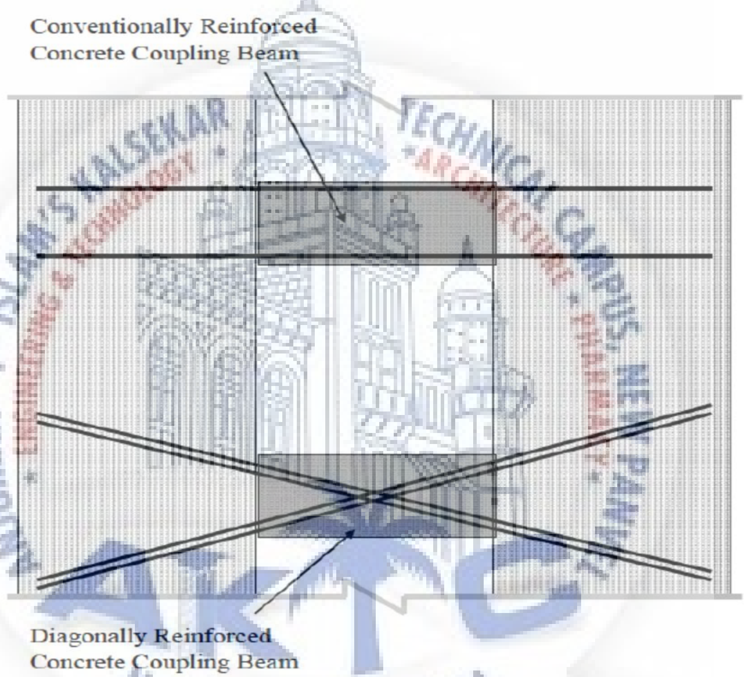


Fig. 1.20: Coupling Beam

1.1.6.3 Strap Beam

A strap footing is a component of a building's foundation. It is a type of combined footing, consisting of two or more column footings connected by a concrete beam. This type of beam is called a strap beam.

It is used when the distance between the columns is so great that a combined trapezoidal footing becomes quite narrow, with high bending moments. In this case the column is provided with its independent footings and a beam is used to connect the two footings. A strap footing is a component of a building's foundation. Refer fig 1.21

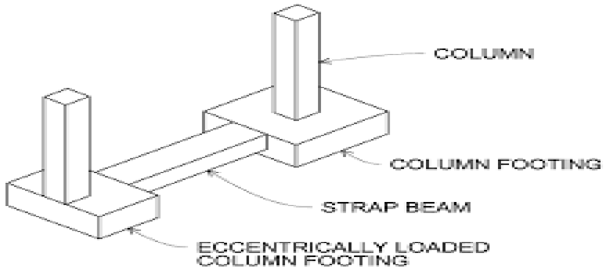


Fig. 1.21: Strap Beam

1.1.6.4 Crank Beam

A crank beam is an angled beam with two kinks, making a 90-degree angle. The top member of the beam is horizontal, while the bottom is vertical. Crank beams are most commonly used as support for roof structures due to their distinct shape. The angle of the middle member of the beam then has to be exactly the same as the pitch of the roof. For these connections, full penetration welds should be used in order to make sure that the crank is strong enough to carry the load. The crank beams are normally provided in stairs.

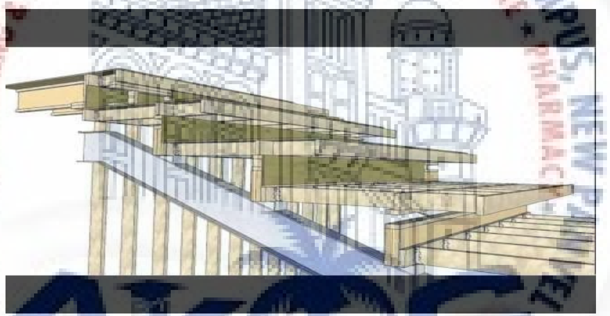


Fig. 1.22 Crank Beam

1.1.6.5 Girder

Beams that take heavy loads, generally steel sections are used. Refer fig 1.22

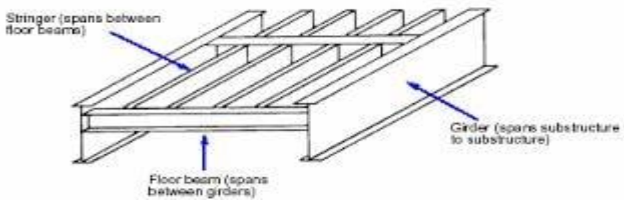


Fig. 1.23: Girder

Chapter 2

Literature Review

Taesang *et al*. 2011 Shown the failure of coupling beam with small length to depth ratio. So, to improve the ductility of coupling beam provides diagonal reinforcement in the beam. If the diagonal reinforcement increase causes problem due to congested reinforcement in some part of the beam. Recent research on the coupling beam has shown that the post tensioning is an effective method for seismic region because it resists the gravity forces, wind forces, and seismic forces. In this paper investigators made new types of coupling beam with energy dissipation device such as metallic damper and frictional damper which reduces framing system in the structures. In the couple shear wall system metallic damper or frictional damper is inserted into the beam. Which gives better performance as compared to conventional reinforced concrete couple shear wall. Damage of these systems are concentrated only at the dampers rather than at the shear wall and beams. quasi-static test is conducted to verify the performance of the reinforced concrete couple shear wall.

Nursiah *et al*. 2014 Coupling beam is defined as the beam that connect with couple shear wall. And it usually required where provided excess stairwell or elevators. It is used to resist high shear and force of earthquake. There is a types of coupling beam. concrete coupling beam. It consists of longitudinal reinforcement, concrete, shear stirrups. It has more stirrups than the ordinary beam. the behaviour of coupling beam is different than the ordinary beam. Concrete coupling beam is unsafe in cyclic load and almost brittle and exhibited shear failure. Hybrid coupling beam which is the combination of the ordinary reinforced concrete beam and steel truss with composite mortar. This system uses steel trusses which is easier to construct and presence of flange in steel trusses may improve flexural capacity of coupling beam. Indonesia is located at highly seismic region; therefore, it needs special notice for construct high risk buildings. So, in Indonesia coupling beams are mostly provided to resist high shear and forces of earthquake.

Stency Mariam *et al*. 2014 M20 grade of concrete is found to give least cost. FE500 grade of steel is found to give least cost
Reinforcement bars diameter has to be found through optimization.

Moayyad *et al*. 2015 Four different type of shear reinforcement was studied.a new type of shear system was introduced called Swimmer bars system improvement in shear strength of reinforced concrete beam was found compared to traditional system.

Mohammed Rashidi *et al*. 2017 It was observed that the ductility factor increases with increasing percentage of reinforcement.
Torsional strength and ductility of the bars have been increased to 45% to 50% respectively in compared to without reinforcement beam. Transverse bars play an important role in torsional strength of reinforced concrete beam compared to longitudinal.

Based on aforementioned literature review we conclude that coupling beam is design using metallic damper and frictional damper which reduces framing system in the structures. a combination of the ordinary reinforced concrete beam and steel truss with composite mortar are used in coupling beam to resist high shear and improve flexural capacity. In fixed beam swimmer bar were used to improve shear resistance of the beam.M20 grade of concrete and Fe500 grade of steel gives the least cost.

Chapter 3 Methodology

3.1 Limit State Method

Limit state method refers to the method which considers the ultimate strength of the material at failure (which is ignored in working stress method) and also assures that the structure is serviceable for its intended period of design. So, LSM comprise two broad points.

3.1.1 Limit State of Collapse (Ultimate Limit State)

Ultimate limit state deals with states just before the structure collapses. This relate to the safety of people and the safety of structure (strength, fatigue, buckling, sliding and overturning). It has safety index of 3.5.

3.1.2 Limit State of Serviceability

Limit state of serviceability deals with functioning of the structure, acceptability of safety and appearance of the structure (deflections, crack, width, and loss of durability). It has safety index of 1.5.

3.2 Methodology to do along with schedule.

1. Design of beams by manually with limit state method (LSM). using IS 456 :2000

2. Design of beams by ETABS software.

3. Detailing of beams by software with the help of AutoCAD software.

Chapter 4

Analysis and Design of Beams

4.1. Fixed Beam

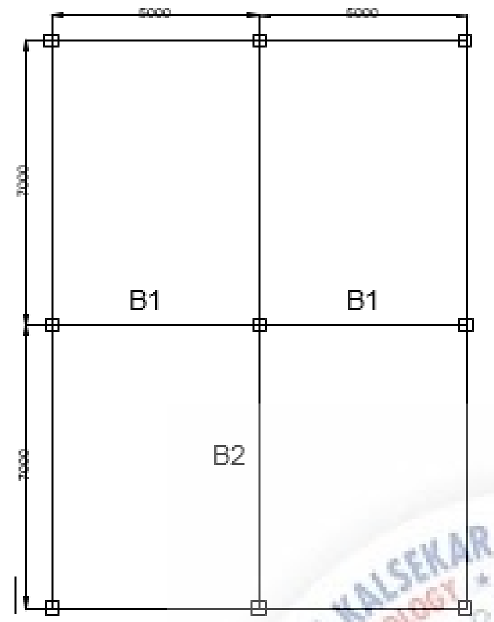
Structural beams resting at supports which get fixed and can't rotate or free to move are fixed beams. They are generally designed for Bending Moments. A fixed beam is supported at both free ends and is restrained against rotation and vertical movement. It is also known as built-in beam.

Fig no 4.1 Fixed beam

4.1.1. Application of Fixed Beams

Fixed beams are used in structural applications in which loads on a beam create a moment in the beam.

4.1.2 Design of Fixed Beam



Load Calculation:

Effective Length, L_{eff}

L_{eff} = clear span + width of the wall = 7+0.23= 7.23 m

L_{eff} = clear span + depth of slab = 7+(0.15-0.03) =7.12 m

Adopt lesser value which is 7.12 m

Load calculation of B_2

Dead load of slab =area× unit weight of concrete × thickness of slab

=\{[(0.5×2.5×2.5) ×4]+[(2×2.5) ×2]\}×25×0.15

=84.375 kN

Live load of slab =Area × 3 kN/m^2

=\{[(0.5×2.5×2.5) ×4]+[(2×2.5) ×2]\}× 3

=67.5 kN

Floor finish of slab= 1.5 kN/m^2 × Area

=1.5 × {[(0.5×2.5×2.5) ×4]+[(2×2.5) ×2]}

=33.75 kN

Total Load = Dead load of slab + Live load of slab + Floor finish of slab

=84.375+67.5+33.75=185.625 kN

Intensity of slab =185.625/7.12 =26.071 kN/m

Brick wall load = height × density × thickness

=2.5 × 20 × 0.3

=11.5 kN/m

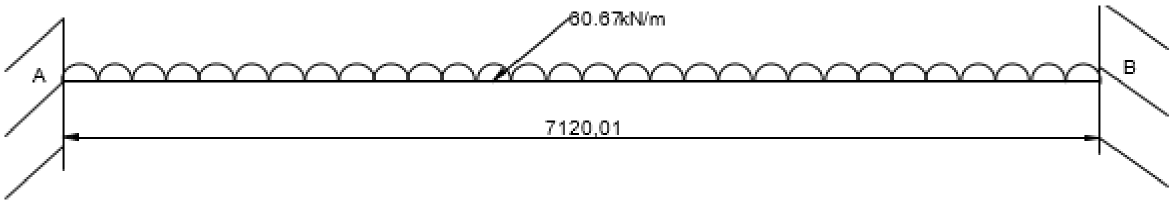
D.L of beam 2 =Area × density

=0.23 × 0.5 × 25

=2.875 kN/m

Total = 40.446 kN/m

Factored intensity = 1.5 × 40.446 = 60.67 kN/m



Δ By Force Flexibility Method

$Ds = 2m + r - 2j + \alpha$

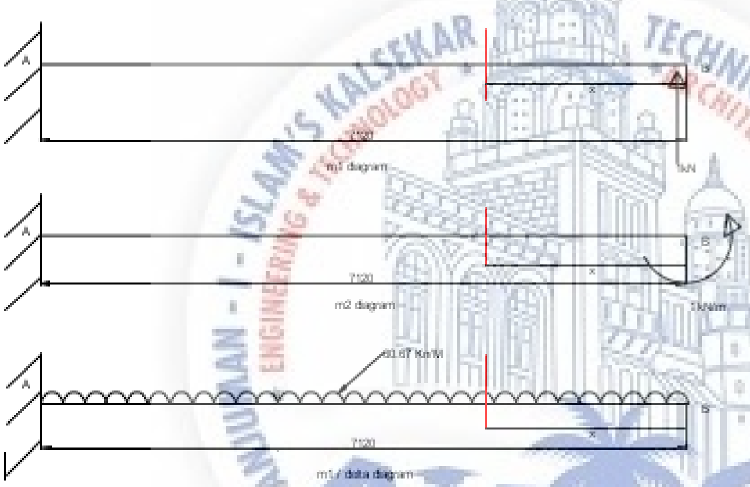
$= (2\times 1) + 4 - (2\times 2) + 0$

$= 2$

Let redundant two force

$V_B = R_1$, $M_B = R_2$.

Now remove redundant



Region	Origin	Limit	M	m_1	m_2	I
AB	B	0 - 7.5	$\frac{60.67 \times x^2}{2}$	$1x$	1	1

Apply Compatibility Equation

$\Delta B_y = 0$

$\Delta_{01} + F_{11}R_1 + F_{12}R_2 = 0$ -------------- 1

$\Delta B_m = 0$

$\Delta_{02} + F_{12}R_1 + F_{22}R_2 = 0$---------------2

Now = $\Delta_{01} = \int_0^l \mathbf{Mm1/EI}\, dx$

Δ_{01} =1/EI $\int_0^{7.12} (-60.67x2/2)\,(1x)\,dx$

Δ_{01} = -119489.647/EI

$\Delta_{02} = \int_0^l \mathbf{Mm2/EI\ dx}$

=1/EI $\int_0^{7.12}(-60.67x2/2)\,(1)$ dx

Δ_{02} = -3649.746/EI

$F_{11} = \int_0^l m1m1/EI$ .dx

=1/EI $\int_0^{7.12}(1x)\,(1x)$. dx

F_{11} = 120.3.1/EI

$F_{12} = F_{21} = \int_0^l \mathbf{m1m2/EI}$ .dx

=1/EI $\int_0^{7.12} (1x)\,(1)$. dx

$F_{12} = F_{21}$ = 25.35/EI

$F_{22} = \int_0^l \mathbf{m2m2/EI}$ .dx

=1/EI $\int_0^{7.12}(1)(1)$ .dx

F_{22} =7.12/EI

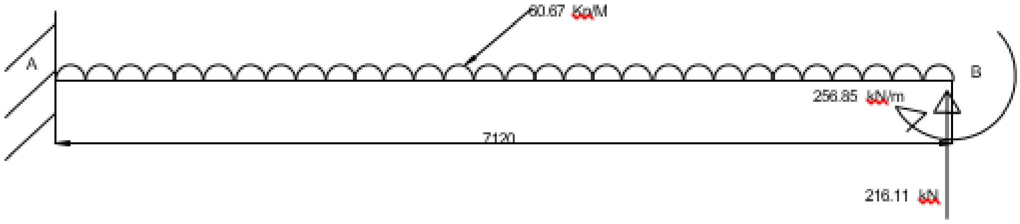
-19489.647 + 120.31 R_1 +5.35 R_2 = 0

-3649.746 + 25.35 R_1 + 7.12R_2 = 0

Solving above equation

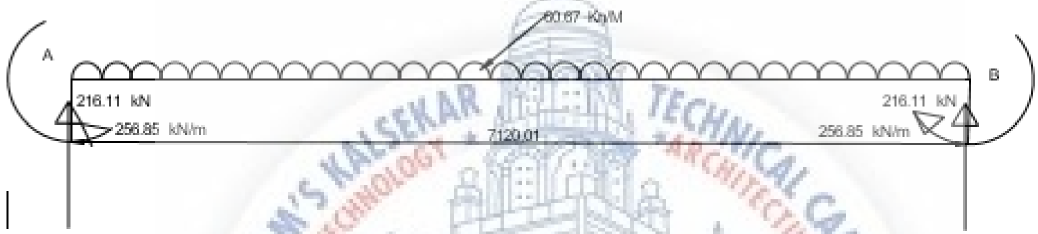
R_1 = 216.11 kN = V_B

R_2 = -256.85kN-m = M_B



V_A = 216.11 kN, M_A = 256.85 kN-m

(due to symmetrical loading alternate support reactions are same)



Now determine whether the section is over or under reinforced section

By bending moment criteria

Assume M20, Fe415

$Mu_{lim} = 0.138 f_{ck} bd^2$

Assuming clear cover = 40 mm, dia. of bars = 20mm

$M_{ulim} = 0.138 \times 20 \times 230\,(500\text{-}40\text{-}10)^2$

= 128.54 kN-m

$M_{ulim} < M_u$

Provide doubly reinforced beam

Grade of material and dimensions are fixed

So, Provide doubly reinforced beam

M_{u2}= Mu-Mu_{lim}=256.85 - 128.54 = 110.021 kN-m

Compression force = tensile force

Cu = Tu

$Cu_1 + Cu_2 = Tu$

$0.36f_{ck}\ x_{ub} + A_{sc}f_{sc} = 0.87fyA_{st}$

d\`/d = 50/450 = 0.11

f_{sc} = 353 Mpa

Mu = Mulim + Mu_2

$256.85\times 10^6 - 128.54\times 10^5 = Mu_2$

Mu_2 + 128.32 kN-m

$Mu_2 = Cu_2\ Z_2$

$= f_{sc}A_{sc}(d-d`)$

$= 353A_{sc}\ (450-50)$

$A_{sc} = 908.78mm^2$

$Cu_2 = Tu_2$

$A_{sc}f_{sc} = 0.87fyA_{st2}$

$908.78 \times 353//0.87 \times 415 = A_{st2}$

$A_{st2} = 888.52mm^2$

$Mu_{lim} = T\times Z$

$=0.87f_y\ A_{stlim}\ (d-0.42x_{umin})$

$128.54\times 10^6 = 0.87\times 415\times A_{stlim}(450-0.42\times 0.48\times 450)$

$A_{stlim} = 990.918\ mm^2$

$A_{st} = A_{stlim} + A_{st2}$

$A_{st} = 1879.44\ mm^2$

Determine whether the section is over or under reinforced section

Compression force = tensile force

Cu = Tu

$0.36f_{ck}x_{ub}+f_{sc}A_{sc} = 0.87f_yA_{stp}$

$(0.36\times 20\times x_u\times 230) + (353\times 1132.56) = 0.87\times 415\times 1887.6$

$x_u = 170$ mm

$x_{umax} = 0.48\times 450 = 216$ mm

$x_u < x_{umax}$

therefore, the section is Under reinforced

Use 22mm dia. of main bar

No of Bars (A_{sc}) = 908.78 / ($\pi/4\times 22^2$) =2.4 = 3 Nos

$A_{scp} = 3\times \pi/4\times 22^2 = 1132.56mm^2$

No of Bars (A_{st}) = 1879.44/ ($\pi/4\times 22^{2)}$ = 4.9 = 5 Nos

$A_{stp} = 5\times \pi/4\times 22^2 = 1887.44mm^2$

Check for Shear

τ_V = Vu/bd = 216.11× 10^2/ (230× 450) = 2.08 N/mm^2

Pt % =Astp× 100/bd = 1887.6/230× 450 = 1.82 %

For M20 pt% = 1.82

$\tau_V > \tau_c$ --------------- (not safe)

Shear Reinforcement Required

2 bars are bentup at supports

V_{sb}= 0.87× f_y ×sinα ×A_{sv}= 0.87× 415× sinα ×2× 0.785× 22^2= 96.99kN

Assuming 2 Leg 10mm dia. bars

$V_{us} = V_u - V_{sb} - V_{uc}$ $V_{uc} = (\tau_c bd)$ = 78.66kN

= 216.11 – 96.99 - 78.66

V_{us} = 119.22kN

S_v = 0.87fyA_{sv}d/V_{sv} = 0.87× 415× 2× 0.785× 10^2/ (119220) =475mm

Check 1) Calculation 475mm

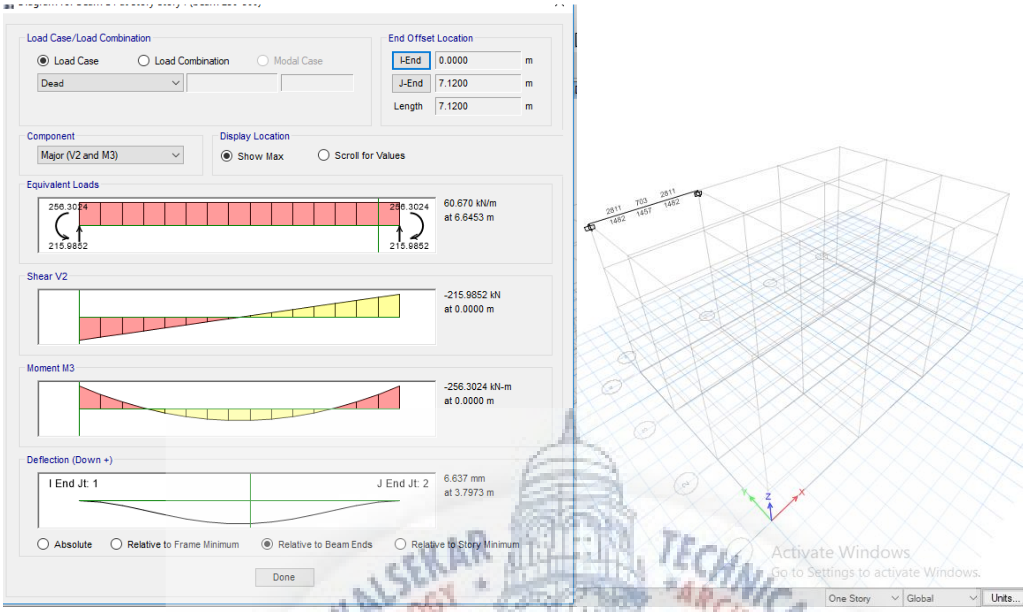
2)0.75d =337.5mm

3)300mm

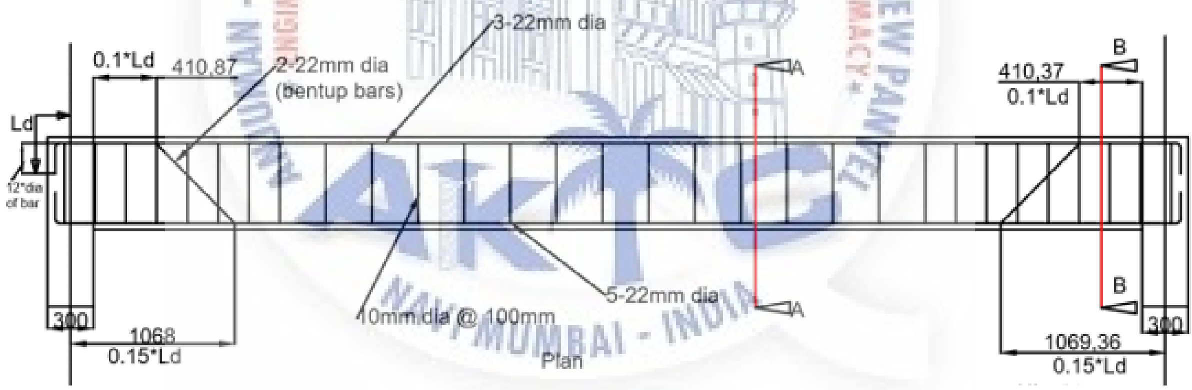
4)Sv < $\frac{A_{st}0.87f_y}{0.4 \times b}$ = 612.2 = 600mm

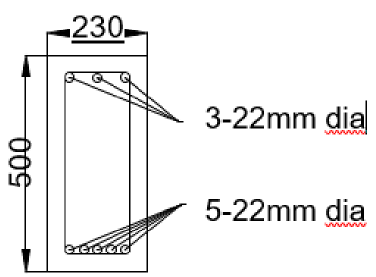
Provide 2 legged 10mm dia bars stirrups @ 300 mm c/c

4.1.3 Design of fixed beam using ETABS

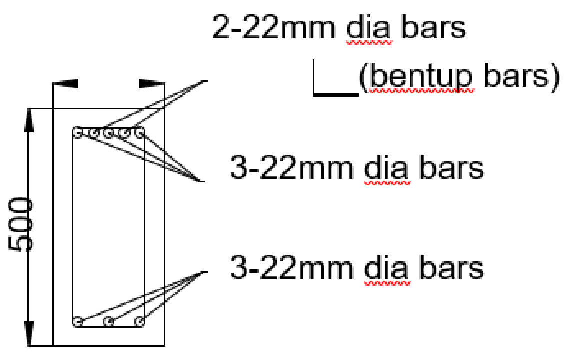


4.1.4 Detailing of fixed beam by AutoCAD





Section A-A



Section B-B

- In detailing part bent up bars are bent at a distance of 0.15 times of L_d from centre of support to starting portion of bent. And 0.1time of L_d from end of the support to end portion of bent of bent up bars.
- L_d is provided at the end of the support.
- Bars are bent with 12 times of diameter of bars at the supports.

4.1.5 Result of fixed beam

- By verifying the value of manual solution and ETABS we came to know that analysis part is correct.
- By manually, the shear force is 216.11kN and bending moment is 256. 85kN-m
- By ETABS software, the shear force is 215.98kN and bending moment is 256.30kN-m

4.2. COUPLING BEAM

Coupling beam is a lateral force resistant component of a structure. Types, advantages and design of coupling beam as per ACI 318- 11 is discussed. There are two types of coupling beams used in structure: 1) Conventionally reinforced concrete coupling beams 2) Diagonally reinforced concrete coupling beams

1)Conventionally Reinforced Concrete Coupling Beam

This type of coupling beam is similar to normal reinforced concrete with bottom and top reinforcement in addition to shear stirrups. It is employed when the beam is quite long compared with its depth. Such beams develop moment hinge at its ends and failure type will be ductile failure.

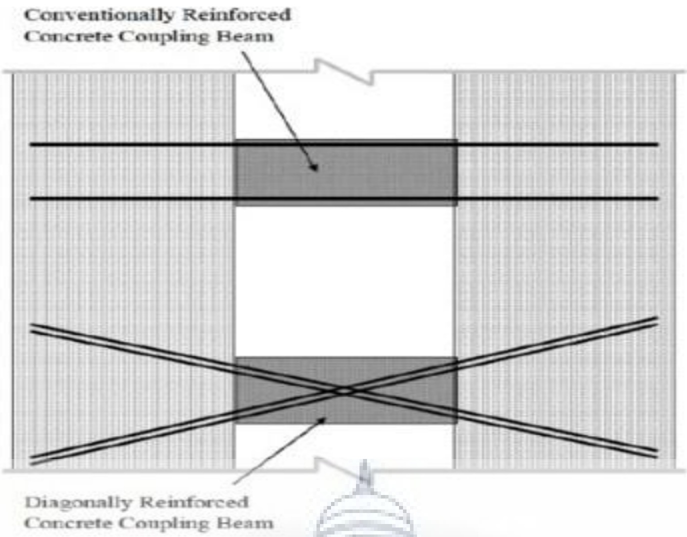


Fig.no.4.2 coupling beam

2) Diagonally Reinforced Concrete Coupling Beam

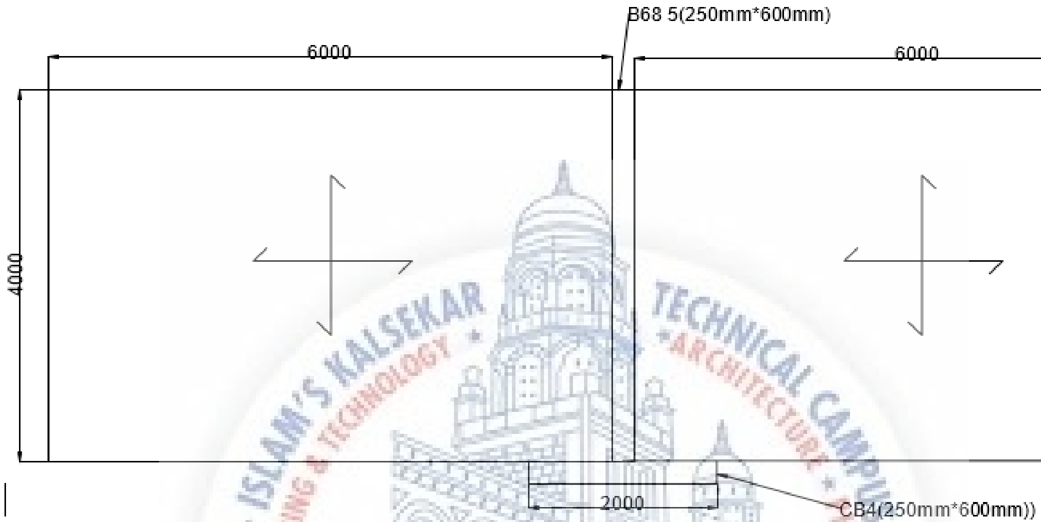
When the ratio of coupling beam length is similar to its depth, the design of the beam is governed by shear and the failure is brittle. Diagonal reinforcement is provided to avoid brittle failure and resist shear. This reinforcement arrangement leads to decrease the amount of shear reinforcement.

Fig.no 4.3 coupling beam

4.2.1 Application of coupling beam

Coupling beam is used effectively when two shear wall or any other elements that are used for withstanding lateral loads is combined. This consequently decrease overturning effect and improve overall stiffness of a system.

4.2.2. Design of coupling beam



Load calculations (B68)

Effective length= clear span + depth

L_{eff} = l+ d = 4+ 0.55 = 4.55m

Effective length= clear span + bearing

L_{eff} = l + 400 = 4+ 0.4 =4.4m

L_{eff} = 4.4 m

Adopted lesser value which is 4.4m

Dead load of slab = Area × thickness × density

= ((0.5 × 2 × 2) × 4) ×0.15×25 =30 kN

Live load = area of slab ×3 kN/m^2

= 0.5×2×2×4×3 = 24 kN (assume 3 kN/m^2)

Floor finish = area of slab ×1.5 kN/m^2

= (0.5×2×2×4) 1.5 = 12kN (assume 1.5 kN/m^2)

Total intensity of load = total load / effective span = 66/4.4 =15 kN/m

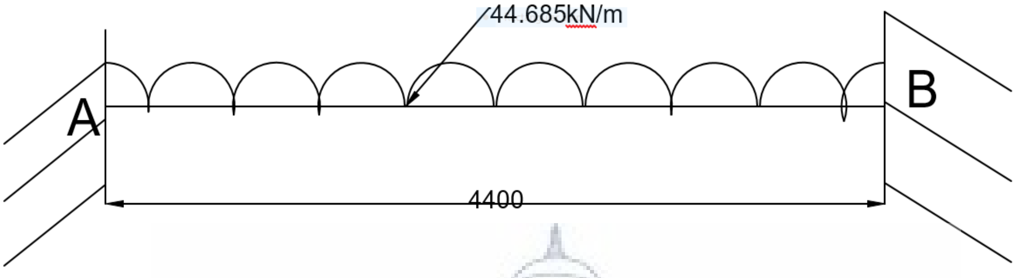
Self-weight of beam = 0.25×0.6×25 = 3.75 kN/m

Brick wall weight = height × density × thickness = 2.4×20×0.23 = 11.04 kN/m

Total load = 15+3.75+11.04=29.79 kN/m

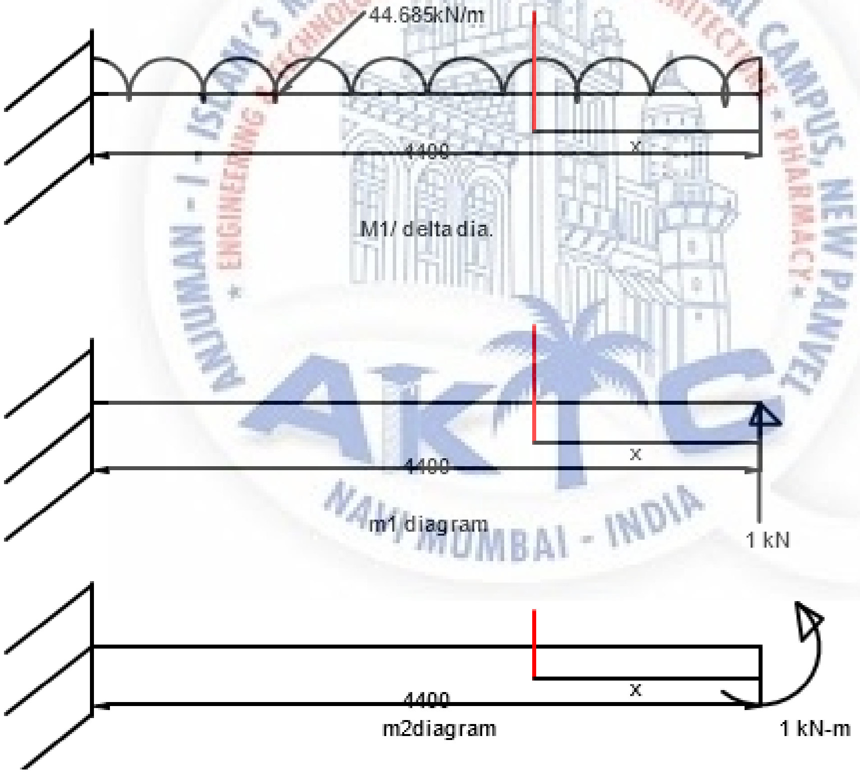
Factored load = 1.5 × 29.79 = 44.685 kN/m

Now, distributed load of 44.685kN/m acting on entire span of beam



DS = 2

Now Redundant 2 forces $V_B=R_1$, $M_B = R_2$



Applying Compatibility Equations

$\Delta o_1+F_{11}R_1+F_{12}R_2$ ....(equation 1)

$\Delta o_2+F_{21}R_1+F_{22}R_2$ ....(equation 2)

Δo_1= 1/EI $\int_0^{4.4} -44.685x2/2 \times x.dx$ = -2093.5/EI

$\Delta o_2 = EI \int_0^{4.4} -44.685x2/2 \times 1\ dx = -634.407/EI$

$F_{11} = 1/EI \int_0^{4.4} x \times x\ dx = 28.4\ /EI$

$F_{21} = F_{12} = 1/\ EI \int_0^{4.4} x \times 1\ dx = 4.68/EI$

$F_{22} = 1/\ EI \int_0^{4.4} 1\ dx = 4.4\ EI$

Equating Equations

$-2093.54+28.4259+9.68R_2 = 0$

$-634.407+9.68R_1+4.4R_2 = 0$

$R_1 = 97.436kN = V_B$

$R_2 = -70.18kN\text{-}m = M_B$

Load calculations (CB4)

Effective length= clear span + depth

L_{eff} = 2+ 0.55 =2.55m

Effective length= clear span + bearing

L_{eff} = 2.4 m

Adopt lesser value which is 2.4m

Dead load of slab = Area × thickness × density

= (0.5 × 1 × 1) 2 ×0.15×25=3.75 kN

Live load = area of slab × 3

= 0.5×1×1×2×3 = 3 kN (assume LL= 3 kN/m^2)

Floor finish = area of slab × 1.5

= 1.5 × (0.5×1×2×1) = 1.5 kN (assume FF=1.5 kN/m^2)

Point load of B_{68} at centre of the CB_4 = 98.3 kN

Total load = 3.75+3+1.5+98.3 = 105.65 kN

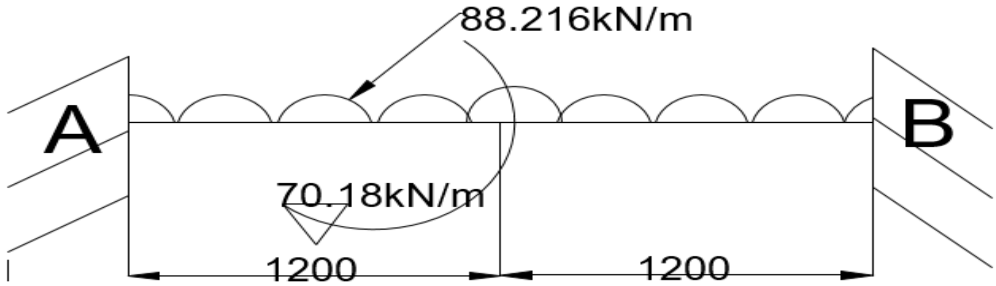
Total intensity of load = total load / effective length =105.65/2.4 =44.021 kN/m

Self-weight of the beam = 0.25×0.6×25 = 3.75 kN/m

Brick wall = 2.4×20×0.23 = 11.04 kN/m

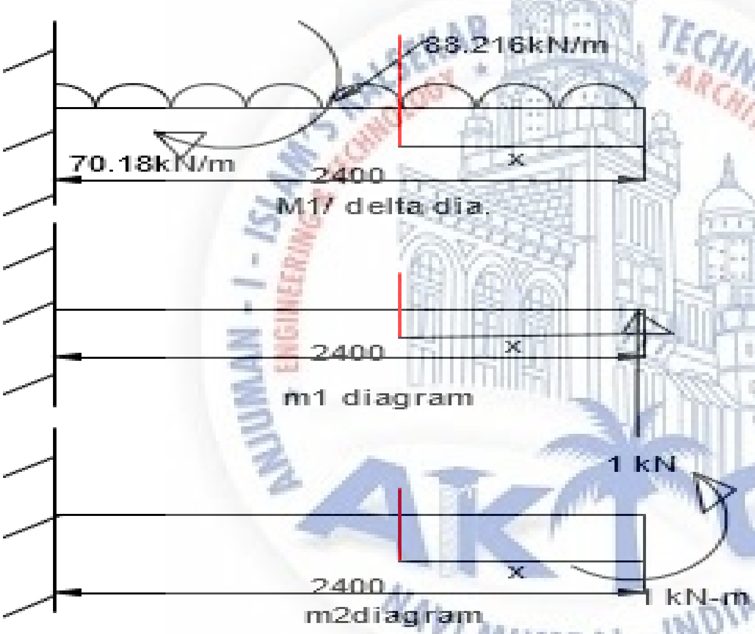
Total intensity load = 44.021+3.75+11.04= 58.81 kN/m

Factored load = 1.5 × 58.81 = 88.216 kN/m.



Redundant 2 forces

$V_B=R_1$ & $M_B=R_2$



Applying Compatibility Equations

$\Delta o_1+F_{11}R_1+F_{12}R_2$ ....(equation 1)

$\Delta o_2+F_{21}R_1+F_{22}R_2$ ....(equation 2)

Region	Origin	Limit	M	m1	m2	I
A	B	0-2.4	-70.18-88.216 x^2	1x	1	-

Δo_1 = 1/EI $\int_0^{2.4}[(-70.18 - 44.108x2) \times x]dx$ = 3567.97/EI

Δo_2 = EI $\int_0^{2.4}[(-70.18 - 44.108x2) \times 1]dx$ = -371.68/EI

F_{11} = 1/EI $\int_0^{2.4}(x2dx)$ = 4.608 /EI

$F_{21} = F12 = 1/\ EI \int_0^{2.4} (xdx) = 2.88/EI$

$F_{22} = 1/\ EI \int_0^{2.4} (1\ dx) = 2.4\ EI$

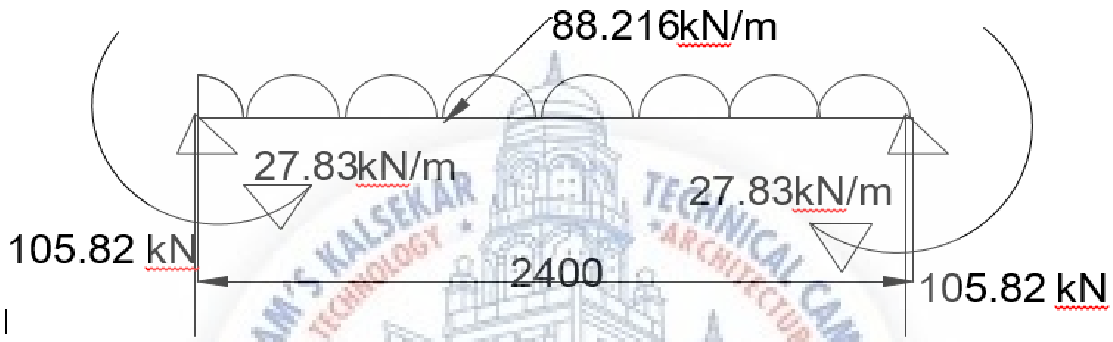
Equating Equations

$-567.98+4.608R_1+2.88R_2 = 0$

$-371.68+2.88R_1+2.4R_2 = 0$

$R_1 = 105.86$ kN = V_B

$R_2 = 27.83$ kN-m $= M_B$



Mulim = $0.133 f_{ck} b d^2$

$= 0.133 \times 30 \times 250 \times 550^2$

$= 301.7$ kN-m

$Mu_{lim} > Mu$ ....(It is single reinforcement section)

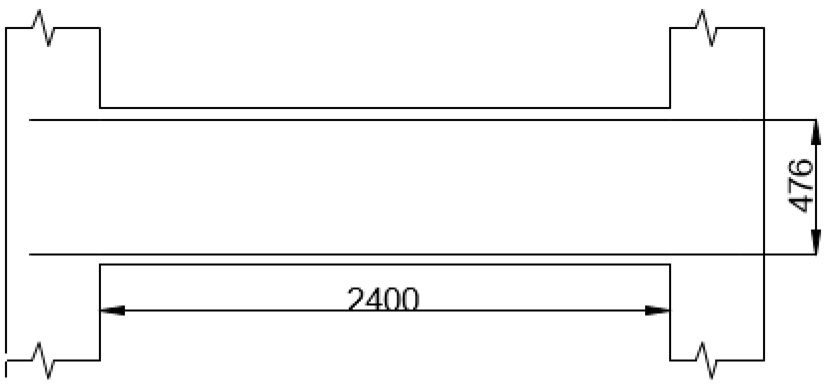
Use M30 fe500

$27.83 \times 10^6 = 0.133 x 30 \times 250 \times d^2$

$d_{req} = 167.03$ mm

$d_{req} < d_{pro} = 550$mm ------------------ok

Straight Reinforcement case is required



$\tau_v > 0.1 \sqrt{fck} \times (L/d)$

L=clear span of coupling beam=2400mm

d=effective depth=476mm

$\tau_v = V_u/bd$

$= 105.82\times10^3/ (250\times550)$

$\tau_v = 0.77\ N/mm^2$

$0.77 < 0.1 \sqrt{30} \times (2400/480)$

$0.77\ N/mm^2 < 2.73\ N/mm^2$

So provide straight reinforcement

Ast = Vu/ 1.74 × fy

d= 600-40-40-10-10-16/2-16/2 =476

$Ast = 105.82\times10^3/ (174\times500)$

$Ast = 121.5\ mm^2$

Use 2 bars of 16 mm diameter

$2 \times (\pi/ 4) \times 16^2 = 401.92\ mm^2$

$Ast_{pro} = 401.92\ mm^2 > Ast_{req} = 121.5\ mm^2$ ----------------------ok

Now, determine vertical reinforcement of coupling beam (stirrups)

$Ast = 0.18\ S_v\ h\ (fck/fy)\ ((Ag/Ak) - 1)$

Where, S_v = spacing =100mm as per IS 13920:2016

Ag= gross area

Ak= cage area

h= centre to centre distance between two horizontal bars

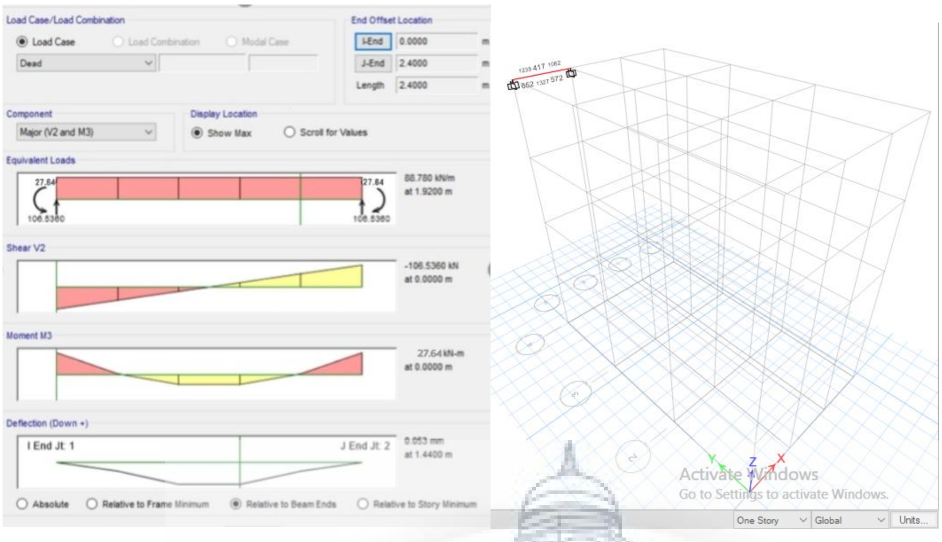
Ast= 0.18 100 (250-40-40-12-12-12) (35/500) {((250 ×600)/ (170× 520))-1}

= 1690.69

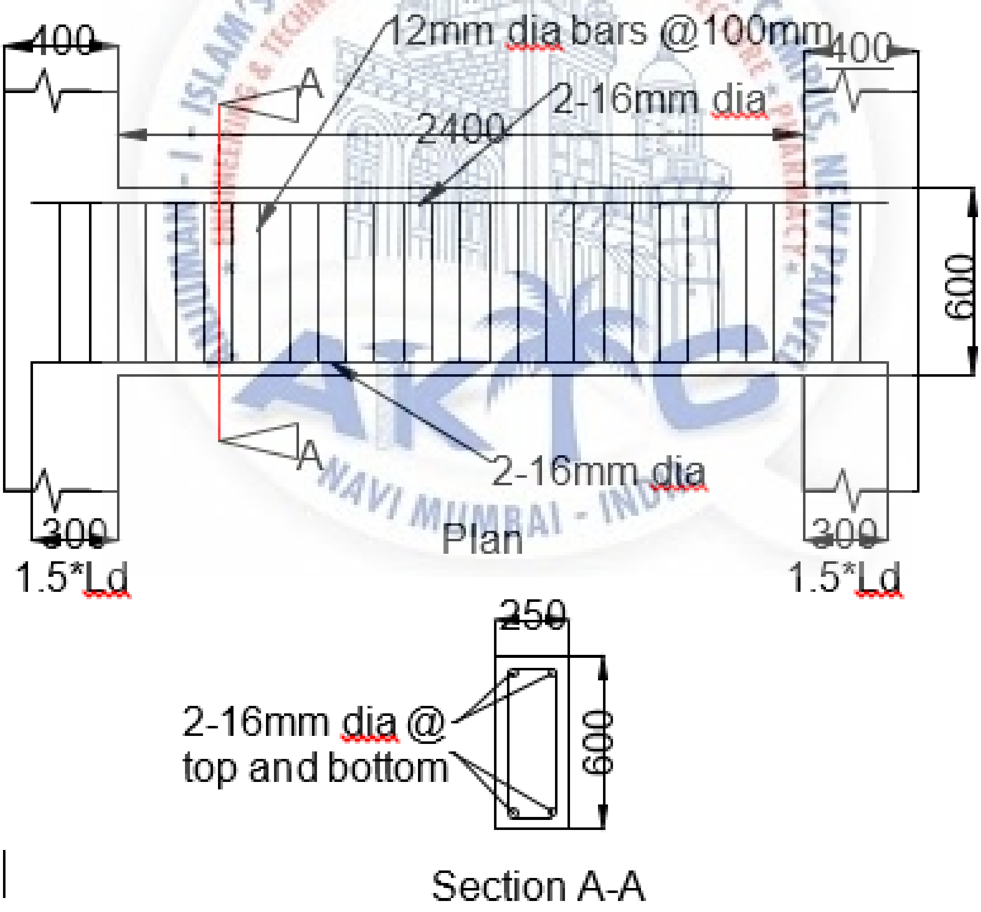
$= 117\ mm^2$

Therefore, 12mm dia bars @ 100mm c/c

4.2.3 Design of coupling beam by ETABS



4.2.4 Detailing of coupling beam by AutoCAD



- In detailing part 1.5 times of development length ‘L_d’ must be provide otherwise it doesn’t behave like a coupling beam.
- There are two cases in coupling beams are follow as below:

1)diagonal reinforcement: when $\tau_v > 0.1 \sqrt{fck} \times (L/d)$ then diagonal reinforcement are provide. Area of diagonal steel reinforcement, $Ast = Vu/ 1.74 \times fy \times \sin\alpha$

where, L=clear span of coupling beam, d=effective depth, α is an angle between diagonal reinforcement and horizontal.

2) straight reinforcement: when $\tau_v < 0.1 \sqrt{fck} \times (L/d)$ then straight reinforcement are provide and sinα is eliminated while determining area of steel due to straight reinforcement.

- Horizontal reinforcement is required only in the diagonal case. horizontal reinforcement is provided to prevent by brittle failure of concrete during earthquake. Usually 12mm dia should be use

4.2.5 Result of coupling beam

- By verifying the value of manual solution and ETABS we come to know that the analysis part is correct.
- By manually the shear force is 105.82kN and bending moment is 27.83kN/m
- By ETABS software shear force is 105.82kN and 27.83kN/m

4.3. DEEP BEAM

Floor slabs under horizontal load, short span beams carrying heavy loads, and transfer girders are examples of deep beams. Deep beam is a beam having large depth/thickness ratio and shear span depth ratio less than 2.5 for concentrated load and less than 5.0 for distributed load. Because the geometry of deep beams, their behaviour is different with slender beam or intermediate beam.

Fig no 4.4 deep beam

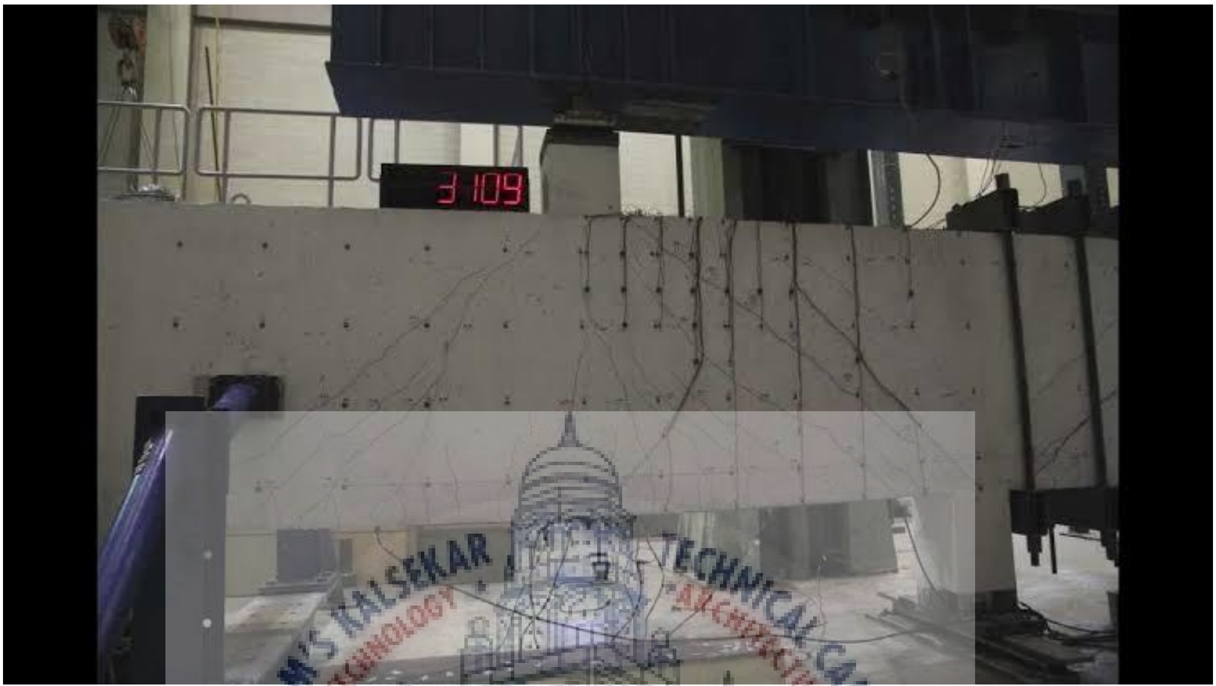


Fig no 4.5 deep beam

4.3.1. Applications of deep beams

Beams, in any case, are designed to resist bending.

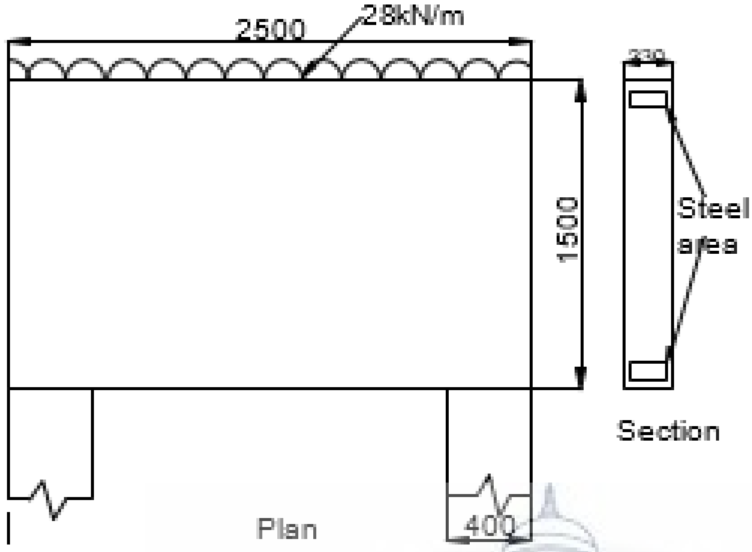
Deep beams, are used to withstand bending moment but of higher magnitudes, which occur due to long span or high magnitude of loads.

Deep beams are used and designed in a usual fashion; however, checks for shear, deflection, and crack are essential for safety.

RC deep beams have many useful applications in building structures such as transfer girders, wall footings, foundation pile caps, floor diaphragms, and shear walls.

4.3.2. Design of deep beam

Problem: Design of reinforcement detail of a simply supported beam b1 of span of 2.5 m & udl 28 kN-m the width of the beam 0.23 m &depth of beam is 1.5 &use M20 Fe415



Solution =>

Given = L=2.5m

w=28kN-m

b=0.23m=230mm

D=1.5m=1500mm

d'=50mm

d = 1500 – 50 =1450

1: $L_{eff}/D < 2$ (Simply supported beam)

$L_{eff}/D < 2.5$ (continuous beam)

Effective length by depth ratio for Simply supported beam

$L_{eff}/D = 2.875/150 = 1.92 < 2$

2: Lever arm (z) for Simply supported beam

1<_ leff/D <_ 2

Z = 0.2 (leff×2×D)

Z = 1.18m

3: Calculation of load

L.L=1.5× 28 = 42 kN/m

D.L=1.5(1 × area of beam × density of concrete)

D.L=1.5(1× 0.23× 1.5× 25) =54.94 kN/m

4: Bending moment

$Mu = wl_{eff}2/8$ = 54.94× 2.87^2/8 = 56.56kN-m

5: Area of tension steel (positive reinforcement)

$Ast = Mu/0.87f_y \times 2 = 56.56 \times 10^6 / 0.857 \times 415 \times 1180 = 237.0675\ mm^2$

There is no curtailment in tension side as per IS 456:2000

Same Ast to be provided on the compression side of beam. Curtailment is possible in compression side of the beam to achieved economy. reinforcements are provided into two layers in compression zone. First layer contains 50 % of Ast of tension zone. And the second layer are divided into two another layer on opposite side at support at a distance of 0.5D, where D is an overall depth and contains 25% Ast of tension zone in both layers as per IS 456:2000.

Percentage of steel = Ast/bd × 100 = 237.0675\230× 1450 × 100 = 0.07% > Ast_{min} = (0.3%)

$Ast_{min} = 0.3/100 \times 230 \times 1450 = 1000\ mm^2$

Use 2-16mm of dia. bars (in tension zone 100% Ast)

$Astp = 2 \times 0.785 \times 16^2 = 401.92 mm^2$

Astreq<Astpro ------------------------ok

Use 2-12mm dia bars (In first layer of compression zone with 50% Ast)

Use 2-10mm dia bars (In second layer of compression zone at each support with 25% Ast)

6: development length (development length should not be less $0.8L_d$ as per IS 456 :2000)

$=0.8\ L_d$; $L_d = \phi \times \sigma_S / (4 \times \tau_{bd})$; $\sigma_S = 0.874 f_y$

=0.8× 12× 0.87× 414/ (4× 1.2× 1.6) { 1.2 (m20) -- mild steel

=602mm 1.6--60% we have to increase.}

7: Zone of placement of Reinforcement

$=0.25D - 0.05l_{eff}$ = 0.25× 1500 - 0.05× 2.87 = 0.23m

Reinforcement are placed with in a zone of 0.23m from bottom for tensile reinforcement and 0.23m from top for compression reinforcement

8: Vertical Reinforcement (stirrups)

$=0.12/100\times b\times 1000 = 276mm^2$

Use 8mm dia. bars

Spacing$=\pi/4\times 8^2 / (276\times 1000)$=182.12mm c/c

we have to provide the reinforcement at both side

so we have to multiply with 2 = 182.12× 2=364.2mm c/c.

Spacing check: 1) 3b =3× 230= 680mm

2) 450mm

Provide 8 mm dia @ 360mm c/c

9: Horizontal Reinforcement (face reinforcement)

Here zone of placement is 0.3D from the centre of beam.

Ast(h) $= 0.2/100\times b\times 1000 = 460mm^2$

Use 2-20mm of dia. bars

Astp$= 0.785\times 20^2\times 2 = 628mm^2$

Spacing $= \pi/4\times 10^2/(460) = 170.73$

For both side multiply by 2; 2× 170.73 = 340mm c/c.

Check 1) 3b= 3 ×230= 680mm

2) 450

3) calculation value=340mm

. # Provide 2-20mm dia @ 340 mm c/c.

10: Check for shear

$\tau_v = V_u/bd$ Vu $=wl/2=55\times 2.8/2 = 68.75\times 10^3$

$68.75\times 10^3/(230\times 1450) = 0.2N/mm^2$

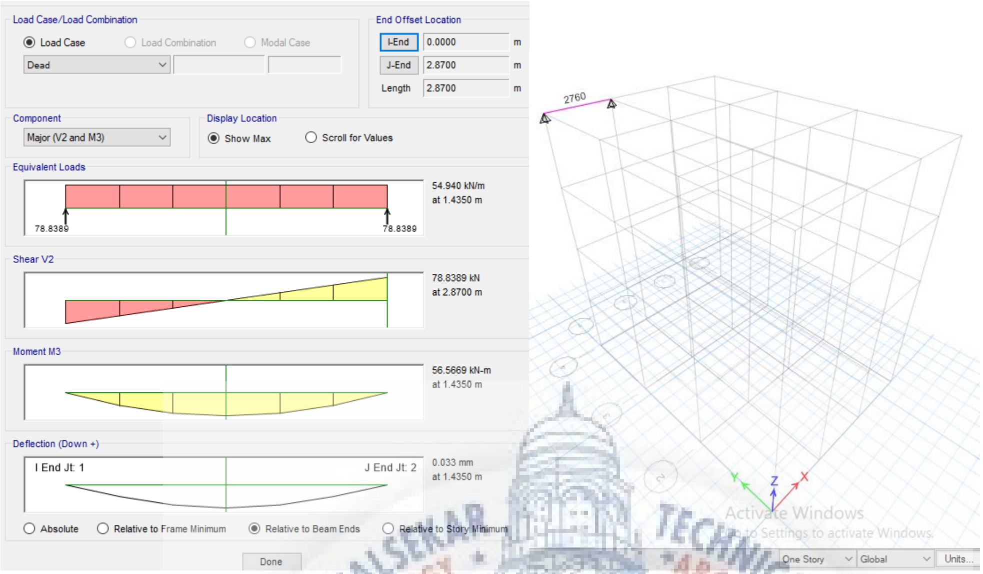
% of Steel =Ast/bd× 100 = 0.002%

$\tau_C = 0.28\ N/mm^2$

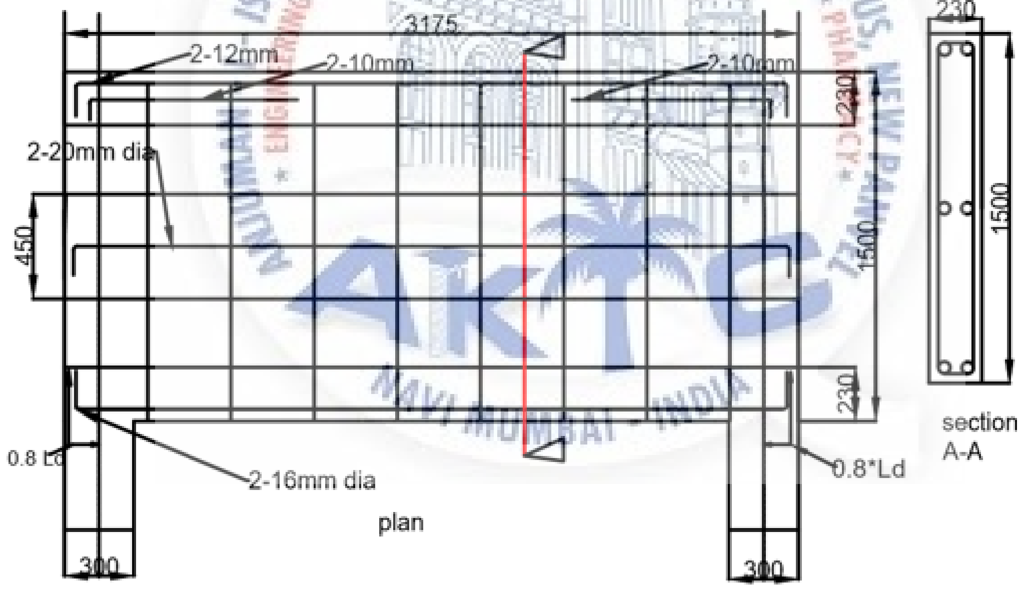
$\tau_V < \tau_C$ ---------- Safe.

If the beam is not safe we have to double the depth.

4.3.3 Design of deep beam by ETABS



4.3.4 Detailing of deep beam by AutoCAD.



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- There is no curtailment in tension side as per IS 456:2000

  Same Ast to be provided on the compression side of beam. Curtailment is possible in compression side of the beam to achieved economy. reinforcements are provided into two layers in compression zone. First layer contains 50 % of Ast of tension zone. And the second layer are divided into two another layer on opposite side at support at a distance of 0.5D from the centre of support. (where D is an overall depth) and contains 25% Ast of tension zone in both layers as per IS 456:2000.

4.3.5 Result of deep beam

- By verifying the value of bending moment and ETABS we come to that the analysis part is correct.
- Bending moment value by manually is 56.566kN/m
- Bending moment value by ETABS software is 56.5669kN/m

4.4. MOMENT FRAME BEAM

Moment-resisting frame is a rectilinear assemblage of beams and columns, with the beams rigidly connected to the columns. Resistance to lateral forces is provided primarily by rigid frame action – that is, by the development of bending moment and shear force in the frame members and joints.

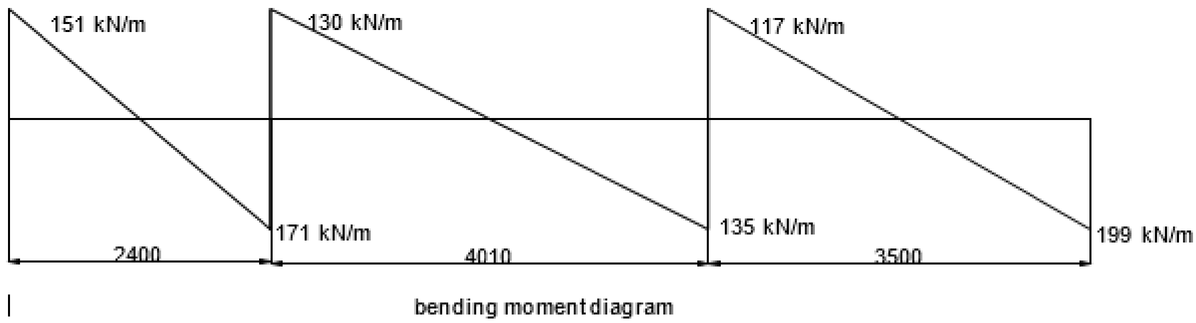
Fig no 4.6 moment frame beam

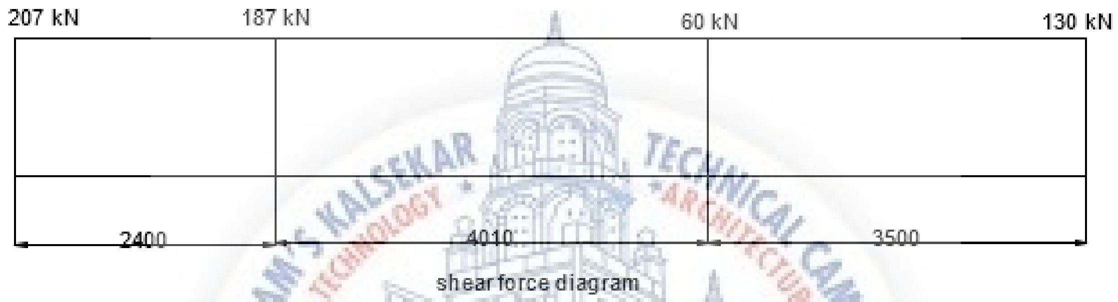
4.4.1. Applications of moment frame beam

In moment resisting frames, the joints or connections, between columns and beams are designed to be rigid.

This causes the columns and beams to bend during earthquake. So these structural members are designed to be strong in bending.

4.4.2. Design of moment frame beam





Calculation of span 1 of 2.4m

- For bottom A_{st}

For maximum bending moment; Use M_{30}, Fe500

M=171 kN-m

d = 600-40-10-20/2 = 540 mm

A_{st} = 0.5fckbd/fy (1- $\sqrt{}$ (1- (4.6Mu/fckbd^2))

= 0.5×30×250×540/500 {1-√(1-(4.6× 171 × 10^6/ 30 × 250× 540^2))}

Ast = 808.71/7291.28 mm^2

Using 2 bars of 25 mm dia.

π/4×25^2=981.25 mm^2

Astp bottom= 981.25 mm^2 > Ast $_{req}$=808.71 mm^2

Now, to find bending moment

A_{st} = 0.5fckbd/fy (1- $\sqrt{}$ (1- (4.6Mu/fckbd^2))

981.25= 0.5×30×250×540/500 {1-√(1-(4.6× Mu/ 30 × 250× 540^2))}

Mu_{bottom} = 202.53 kN-m

- For top Ast

Mu = 151 kN-m, d = 540 mm

A_{st} = 0.5fckbd/fy (1- √ (1- (4.6Mu/fckbd^2))

= 0.5×30×250×540/500 {1-√(1-(4.6× 151× 10^6/ 30 × 250× 540^2))}

A_{streq} =704.406 mm^2

Using 2 bars of 25 mm diameter

π/4×25^2=981.25 mm^2

Ast_P bottom= 981.25 mm^2 > Astreq 704.406 mm^2

Now,

A_{st} = 0.5fckbd/fy (1- √1- 4.6Mu/fckbd^2)

981.25 = 0.5×30×250×540/500 (1- 1- 4.6×Mu/30×250×540^2)

$M_{u\ top}$ = 202.58 kN-m

Now Shear force

V= {1.4(Mu top +Mu bottom)}/L .... (1.25/0.87 =1.4 material safety factor)

= 1.4(202.58 + 202.57)/2.4

Vu=236.34 kN > 207 kN

Check for Shear

τ_v = Vu/bd =236.34 / 250×540

τ_v = 1.75 N/mm^2

Pt % =100Ast/bd = 100× 981.25/250×540

Pt % =0.726 %

For M30 & Pt % = 0.726 %

τ_v = 0 585 N/ mm^2

$\tau_v > \tau_c$ -- Not Safe

Shear reinforcement is required

$V_u = V_{us} + V_c$

$V_c = \tau_c$ × bd= 0.585×250×540=78.97 kN

$V_{us} = V_u - V_c$ =236.34 – 78.97 = 157.37 kN

A_{st} (stirrups) = V_{us}×S/(0.87fy×d×2) (multiply by 2 for 2-legged stirrup)

{don't take 0.87 because we already considered material safety factor in V= 1.4(Mu top +Mu bottom)/4}

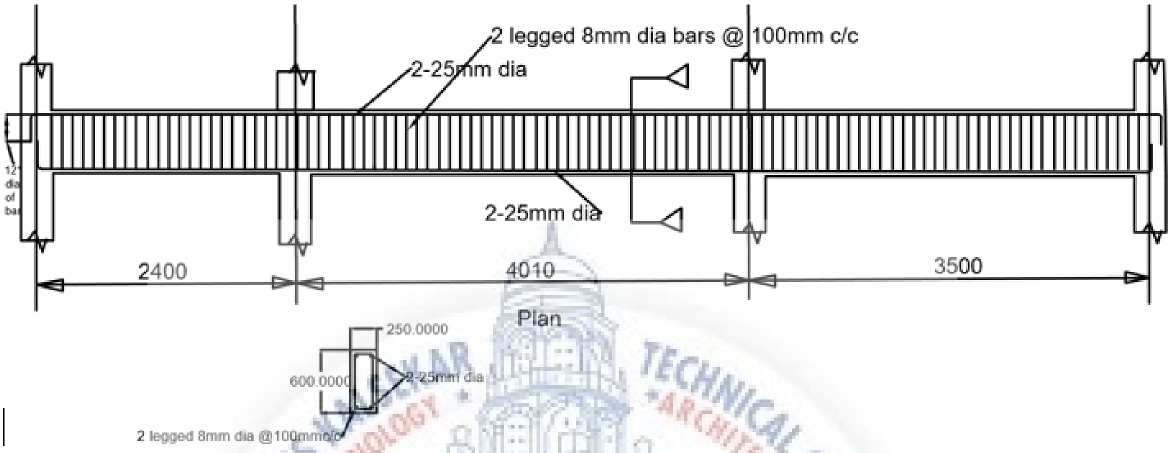
A_{st} (stirrups) = 157.37×10^3×100//500×540×2

A_{st} (stirrups) = 35.11 mm^2

(Assume spacing 100 and 2 leg stirrups)

 # Provide two legged stirrups 8mm bar diameter @ 100 mm c/c.

4.4.3 Detailing of moment frame beam by AutoCAD



- Detailing of moment frame beam is similar to fixed beam.
- It doesn't behave like a moment frame beam above 6m of span

4.4.4 Result of moment frame beam.

- In this case we have design beam manually only
- We were designed a beam by top and bottom bending moment of 202.85kN/m
- We were calculated for span 1 only and for different span it can be calculated by above procedure.

Chapter 5

Conclusion of beams

5.1 Fixed beam

- Fixed beams are used to resist horizontal and vertical load and moments
- It is not for laterally loads such as, wind load, earthquake loads, etc.

5.2 Coupling beam

- Coupling beams are design to resist lateral forces such as, wind load, earthquake loads, etc.
- It is usually used in seismic region. i.e.; Indonesia is a highly seismic region where coupling beams are mostly used.

5.3 Deep beam.

- Deep beams are mostly used when columns are closed to each other.
- It's used to prevent maximum bending moment.
- If length of deep beam is four time of depth.it is called as a deep beam
- If depth is more than 750mm provide face reinforcement at the centre of deep beam. Side face reinforcement is to resist the deep beam by bucking of stirrups.

5.4 Moment frame beam.

- Moment frame beam also are design to resist lateral forces such as, wind load, earthquake loads, etc.
- It is usually used in seismic region. i.e.; Indonesia is a highly seismic region where coupling beams are mostly used.
- It's important for structures of building which make the structure durable and gives strength of structure during earthquake.
- It doesn't behave like a moment frame beam above 6m of span

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