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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L1

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I** **Date of Lecture:**

Topic of Lecture: Concept Ultimate load method and limit sate method

Introduction : The acceptable limits of safety and serviceability requirements before failure occurs is called a **limit state**. This **method** is based on the concept of safety at **ultimate loads** (**ultimate load method**) and serviceability at working **loads** (working stress **method**).

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Concept of WSM
- ✓ Ultimate load

Detailed content of the Lecture:

Limit State, Working Stress and Ultimate Load Method of Structural Design

- ✓ There are three methods of structural design, i.e. working stress, limit state and ultimate load method of structural design. These design methods are used for reinforced concrete as well as steel structure design.
- ✓ Methods of Structural Design
- ✓ **Working stress method (WSM)**
- ✓ **Ultimate load method (ULM)**
- ✓ **Limit state method (LSM)**
- ✓ Working stress method (WSM)

- ✓ This was the traditional method of design not only for reinforced concrete, but also for structural steel and timber design.

- ✓ The method basically assumes that the structural material behaves as a linear elastic manner, and that adequate safety can be ensured by suitably restricting the stresses in the material induced by the expected **“working loads”** on the structure.
- ✓ As the specified permissible stresses are kept well below the material strength, the assumption of linear elastic behavior is considered justifiable. The ratio of the strength of the material to the permissible stress is often referred to as the **factor of safety.**
- ✓ However, the main assumption linear elastic behavior and the tacit assumption that the stresses under working loads can be kept within the ‘permissible stresses’ are not found to be realistic.

- ✓ Many factors are responsible for this such as a long term effort of creep and shrinkage, the effects of stress concentrations, and other secondary effects. All such effects resulting significant local increases in a redistribution of the calculated stresses.

- ✓ The design usually results in relatively large sections of structural members, thereby resulting in better serviceability performance under the usual working loads.Ultimate load method (ULM)

- ✓ With the growing realization of the shortcomings of **WSM** in reinforced concrete design, and with increased understanding of the behavior of reinforced concrete at ultimate loads, the ultimate load of design is evolved and became an alternative to WSM.
- ✓ This method is sometimes also referred to as the load factor methods are the ultimate strength. In this method, the stress condition at the site of impending collapse of the structure is analyzed, and the nonlinear stress-strain curves of concrete and steel are made use of.

- ✓ The concept of ‘modular ratio’ and its associated problems are avoided entirely in this method. The safety measure design is introduced by an appropriate choice of the load factor, defined as the ratio of the ultimate load to the working load.

- ✓ The ultimate load method makes it possible for different types of loads to be assigned different load factors under combined loading conditions, thereby overcoming the related shortcoming of **WSM.**
- ✓ This method generally results in more slender sections, and often economical designs of beams and columns, particularly when high strength reinforcing steel and concrete are used. However, the satisfactory 'strength' performance at ultimate loads does not guarantee satisfactory **'serviceability'** performance at the normal service loads.
- ✓ The designs sometimes result in excessive deflections and crack-widths under service loads, owing to the slender sections resulting from the use of high strength reinforcing steel and concrete.

- ✓ The distribution of stress resultants at ultimate load is taken as the distribution at the service loads, magnified by the load factor(s); in other words, analysis is still based on linear elastic theory Limits States

- ✓ A limit state is a state of impending failure, beyond which a structure ceases to perform its intended function satisfactorily, in terms of either safety of serviceability i.e. it either collapses or becomes unserviceable.There are two types of limit states:

- ✓ **Ultimate limit states (limit states of collapse):-** which deal with strength, overturning, sliding, buckling, fatigue fracture etc.
- ✓ **Serviceability limit states: –** which deals with discomfort to occupancy and/ or malfunction, caused by excessive deflection, crack width, vibration leakage etc., and also loss of durability etc.

Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=QFxe-d7NM8U** **2. https://www.youtube.com/watch?v=cQKrzbhmxP8**
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LECTURE HANDOUTS

L2

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I** **Date of Lecture:**

Topic of Lecture: Advantages of limit state method over other methods

Introduction :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.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Concept of WSM
- ✓ Ultimate load method
- ✓ limit state methode

Detailed content of the lecture:

Advantages and Limitations of Ultimate Limit State Design Methods for Braced Excavations

Abstract

- ✓ This paper examines the advantages and limitations of employing ultimate limit state methods for the design of braced excavations.
- ✓ Braced excavation design requires both skill and careful evaluation of many factors that can affect performance.
- ✓ Traditionally in the US, braced excavations are designed with a serviceability approach where soil parameters are conservatively estimated and the performed analysis yields the service displacements, moments, and forces.
- ✓ Design forces are then calculated by applying a global safety factor on the service design results, while the wall embedment is determined by calculating limit equilibrium safety factors against wall rotation and passive resistance that range from 1.2 to 1.5. In Europe, in contrast to the US, an ultimate limit state design approach has been adopted in geotechnical design

including the design of braced excavations.

- ✓ In this design philosophy both wall and supports are designed based on an ultimate limit condition. The ultimate design forces are typically determined by reducing the characteristic soil strength parameters or by multiplying the effects of actions and dividing the effects of resistances by various safety factors.
- ✓ At the end, a safety factor of one or greater is required for all structures and other types of safety factors.
- ✓ Back in the US, there is an increasing trend of promoting ultimate limit state design in geotechnical design, including braced excavations. In the author's experience the ultimate limit state method works reasonably well for most limit equilibrium methods but can produce very inconsistent results in many cases when numerical analyses are employed.
- ✓ Hence, the advantages and limitations of the ultimate limit state design should be carefully weighted by practitioners and academia in the US before, and if, the ultimate limit state philosophy is incorporated in a legally binding building code.

Video Content / Details of website for further learning (if any):

1.https://www.youtube.com/watch?v=TefLaCKB8uM

2. https://www.youtube.com/watch?v=pw1ri0l96R0

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LECTURE HANDOUTS

L3

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I** **Date of Lecture:**

Topic of Lecture: Limit state philosophy as detailed in current IS Code

Introduction : Thus the philosophy of limit state design method is to see that the structure remains fit for use throughout its designed life by remaining within the acceptable limit of safety and serviceability requirements based on the risks involved**.**

Prerequisite knowledge for Complete understanding and learning of Topic:

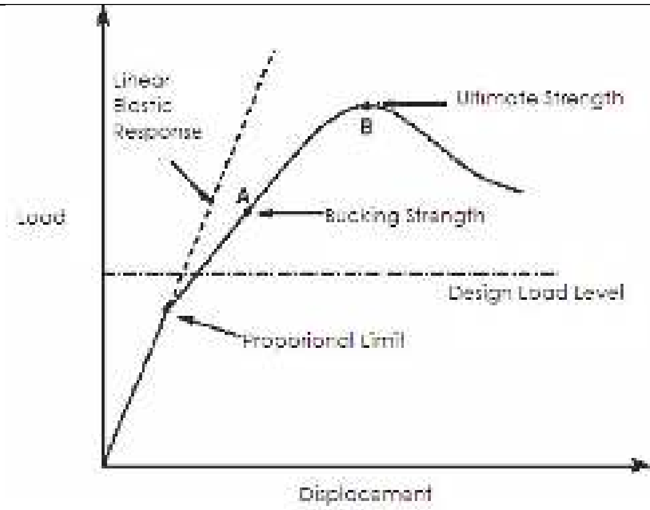
- ✓ Concept of WSM
- ✓ Ultimate load method
- ✓ limit state methode

Detailed content of the Lecture:

- ✓ **Different Types of Limit State Design Philosophies**
- ✓ Structures are designed according to a standardized code that have properties (or specific criteria) that need to be met during the design procedure. The *limit state* of a structure is when the structure goes beyond the specified criteria and it 'breaks'. *Limit state design* can therefore be defined as the process of designing a structure so that it doesn't break and remains fit for its designed use.
- ✓ There are numerous design philosophies used by civil engineers. The three most prominent, as found through research, will be briefly discussed. These are:
- ✓ Working Stress Method (WSM)
- ✓ Ultimate Load Method (ULM)
- ✓ Limit State Method (LSM).
- ✓ The **Working Stress Method** assumes that all material used in the design behaves in a linear elastic manner and calculations are based on service conditions. The expected working loads on the structure are induced as stresses on the structure during the design and these are restricted (to be below the permissible stresses) to ensure adequate safety. The factor of safety is the ratio of the strength of the material to the permissible stress. However, as working loads cannot be

kept within the permissible stresses this method is not always viable.

- ✓ The assumption in the **Ultimate Load Method** is that the material is not linear-elastic meaning that different loads can have different safety factors. Calculations are based on ultimate load conditions and the stress conditions at the site of failure or impending collapse is analysed. This results in more slender (therefore more economic!) sections. However, this method can result in cracks and deflections that are excessive due to the serviceability properties not being met.
- ✓ In the **Limit State Method** (aka as *Limit State Design*), the design of the structure is considered for both the serviceability and ultimate load state. This is therefore the better design philosophy to employ. The two different limit states are the *Ultimate Limit State* (ULS) and the *Serviceability Limit State* (SLS), for which distinction are made in the code SANS10160: 5.1.3... These states each have their own minimum level of reliability - which is colloquially known as the *Safety Index*.
- ✓ The different limit states of Limit State Design:
- ✓ *Ultimate Limit State* deals with states just before the structure collapses. This relates to the safety of people and the safety of the structure (strength, fatigue, bucking, sliding and overturning). It has a safety index of $\beta = 3.5$.
- ✓ *Serviceability Limit State* deals with functioning of the structure, acceptability of safety and appearance of the structure (deflections, crack width, malfunction and loss of durability). This has a safety index $\beta = 1.5$.
- ✓ Calculations concerning the effect of an applied load and the strength or resistance of the structure must fall within the Safety Index. This is done by means *Partial Safety Factors.* Partial safety factors have emerged within limit state design as a means of adjusting parameters to account for variations so that the appropriate values are used for design purposes. Partial safety factors are derived from considering a frequency distribution statistical analysis of actions on a structure. Nominal loads, found on symmetric bell curves, have a probability of being exceeded by 5%. The overlap of nominal loading of mean load and mean strength curves describes the failure condition. This indicates the necessity of having a material/resistance partial safety factor, .
- ✓ For each design method and limit state, a different set of design parameters are used. In the *Ultimate Load Method* for reinforced concrete design, partial safety factors of 1.5 for concrete and 1.15 for steel are used. While in the *Working Stress Method*, the safety factor is often referred to as being the ratio of the strength of the material to the permissible stress. However, in the *Ultimate Limit State*: safety factors of 1.2 times the dead loads, 1.6 times the live loads and 1.3 times the wind loads are implemented.
- ✓ **Conclusion**
- ✓ Design can be seen as the process of creating something that does not currently exist. It is of utmost importance that engineers understand the intricate steps used in the design process and the impact that it will have on the final product. Therefore, engineers need to make use of their knowledge of material properties along with their ability to analyse, predict and assume the future behavior of their design to meet a previously specified need. The success of the design depends on the thoroughness of the engineer’s knowledge and a clear understanding of the expected behavior of the final product.



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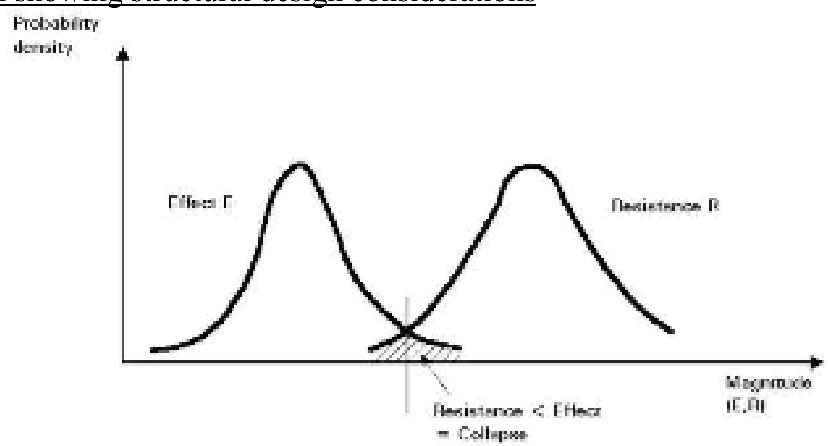
- Above: Graph showing structural design considerations



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- Above: Graph showing that collapse is a certainty when the Design Resistance (R) is less than the Effect of Actions (E)
- **About the author**
- Shánal Nathoo studied Civil Engineering at the University of KwaZulu-Natal where he received certificates of merit for excellence in the subjects: *Water & Environmental Engineering*, and *Management & Labour Relations.*
- During his spare time, he has held several roles in business (where he acquired a working knowledge of finance and programming) and published books to raise funds for donation to the organisation CANSA South Africa.
- For further information (or queries) on the topics presented in this article, feel free to contact Shánal via any of the links on his website: http://bit.ly/2u6WBHo
- Structures are designed according to a standardized code that have properties (or specific criteria) that need to be met during the design procedure. The limit state of a structure is when the structure goes beyond the specified criteria and it 'breaks'. Limit state design can therefore be defined as the process of designing a structure so that it doesn't break and remains fit for its designed use.

Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=TefLaCKB8uM** **2.https://www.youtube.com/watch?v=pw1ri0l96R0**
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LECTURE HANDOUTS

L4

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I**

Date of Lecture:

Topic of Lecture: Design of rectangular beam section by working stress

Introduction : A **rectangular section beam** is 80mm wide, 120mm deep and is simply supported at each end over a span of 4m.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Ultimate load method
- ✓ Limit state method
- ✓ Limit state philosophy

Detailed content of the Lecture:

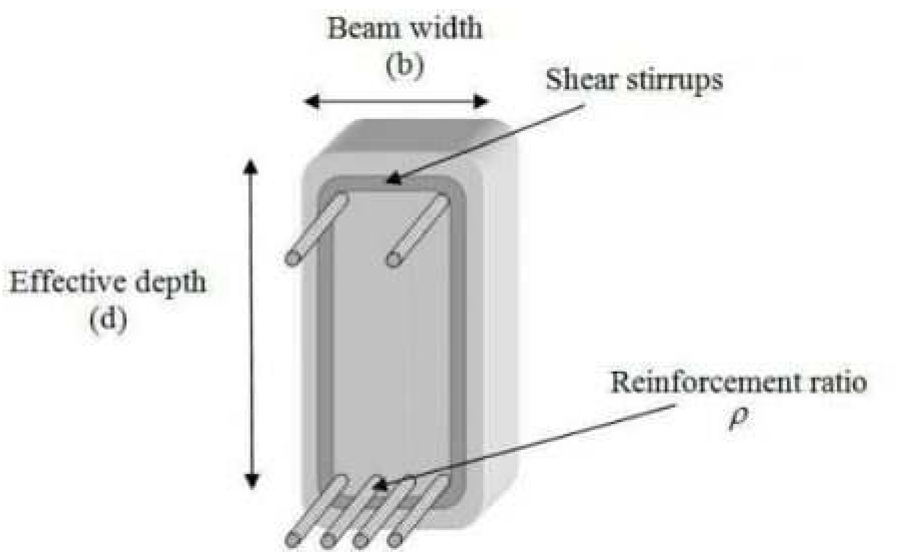
Design of Rectangular Reinforced Concrete Beam

- ✓ Reinforced concrete beams are structural elements that designed to carry transverse external loads. The loads cause bending moment, shear forces and in some cases torsion across their length.
- ✓ Moreover, concrete is strong in compression and very weak in tension. Thus, Steel reinforcement used to take up tensile stresses in reinforced concrete beams.
- ✓ Furthermore, beams support the loads from slabs, other beams, walls, and columns. They

transfer the loads to the columns supporting them.

- ✓ , the choice is influenced by ductility requirement, construction and economic consideration.

- ✓ lastly, it is recommended to use 0.6*maximum reinforcement ratio.

- ✓ 

- ✓ **Reinforcing bar sizes**
- ✓ Generally, it is advised to avoid the use of large bar sizes for beams. This is because such bars cause flexural cracking and required greater length to develop their strength.

- ✓ However, large bar size placement cost is smaller than the installation cost of large number of small bar sizes.

- ✓ Moreover, common bar sizes for beams range from NO.10 to NO.36 (SI unit) or NO.3 to NO.10 (US customary unit), and the two larger diameter bars NO.43 (NO.14) and NO.57 (NO.18) are used for columns

- ✓ Furthermore, it is possible to mix different bar diameter to meet steel area requirements more closely.

- ✓ Finally, the maximum number of bars which can be installed in a beam of given width is

controlled by the bar diameter, minimum spacing, maximum aggregate size, stirrup diameter, and concrete cover requirements
Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=iG0KWhTpnJw** **2.https://www.youtube.com/watch?v=iG0KWhTpnJw**
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LECTURE HANDOUTS

L5

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I** **Date of Lecture:**

Topic of Lecture: Cracked and uncracked section

Introduction : Cracked concrete will be seen on reinforced-**concrete** members under service conditions and in the tension zone. **Uncracked concrete** is where the tensile stress in the **concrete** is smaller than the tensile strength of the **concrete** and there will be no **cracking** occurring.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Limit state philosophy
- ✓ Design of rectangular beam section

Detailed content of the Lecture:

- ✓ **Cracked concrete** will be seen on reinforced-**concrete** members under service conditions and in the tension zone.
- ✓ **Uncracked concrete** is where the tensile stress in the **concrete** is smaller than the tensile strength of the **concrete** and there will be no **cracking** occurring.
- ✓ The term '**cracked concrete**' refers to **concrete** that may experience **cracking** passing through the plane of the anchor at some time after installation of the system. ... **Concrete** may **crack** due to a variety of reasons.
- ✓ One of the most important design considerations when selecting an anchor is the state of the **concrete**.
- ✓ The **cracked moment of inertia** is **calculated** in general to locate the neutral axis for a transformed **section**.
- ✓ Concept of **cracked moment of inertia** is applied in case of transformed beams.
- ✓ A beam is transformed completely from steel area to concrete area by multiplying the modular ratio m to the area of the desired beam
- ✓ **Concrete** is brittle in nature and have roughly 10% of compressive strength of **concrete**.
- ✓ At low tensile stresses **concrete** does not **crack** and behave as an **uncracked section**.
- ✓ The water retaining structures are designed as **uncracked section** by limiting stress

in **concrete** & steel within permissible limit ✓ The **cracked moment of inertia** is **calculated** in general to locate the neutral axis for a transformed **section**. ✓ Concept of **cracked moment of inertia** is applied in case of transformed beams. ✓ A beam is transformed completely from steel area to concrete area by multiplying the modular ratio m to the area of the desired beam.
Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=kpYhCESbJAc** **2 https://www.youtube.com/watch?v=kpYhCESbJAc**
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LECTURE HANDOUTS **L6**

CIVIL **V/III**

Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : I **Date of Lecture:**

Topic of Lecture: Design of one way slab

Introduction : One way slab is a **slab** which is supported by beams on the two opposite sides to carry the load along **one** direction. In **one way slab**, the ratio of longer span (l) to shorter span (b) is equal or greater than 2, i.e Longer span (l)/Shorter span (b) ≥ 2

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Working stress
- ✓ Cracked section
- ✓ Uncracked section

Detailed content of the Lecture:

Design a one-way slab for the inside of a building using the span, loads, and other data given in Figure 1. Normal-weight aggregate concrete is specified with a density of 145 pcf. (assuming cover 3/4 in)

Figure 1

The minimum thickness for one-way slab simply supported=L/20 using table 1(ACI 9.5.2.1)

h=10/20=0.5=6in

	Minimum thickness, h			
	Simply supported	One end continuous	Both ends continuous	Cantilever
Member	Members not supporting or attached to partitions or other construction likely to be damaged by large deflections			
Solid one-way slabs	$\ell/20$	$\ell/24$	$\ell/28$	$\ell/10$
Beams or ribbed one-way slabs	$\ell/16$	$\ell/18.5$	$\ell/21$	$\ell/8$
Notes: Values given shall be used directly for members with normalweight concrete and Grade 420 reinforcement. For other conditions, the values shall be modified as follows: a) For lightweight concrete having equilibrium density, w_c, in the range of 1440 to 1840 kg/m^3, the values shall be multiplied by $(1.65 - 0.0003w_c)$ but not less than 1.09. b) For f_y other than 420 MPa, the values shall be multiplied by $(0.4 + f_y/700)$.				

now

we will calculate d=(6-3/4(cover)-1/4(estimated as half diameter of reinforcement)

d=5 in

now we will calculate dead load

concrete density=145pcf, Usually 5 pcf is added to account for the weight of reinforcement, so 150

pcf is used in calculating the weight of a normal-weight concrete member.

dd=(6in*ft/12)*1*150/=75 lb/ft

LL=200*(1)=200lb/ft

Wu=1.2*75+1.6*200=410 lb/ft

maximum moment for simply supported span =(Wu*L^2)/8

=(410*10^2)/8=8/=5,125lb-ft=61,500lb-in

now we can calculate ρ

$\rho=(0.85*fc'/fy)*(1-\sqrt{(1-(2*Rn/0.85*fc'))}$

$Rn=Mu/(\phi*b*d^2)$

$Rn=(61500)/(0.9*12*(5^2))=227.7$

$\rho=(0.85*4000'/6000)*(1-\sqrt{(1-(2*227.7/0.85*4000))}=0.00393$

checking for ρmin

$\rho_{min}=(3\sqrt{fc'}/fy)$ **and not less than** $200/fy$

$\rho_{min}=3*\sqrt{4000}/6000$ **and not less than** $200/60000$

$\rho_{min}=0.0003$

$\rho>\rho_{min}$ **ok**

$As=0.00393*b*d$

$As=0.00393*12*6=0.282$ **in2/ft**

Use #4 @ 10 in. from Table A.6 (As = 0.24 in2/ft)

Spacing < maximum of 18 in. as per ACI 7.6.5

Transverse direction-shrinkage and creep

steel G60

then $As=0.0018*b*d=0.0018*12*6=0.1296$**in2**

Use #3 @ 10 in. (0.13 in2/ft)

Use #3 @ 10 in. (0.13 in2/ft) ok

The bar #4 is placed below bar #3 because the effective depth is important for main reinforcement calculation (flexural calculation)

Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=VEFk30zcnOs** **2.https://www.youtube.com/watch?v=VEFk30zcnOs**
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LECTURE HANDOUTS

L7

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I** **Date of Lecture:**

Topic of Lecture: Design of two way slab

Introduction : Two way slab is a **slab** supported by beams on all the four sides and the loads are carried by the supports along both directions, it is known as **two way slab**. In **two way slab**, the ratio of longer span (l) to shorter span (b) is less than 2. ... So, main reinforcement is provided in both direction for **two way slabs**.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Cracked section
- ✓ uncracked section
- ✓ One way slab

Detailed content of the Lecture:

Two Way Slab Design by Direct Design Method as per ACI 318-11

Two way slab design by direct design method as per ACI 318-11, step by step procedure and limitations of direct design method for two way slab is presented. Generally, there are two types of slab which are one way and two way slabs.

The one-way slab is deflected in one way direction and primary reinforcement is placed in one direction whereas the two-way slab deflect in two directions and primary reinforcement placement is in two directions.

ACI 318-11 Code provides two methods for two way slab design one of which is direct design method.

Direct design method, that could have been named the direct analysis method because it determines or prescribes moments for different parts of the slab panel without the need to conduct structural analysis, is explained in the following sections.

Procedures of Two Way Slab Design by Direct Design Method

1. Determine slab type and layout
2. Choose slab thickness that should be adequate for avoiding excessive deflections and satisfy shear at interior and exterior columns.
3. Choose design method (direct design method in this case)
4. Calculate positive and negative moments in the slab
5. Distribute moments across slab width
6. Specify portion of moments to the beams, if beams are present
7. Compute reinforcements for moments that found in two previous points
8. Check shear strength

Limitations of Direct Design Method

- There must be at least three continuous spans in each direction. If there are fewer panels, the interior negative moments tend to be too small.
- Panels should be rectangular and the ratio of longer/ shorter spans within the panel must not exceed 2 otherwise one way actions will prevail.
- In each direction, successive span lengths must not differ by more than one third of the largest span length.
- Column offset of more than 10% of the span (in the direction of offset) from either axis between centerline of successive column is not permitted.
- This method is applicable for slab that subjected to gravity load only.
- Unfactored service live load should not to be more than two times unfactored dead load.
- f beams were used, beam relative stiffness between two perpendicular directions must be between 0.2-0.5.

Two Way Slab Design by Direct Design Method

Before the start of two way slab design, slab depth should be determined in addition to specify column strips and middle strips. In this article, it is assumed that slab thickness is determine but calculation of column and middle strips is explained in the following section:

Column and middle strips

There are continuous variations of moments across slab panel therefore to help placement of steel, design moments are averaged over column strips and middle strips.

The column strips are located over columns and have a width on each side of the column centerline equal to smaller panel dimension divided by four and middle strips is located between two column strips. Figure-1 and Figure-2 illustrate middle strip and column strip for long and short directions of panel.

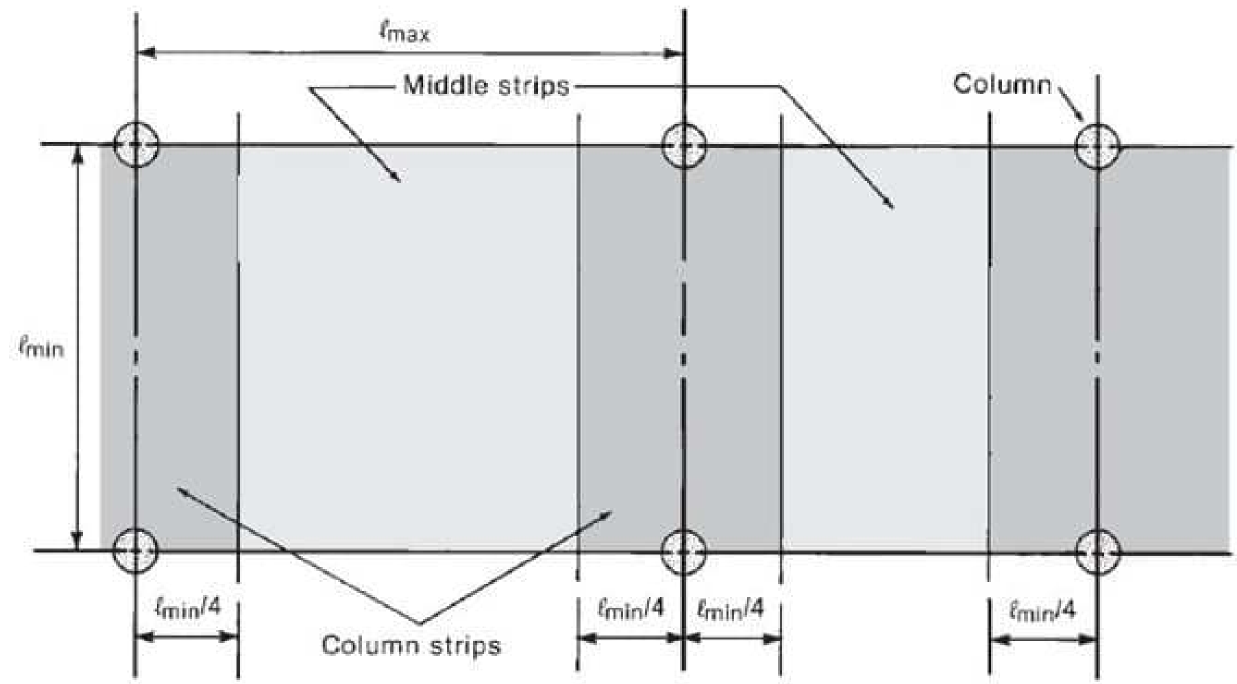

Figure-1: Column and Middle Strip in Short Direction of the Panel

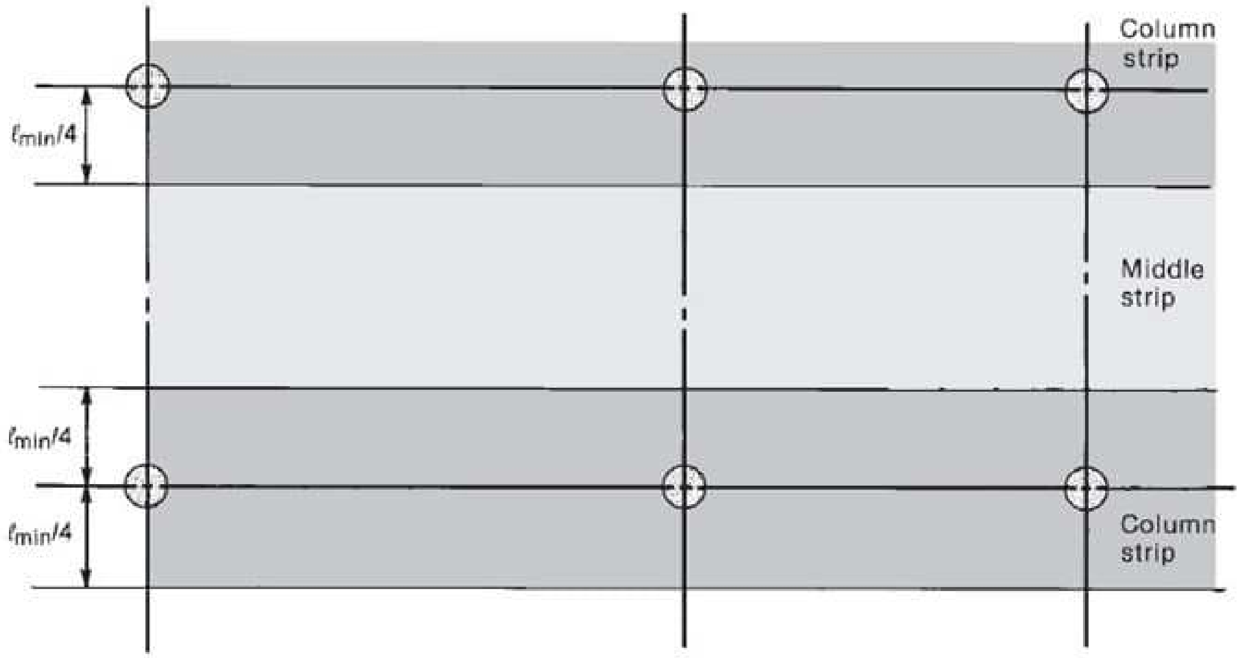

Figure-2: Column and Middle Strips in Long Direction of the Panel

Total static moment for a span (M_o):

Clear span (l_n) which is extended from face to face of walls or columns, in the direction of moments is used to compute total static moment in a panel. Factored moment in as span is calculated as per the following equation:

$$M_o = \frac{w_u l_2 l_n^2}{8} \quad \rightarrow \text{Equation-1}$$

Where:

w_u: Ultimate load per unit area of the slab

l_n: Clear span in (M_o) direction measured face to face of walls, columns, brackets, or capitals, and should be equal or larger than $0.65 l_1$

l_1: span length in the direction of (M_o)

l_2: span length perpendicular to l_1

Video Content / Details of website for further learning (if any):
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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L8

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I** **Date of Lecture:**

Topic of Lecture: Two way slab

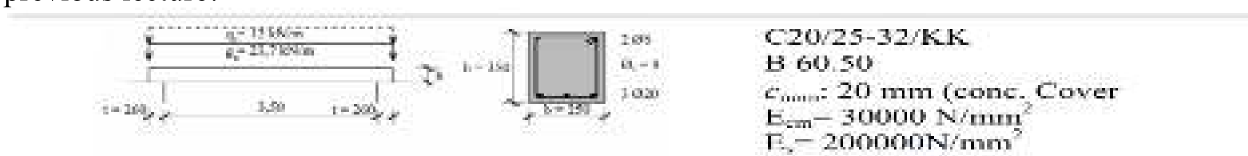
Introduction : A **rectangular beam** is one which is generally used as compression in top fibre and tension in bottom fibre of that **beam**. Whereas a t **beam** having **beam** and slab composite section. A t **beam** is more economical than **rectangular beam**.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ One way slab
- ✓ Two way slab

Detailed content of the Lecture:

Determine the cracking moment of the beam section investigated in the numerical example of the previous lecture!



Some details of the calculations shown earlier to determine the resistance moment of the section:

Design load intensity:

$$p_{Ed} = \gamma_G g_k + \gamma_Q q_k = 1{,}35 \cdot 23.7 + 1{,}5 \cdot 12 = 50{,}0 \text{ kN/m}$$

$$M_{Ed} = p_{Ed} \frac{l^2_{eff}}{8} = 50 \cdot \frac{3{,}76^2}{8} = 88{,}36 \text{ kNm}$$

The top reinforcement will be neglected, the area of 3Ø20 on tension side:

$$A_s = 942 \text{ mm}^2 \text{ (VS. 8. o.)}$$

Effective depth:

$$d = 350 - 20 - 8 - 20/2 = 312 \text{ mm} \quad \dots\ x_c = 122 \text{ mm}$$

$$z = d - x_c/2 = 312 - 61 = 251 \text{ mm}$$

$M_{Rd} = A_s f_{yd} z = 942 \cdot 435 \cdot 251 = 102{,}66 \cdot 10^6$ Nmm = 102,66 kNm $> M_{Ed} =$ 88,36 kNm the section is safe

To determine the cracking moment, tensile strength of the concrete is needed.

From DA table for concrete C20/25: $f_{ctd} = 1$ N/mm^2

$$\underline{\Sigma S = 0:} \quad b x_1 \frac{x_1}{2} - b(h - x_1)\frac{h - x_1}{2} - \alpha_c A_s (d - x_1) = 0 \rightarrow \quad x_1$$

$$\alpha_c = \frac{E_s}{E_{cm}} = \frac{200000}{30000} = 6{,}67$$

$$250 \cdot x_1 \frac{x_1}{2} - 250 \cdot (350 - x_1) \cdot \frac{350 - x_1}{2} - 6{,}67 \cdot 942 \cdot (312 - x_1) = 0$$

$$x_1 = 212{,}7 \text{ mm}$$

$$I_{i1} = \frac{b x_1^3}{3} + \frac{b(h - x_1)^3}{3} + \alpha_c A_s (d - x_1)^2 = \frac{250 \cdot 212{,}7^3}{3} + \frac{250 \cdot (350 - 212{,}7)^3}{3} +$$

$$+ 6{,}67 \cdot 9{,}42 \cdot (312 - 212{,}7)^2 =$$

$$9{,}019 \cdot 10^8 + 2{,}157 \cdot 10^8 + 0{,}619 \cdot 10^8 = 11{,}795 \cdot 10^8 \text{ mm}^4$$

$$M_{cr} = f_{ct,d} \frac{I_{i1}}{h - x_1} = 1{,}0 \cdot \frac{11{,}795 \cdot 10^8}{350 - 212{,}7} = 8{,}59 \cdot 10^6 \text{Nmm} = 8{,}59 \text{ kNm}$$

Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=IMEWmq6VKCI** **2. https://www.youtube.com/watch?v=IMEWmq6VKCI**
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LECTURE HANDOUTS

L9

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I** **Date of Lecture:**

Topic of Lecture: Design of two way slab

Introduction : Two way slab is a **slab** supported by beams on all the four sides and the loads are carried by the supports along both directions, it is known as **two way slab**. In **two way slab**, the ratio of longer span (l) to shorter span (b) is less than 2. ... So, main reinforcement is provided in both direction for **two way slabs**.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Cracked section
- ✓ uncracked section
- ✓ One way slab

Detailed content of the Lecture:

Two Way Slab Design by Direct Design Method as per ACI 318-11

Two way slab design by direct design method as per ACI 318-11, step by step procedure and limitations of direct design method for two way slab is presented. Generally, there are two types of slab which are one way and two way slabs.

The one-way slab is deflected in one way direction and primary reinforcement is placed in one direction whereas the two-way slab deflect in two directions and primary reinforcement placement is in two directions.

ACI 318-11 Code provides two methods for two way slab design one of which is direct design method.

Direct design method, that could have been named the direct analysis method because it determines or prescribes moments for different parts of the slab panel without the need to conduct structural analysis, is explained in the following sections.

Procedures of Two Way Slab Design by Direct Design Method

1. Determine slab type and layout
2. Choose slab thickness that should be adequate for avoiding excessive deflections and satisfy shear at interior and exterior columns.
3. Choose design method (direct design method in this case)
4. Calculate positive and negative moments in the slab
5. Distribute moments across slab width
6. Specify portion of moments to the beams, if beams are present
7. Compute reinforcements for moments that found in two previous points
8. Check shear strength

Limitations of Direct Design Method

- There must be at least three continuous spans in each direction. If there are fewer panels, the interior negative moments tend to be too small.
- Panels should be rectangular and the ratio of longer/ shorter spans within the panel must not exceed 2 otherwise one way actions will prevail.
- In each direction, successive span lengths must not differ by more than one third of the largest span length.
- Column offset of more than 10% of the span (in the direction of offset) from either axis between centerline of successive column is not permitted.
- This method is applicable for slab that subjected to gravity load only.
- Unfactored service live load should not to be more than two times unfactored dead load.
- f beams were used, beam relative stiffness between two perpendicular directions must be between 0.2-0.5.

Two Way Slab Design by Direct Design Method

Before the start of two way slab design, slab depth should be determined in addition to specify column strips and middle strips. In this article, it is assumed that slab thickness is determine but calculation of column and middle strips is explained in the following section:

Column and middle strips

There are continuous variations of moments across slab panel therefore to help placement of steel, design moments are averaged over column strips and middle strips.

The column strips are located over columns and have a width on each side of the column centerline equal to smaller panel dimension divided by four and middle strips is located between two column strips. Figure-1 and Figure-2 illustrate middle strip and column strip for long and short directions of panel.

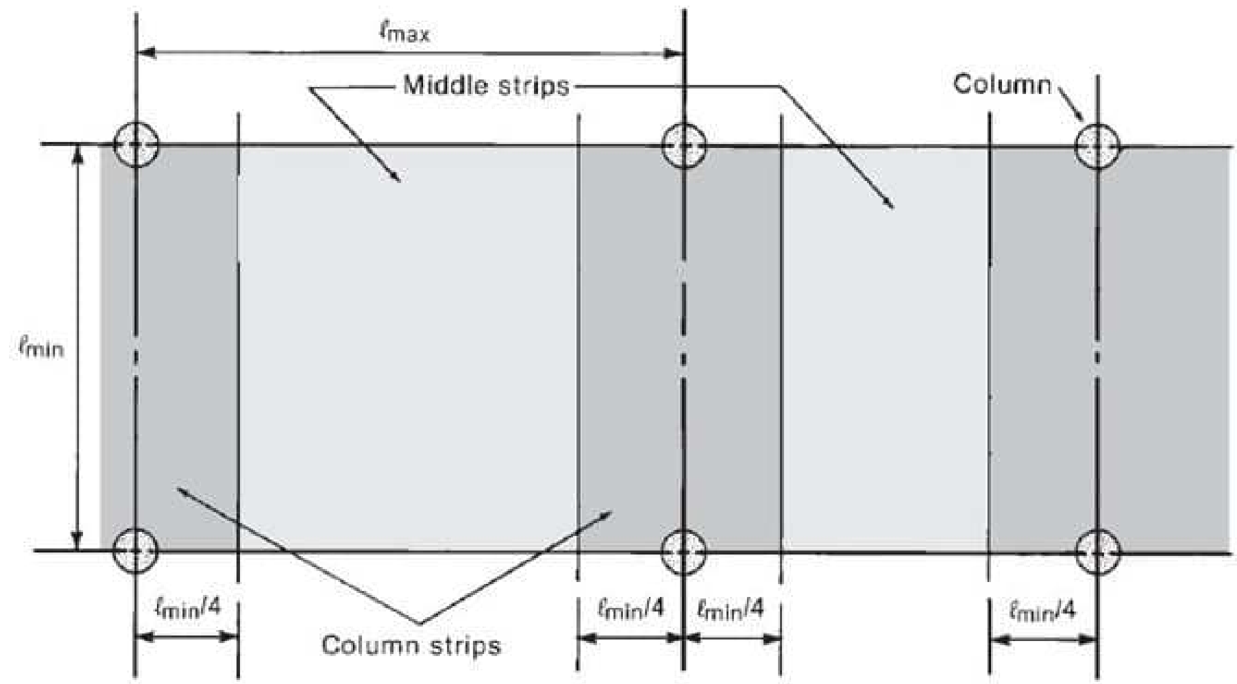

Figure-1: Column and Middle Strip in Short Direction of the Panel

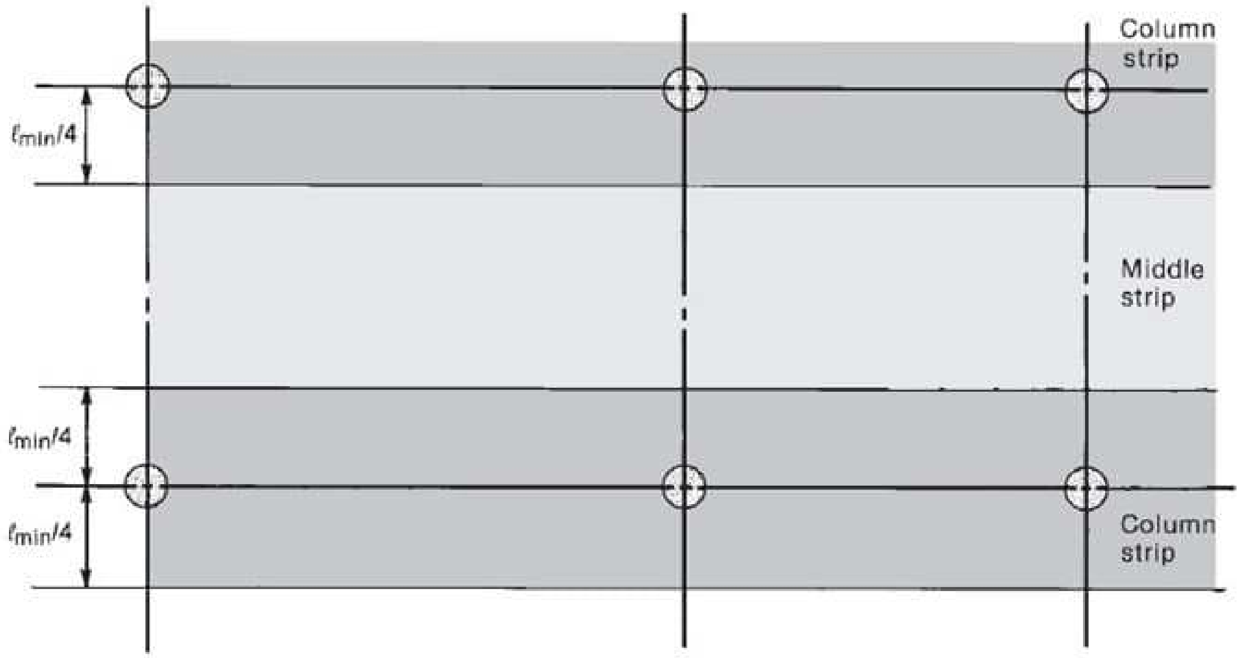

Figure-2: Column and Middle Strips in Long Direction of the Panel

Total static moment for a span (M_o):

Clear span (l_n) which is extended from face to face of walls or columns, in the direction of moments is used to compute total static moment in a panel. Factored moment in as span is calculated as per the following equation:

$$M_o = \frac{w_u l_2 l_n^2}{8} \quad \rightarrow \text{Equation-1}$$

Where:

w_u: Ultimate load per unit area of the slab

l_n: Clear span in (M_o) direction measured face to face of walls, columns, brackets, or capitals, and should be equal or larger than $0.65l_1$

l_1: span length in the direction of (M_o)

l_2: span length perpendicular to l_1

Video Content / Details of website for further learning (if any):
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LECTURE HANDOUTS **L10**

CIVIL **V/III**

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **II** **Date of Lecture:**

Topic of Lecture: Design of singly reinforced section

Introduction : The **flanged beam** may be considered as a **rectangular beam** of width bf and effective depth d if the neutral axis is in the **flange** as the concrete in tension is ignored. However, if the neutral axis is in the web, the compression is taken by the **flange** and a part of the web.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ One way slab
- ✓ Two way slab
- ✓ Working stress method

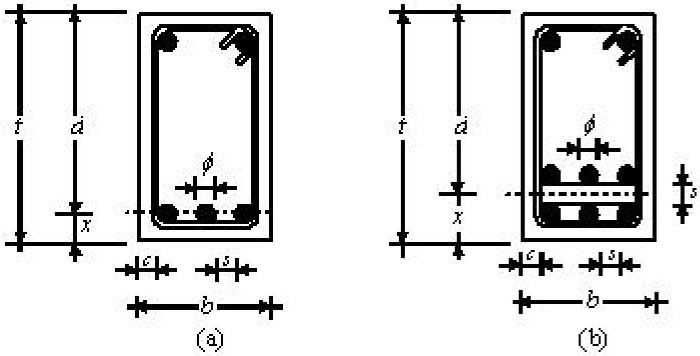
Detailed content of the Lecture:

SPACING OF REINFORCEMENT AND CONCRETE COVER

The spacing of reinforcement and the concrete cover should be sufficient to make concreting more easier; consequently, the concrete surrounding the reinforcement can be efficiently vibrated, resulting in a dense concrete cover which provides suitable protection of the reinforcement against corrosion.

1.8.1 Spacing of Reinforcement

Figure 1.19 shows two reinforced concrete sections. The bars are placed such that the clear spacing *s* shall be at least equal to the maximum diameter of the bars, or 25 mm, or 1.50 times maximum size of aggregate, whichever is greatest, according to the Egyptian Code. Vertical clear spacing between bars, in more than one layer, shall not be less than 25 mm.



In a slab-beam floor system, the smallest effective flange width *B* was found to be 1450 mm, the web width *b* was 250 mm and the slab thickness was 120 mm, Fig. 1.36a. Design a *T*-section to resist an ultimate external moment *Mu* of 240 kNm. Given: *fcu* = 20 N/mm2 and steel 240/350.

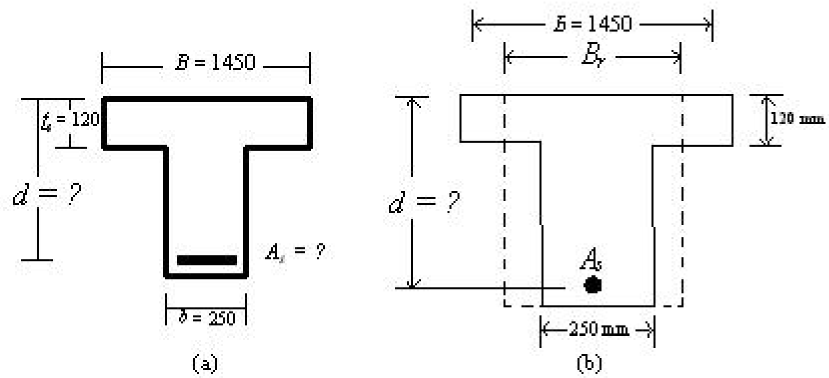


FIGURE 1.36. Example 1.6.

Solution:

Since the effective depth is not given, a reduced flange width is assumed; say .
Thus, mm.

That is, an equivalent rectangular section, Fig. 1.36b, can be chosen with *Br* = 580 mm and

which results in *d* = 380 mm. Assume two rows of steel bars (to be checked later).

t = 380.8 + 75 = 455.8 mm; say *t* = 500 mm actual *d* = 500 - 75 = 425 mm

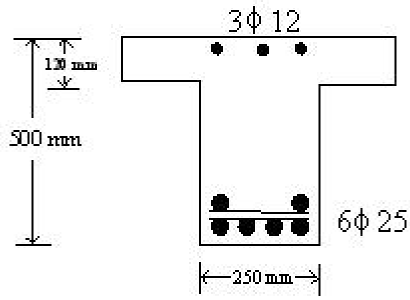
Proceed as in the previous example to calculate *As*.

Assume *a* £ *ts*

a = 46 mm which is less than *ts*

For equilibrium, *T* = *C*, we have

should not be less than 0.10 *As*, use 3 f 12.



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LECTURE HANDOUTS

L11

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **II** **Date of Lecture:**

Topic of Lecture: Design of doubly reinforced rectangular and flanged beams

Introduction : The **flanged beam** may be considered as a **rectangular beam** of width bf and effective depth d if the neutral axis is in the **flange** as the concrete in tension is ignored. However, if the neutral axis is in the web, the compression is taken by the **flange** and a part of the web.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ One way slab
- ✓ Two way slab
- ✓ Working stress method

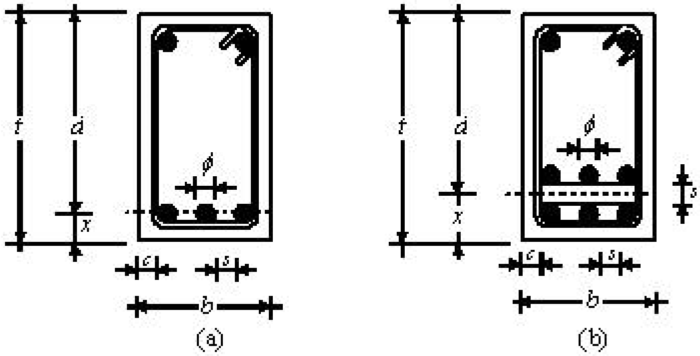
Detailed content of the Lecture:

SPACING OF REINFORCEMENT AND CONCRETE COVER

The spacing of reinforcement and the concrete cover should be sufficient to make concreting more easily; consequently, the concrete surrounding the reinforcement can be efficiently vibrated, resulting in a dense concrete cover which provides suitable protection of the reinforcement against corrosion.

1.8.1 Spacing of Reinforcement

Figure 1.19 shows two reinforced concrete sections. The bars are placed such that the clear spacing *s* shall be at least equal to the maximum diameter of the bars, or 25 mm, or 1.50 times maximum size of aggregate, whichever is greatest, according to the Egyptian Code. Vertical clear spacing between bars, in more than one layer, shall not be less than 25 mm.



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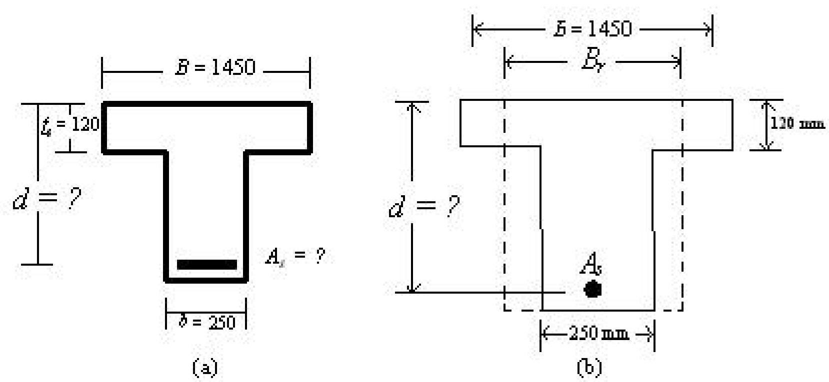

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which results in *d* = 380 mm. Assume two rows of steel bars (to be checked later).

t = 380.8 + 75 = 455.8 mm; say *t* = 500 mm actual d = 500 - 75 = 425 mm

Proceed as in the previous example to calculate As.

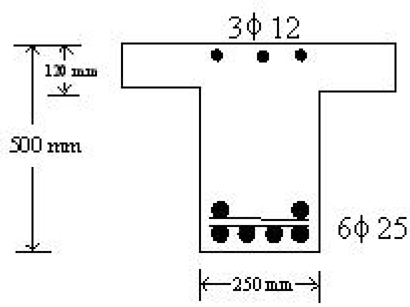
Assume a £ ts

a = 46 mm which is less than ts

For equilibrium, $T = C$, we have

mm2 choose 6 f 25 (2950 mm2)

should not be less than 0.10 As, use 3 f 12.



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LECTURE HANDOUTS

L12

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **II** **Date of Lecture:**

Topic of Lecture: Use of design aids for flexure behavior of R.C beams in shear and torsion

Introduction : Design Aids. Various charts and tables are provided as **design aids** for **designing** of the reinforced concrete. The basic purpose to introduce **design aids** is to minimize the **design** time by using the provisions given by code. Various designs of beams, slab and columns **use** these codes and **design** data.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Shear and torsion
- ✓ Design of R.C
- ✓ Combained bending

Detailed content of the Lecture:

- ✓ **Design Aids are Instrumental in Constructing Concrete Buildings**
- ✓ Slightly more than half of all low-rise buildings in the United States are constructed from concrete. Designers select concrete for one-, two-, and three-story stores, restaurants, schools, hospitals, commercial warehouses, terminals, and industrial buildings because of its durability and ease of construction.
- ✓ In addition, concrete is often the most economical choice: load-bearing concrete exterior walls serve not only to enclose the buildings and keep out the elements, but also carry roof and wind loads, eliminating the need to erect separate cladding and structural systems.
- ✓ While steel construction can be advantageous in regions of the country where local market conditions and traditions favor it, concrete is the most cost-effective choice throughout much of the South and West regions with strong masonry traditions.
- ✓ Concrete is often used in low-rise construction in Florida, where the material's ability to weather hurricanes and tornadoes, and its resistance to insects, are valued.
- ✓ Builders in California select concrete for its fire resistance.
- ✓ See the linked topics for a rundown of concrete design aids.
- ✓ **Publications**

- ✓ *Resilient Design Guide: Concrete Construction Edition*
  The purpose of the Resilient Design Guide: Concrete Edition is to provide information regarding the effective use of above- and below-grade concrete wall systems, as well as concrete floor systems to illustrate cost-effective, robust practices for residential construction.
- ✓ *PCA Notes on ACI 318-11 Building Code, EB712*
  The emphasis is placed on "how-to-use" the code incorporating discussions behind the code provisions and fully worked design solutions to real world problems
- ✓ The manual has been found to be also an invaluable aid to educators, contractors, materials and product manufacturers, building code authorities, inspectors, and others involved in the design, constructin, and regulation of concrete structures

  ✓

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=1G9W9cEuzsg
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LECTURE HANDOUTS

L13

CIVIL

V/III

Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : II **Date of Lecture:**

Topic of Lecture: Shear and Torsion reinforcement

Introduction : Beams exceeding the depth of 750 mm and subjected to bending moment and **shear** shall have side face **reinforcement**. However, if the beams are having **torsional** moment also, the side face **reinforcement** shall be provided for the overall depth exceeding 450 mm

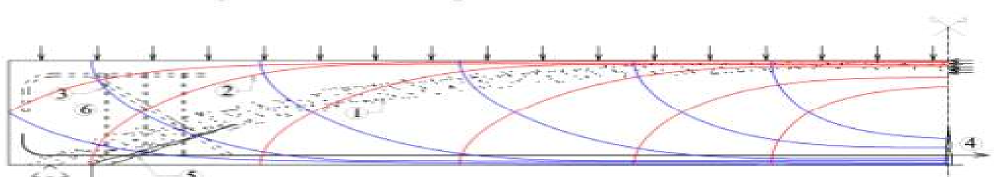
Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Singly reinforced
- ✓ Doubly reinforced

Detailed content of the Lecture:

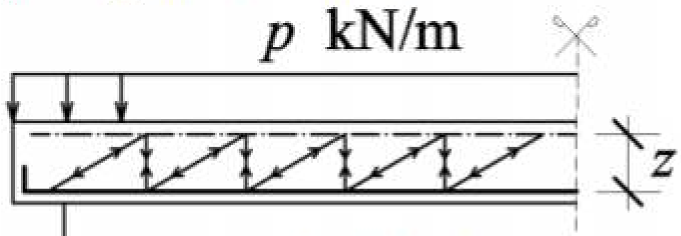
I. Shear

1. Ways of modeling shear transfer in rc beams



1: tha vault action
2: compression trajectories
3: tension trajectories
4: 1st shear crack, tension in the bottom reinforcement
5: 1st shear crack
6: elements of the shear reinforcement crossing the shear crack: links and bent-up bars

The truss model of Mörsch showing the way of transmitting shear to the support of simple supported rc beams



-lower chord: reinforcement equilibrating tension originated by flexure

-on top: concrete compression chord

-compressed concrete struts, with inclination angle θ

-vertical tie-up forces absorbed by links

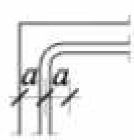
In the following the concrete compression strut inclination angle θ=45° is considered for convenience in manual calculations.

In EC2 $1 \le \cot\theta \le 2.5$ is allowed, that is: $21,6^\circ \le \theta \le 45^\circ$

6. The torsional moment capacity of rc beams

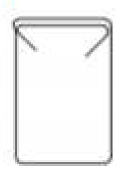
$$T_{Rd} = Min\begin{Bmatrix} T_{Rd,s} \\ T_{Rd,A_{sl}} \end{Bmatrix} \le T_{Rd,\max} = \upsilon f_{cd} A_c t_{eff}$$

Here $t_{eff}=\max\left[\frac{A_c}{p_c}, 2a\right]$



Uniformly distributed – closed - links and longitudinal bars should be designed, independently from links iand longitudinal bars designed for shear and moment.

Closed links to be designed for torsion



Video Content / Details of website for further learning (if any):

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2. https://www.youtube.com/watch?v=fZAlg-ri7HY

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LECTURE HANDOUTS

L14

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **II** **Date of Lecture:**

Topic of Lecture: Limit state design of reinforced concrete members for combined bending shear and torsion

Introduction : Singly reinforced **beam**(**Limit state** method of **design**) A structure with appropriate degree of reliability should be able to withstand safely. All loads, that are reliable to act on it throughout it's life and it should also satisfy the subs ability requirements, such as limitations on deflection and cracking.

Prerequisite knowledge for Complete understanding and learning of Topic:

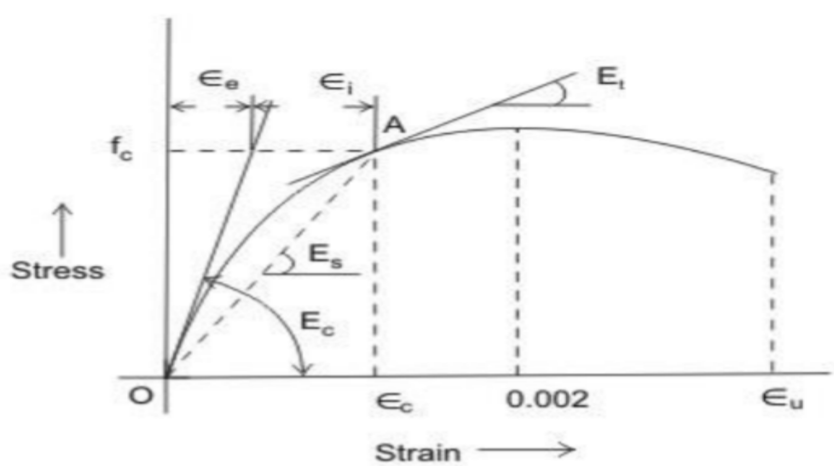
- ✓ Flanged beams
- ✓ Shear
- ✓ Torsion

Detailed content of the Lecture:

- ✓ Introduction Reinforced concrete, as a composite material, has occupied a special place in the modern construction of different types of structures due to its several advantages. Due to its flexibility in form and superiority in performance, it has replaced, to a large extent, the earlier materials like stone, timber and steel. Further, architect's scope and imaginations have widened to a great extent due to its mouldability and monolithicity.
- ✓ Thus, it has helped the architects and engineers to build several attractive shell forms and other curved structures. However, its role in several straight line structural forms like multistoried frames, bridges, foundations etc. is enormous.
- ✓ Concrete Concrete is a product obtained artificially by hardening of the mixture of cement, sand, gravel and water in predetermined proportions.
- ✓ Depending on the quality and proportions of the ingredients used in the mix the properties of concrete vary almost as widely as different kinds of stones
- ✓ Concrete has enough strength in compression, but has little strength in tension. Due to this, concrete is weak in bending, shear and torsion. Hence the use of plain concrete is limited applications where great compressive strength and weight are the principal requirements and where tensile stresses are either totally absent or are extremely low.
- ✓ Properties of Concrete The important properties of concrete, which govern the design of concrete mix are as follows
- ✓ (i) Weight The unit weights of plain concrete and reinforced concrete made with sand, gravel

of crushed natural stone aggregate may be taken as 24 KN/m3 and 25 KN/m3 respectively.

- ✓ (ii) Compressive Strength With given properties of aggregate the compressive strength of concrete depends primarily on age, cement content and the water cement ratio are given Table 2 of IS 456:2000.
- ✓ Characteristic strength are based on the strength at 28 days. The strength at 7 days is about two-thirds of that at 28 days with ordinary portland cement and generally good indicator of strength likely to be obtained.
- ✓ (iii) Increase in strength with age There is normally gain of strength beyond 28 days. The quantum of increase depends upon the grade and type of cement curing and environmental conditions etc.
- ✓ (iv) Tensile strength of concrete The flexure and split tensile strengths of various concrete are given in IS 516:1959 and IS 5816:1970 respectively when the designer wishes to use an estimate of the tensile strength from compressive strength, the following formula can be used Flexural strength, $f_{cr}=0.7\sqrt{f_{ck}}$ N/mm
- ✓ (v) Elastic Deformation The modulus of elasticity is primarily influenced by the elastic properties of the aggregate and to lesser extent on the conditions of curing and age of the concrete, the mix proportions and the type of cement. The modulus of elasticity is normally related to the compressive characteristic strength of concrete $E_c=5000\sqrt{f_{ck}}$ N/mm2 Where E_c= the short-term static modulus of elasticity in N/mm2 f_{ck}=characteristic cube strength of concrete in N/mm2
- ✓ (vi) Shrinkage of concrete Shrinkage is the time dependent deformation, generally compressive in nature. The constituents of concrete, size of the member and environmental conditions are the factors on which the total shrinkage of concrete depends.
- ✓ However, the total shrinkage of concrete is most influenced by the total amount of water present in the concrete at the time of mixing for a given humidity and temperature. The cement content, however, influences the total shrinkage of concrete to a lesser extent.
- ✓ The approximate value of the total shrinkage strain for design is taken as 0.0003 in the absence of test data (cl. 6.2.4.1). (vii) Creep of concrete



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LECTURE HANDOUTS

L15

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **II** **Date of Lecture:**

Topic of Lecture: Use of design aids

Introduction : Design Aids. Various charts and tables are provided as **design aids** for **designing** of the reinforced concrete. The basic purpose to introduce **design aids** is to minimize the **design** time by using the provisions given by code. Various designs of beams, slab and columns **use** these codes and **design** data.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Shear and torsion
- ✓ Design of R.C
- ✓ Combained bending

Detailed content of the Lecture:

- ✓ **Design Aids are Instrumental in Constructing Concrete Buildings**
- ✓ Slightly more than half of all low-rise buildings in the United States are constructed from concrete. Designers select concrete for one-, two-, and three-story stores, restaurants, schools, hospitals, commercial warehouses, terminals, and industrial buildings because of its durability and ease of construction.
- ✓ In addition, concrete is often the most economical choice: load-bearing concrete exterior walls serve not only to enclose the buildings and keep out the elements, but also carry roof and wind loads, eliminating the need to erect separate cladding and structural systems.
- ✓ While steel construction can be advantageous in regions of the country where local market conditions and traditions favor it, concrete is the most cost-effective choice throughout much of the South and West regions with strong masonry traditions.
- ✓ Concrete is often used in low-rise construction in Florida, where the material's ability to weather hurricanes and tornadoes, and its resistance to insects, are valued.
- ✓ Builders in California select concrete for its fire resistance.
- ✓ See the linked topics for a rundown of concrete design aids.

- **Publications**
- *Resilient Design Guide: Concrete Construction Edition*
  The purpose of the Resilient Design Guide: Concrete Edition is to provide information regarding the effective use of above- and below-grade concrete wall systems, as well as concrete floor systems to illustrate cost-effective, robust practices for residential construction.
- *PCA Notes on ACI 318-11 Building Code, EB712*
  The emphasis is placed on "how-to-use" the code incorporating discussions behind the code provisions and fully worked design solutions to real world problems
- The manual has been found to be also an invaluable aid to educators, contractors, materials and product manufacturers, building code authorities, inspectors, and others involved in the design, constructin, and regulation of concrete structures
- The over 900 page publication adds to the understanding of the art and science of structural engineering through presentation of the latest research and design procedures.
- By incorporating discussions of the history and philosophy of concrete design, the document strives to inform the reader of both the 'letter of the law' and, more importantly, the 'spirit' behind the code provisions.
- *Simplified Design of Reinforced Concrete Buildings, EB204*
  This new, fourth edition presents practicing engineers with timesaving analysis, design, and detailing methods of primary framing members of a reinforced concrete building.
- Revised and updated to ACI 318-11, it incorporates seismic and wind load provisions to comply with the International Building Code (2009 IBC).
- All equations, design aids, graphs, and code requirements have been updated to the current codes. Expanded illustrations of the theory and fundamentals and new timesaving design aids were added to include a wider range of concrete strengths. Also contains a new chapter on sustainable design.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=1G9W9cEuzsg
https://www.youtube.com/watch?v=1G9W9cEuzsg

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V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **II** **Date of Lecture:**

Topic of Lecture: Design requirement for bond and anchorage as per IS code

Introduction : This **bond** is seen when a bar carrying certain force is removed. In such cases, it is necessary to transfer this force in the bar to the surrounding concrete over a certain length.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Limit state design of R.C
- ✓ Shear and torsion
- ✓ Use of design aids

Detailed content of the Lecture:

Bond stress:

The stress which is acting on the outer interface of steel to the surrounding concrete is called bond stress. This stress helps in keeping bond between reinforcement and concrete together. Bond stress resists any force that tries to pull out the rods from the concrete.

When you try to pull out the reinforcement bar from hardened concrete, then this Bond stress resists the bar to come out.

By the way different grades of concrete has different bond stress.

well, these bonds are classified into two types:-

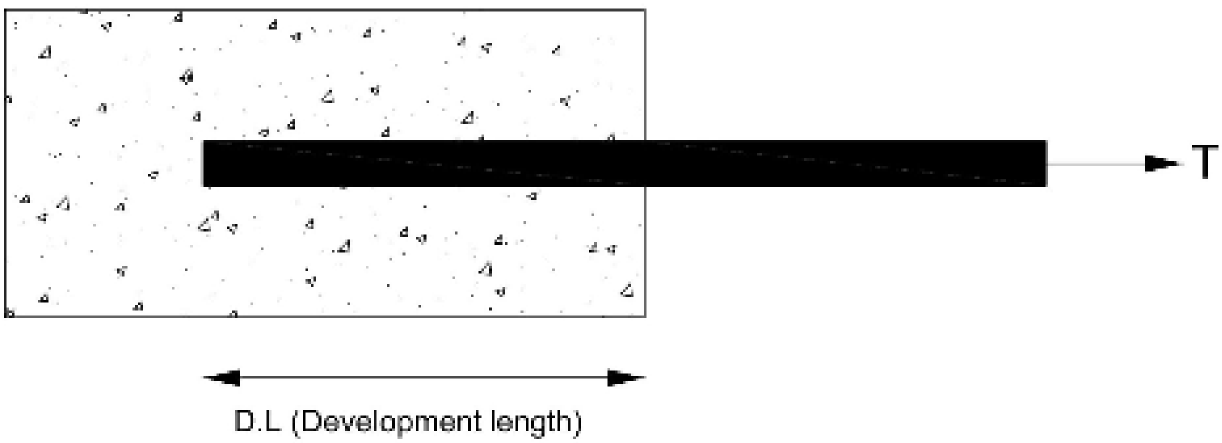
1. Anchorage bond (Development length)
2. Flexular bond.

Anchorage bond:-

This bond is seen when a bar carrying certain force is removed. In such cases, it is necessary to transfer this force in the bar to the surrounding concrete over a certain length.

This length of bar required to transfer the force in the bar to the surrounding concrete through bond is called "Development length (D.L.)"

Development length (DL) is determined by performing Pull out Test.



It is clear from the above image, that reinforcing bar is embedded in concrete and subjected to a pull **T**

T = Design Stress x area of bar = 0.87 Fy x (Pi/4) x d2

d= Dia of bar

This force must be transferred from steel to concrete through bond acting over the interface (perimeter) of the bar over a length (D.L.)

If Tbd = Avg Design bond stress

Then Ultimate Bond force = Pull out force

Tbd (Pi x d) x D.L. = 0.87 Fy [(Pi/4 x d^2)]

D.L = [0.87 x Fy x d] / [4 Tbd]

hence all bars should extend to a distance of (DL) beyond the section where they are required to take full design force.

it is not possible to provide straight bars at all the times due to lack of space at supports. In such scenarios we provide them as hooks and bends.

The anchorage value (hook length) = **16d**

The anchorage value (Bend length) =**4d (45degree angle)**

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=HiHJN4gDLXo
2. https://www.youtube.com/watch?v=HiHJN4gDLXo

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CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **II** **Date of Lecture:**

Topic of Lecture: Servicibility requirements

Introduction : Serviceability requirements of foundations include settlement, heave, tilt, vibration, lateral movement, and durability. Failure to meet these **serviceability requirements** leads to aesthetic issues, diminished usefulness of the structure, and increased maintenance costs.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Use of design aids
- ✓ Bond
- ✓ anchorage

Detailed content of the Lecture:

Serviceability Requirements

Serviceability is the ease with which a deployed system can be maintained, including tasks such as monitoring the system, repairing problems that arise, adding and removing users from the system, and upgrading hardware and software components.

When planning requirements for serviceability, consider the topics listed in the following table.

Table 3–6 Topics for Serviceability Requirements

Topic	Description
Downtime planning	Identify maintenance tasks that require specific services to be unavailable or partially unavailable. Some maintenance and upgrades can occur seamlessly to users, while others require interruption of service. When possible, schedule with users those maintenance activities that require downtime, allowing the users to plan for the downtime.
Usage patterns	Identify the usage patterns to determine the best time to schedule maintenance. For example, on systems where peak usage is during normal business hours, schedule maintenance in the evening or weekends. For geographically distributed systems, identifying these times can be more challenging.
Availability	Serviceability is often a reflection of your availability design. Strategies for minimizing downtime for maintenance and upgrades revolve around your availability strategy. Systems that require a high degree of availability have limited opportunities for maintenance, upgrades, and repair. Strategies for handling availability requirements affect how you handle maintenance and upgrades. For example, on systems that are distributed geographically, servicing can depend on the ability to route workloads to remote servers during maintenance periods. Also, systems requiring a high degree of availability might require more sophisticated solutions that automate restarting of systems with little human intervention.
Diagnostics and monitoring	You can improve the stability of a system by regularly running diagnostic and monitoring tools to identify problem areas. Regular monitoring of a system can avoid problems

	before they occur, help balance workloads according to availability strategies, and improve planning for maintenance and downtime.

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=rCLKY2vnR1A
2. https://www.youtube.com/watch?v=rCLKY2vnR1A

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Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : II **Date of Lecture:**

Topic of Lecture:serviceability requirements

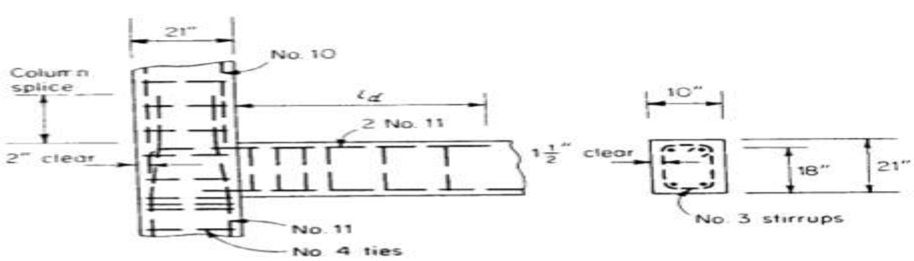
Introduction : Design Aids are Instrumental in Constructing Concrete Buildings. ... Concrete is often used in low-rise construction in Florida, where the material's ability to weather hurricanes and tornadoes, and its resistance to insects, are valued. Builders in California select concrete for its fire resistance.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Shear
- ✓ Torsion
- ✓ Design of aids

Detailed content of the Lecture:

10.8. Example. Development length in tension. Figure below shows a beam–column joint in a continuous building frame. Based on frame analysis, the negative steel required at the end of the beam is 2.90 in^2 and two No. 11 bars are used. providing $A_s = 3.12$ in^2. Beam dimensions are $b = 10$ in $d = 18$ in and $h = 21$ in. The design will include No. 3 stirrups spaced four at 3 inches followed by a constant 5 inches spacing in the region of the support. with 1.5 in. clear cover. Normal density concrete is to be used, with $f'_c = 4000$ psi. and rebars have $f_y = 60{,}000$ psi. Find the minimum distance l_d at which the negative bars can be cut off based on development of the required steel area at the face of the column.



ACI Sect. 12.2.3

$$l_d = \left[\frac{3}{40}\frac{f_y}{\lambda\sqrt{f_c'}}\frac{\Psi_t\Psi_e\Psi_s}{\left(\frac{c+K_{tr}}{d_b}\right)}\right]d_b$$

$$c = \text{spacing or cover dimension} = \begin{cases} \frac{\text{center to center spacing}}{2} = \frac{1}{2}(4.83) = 2.41\ in \quad \leftarrow \text{Controls} \\ 1.5 + 3/8 + 1.41/2 = 2.58\ in \end{cases}$$

$$A_{tr} = 0.22$$

$$K_{tr} = \frac{A_{tr}40}{s\,n}$$

$$K_{tr} = \frac{0.22 \times 40}{5 \times 2} = 0.88$$

$$\frac{c + K_{tr}}{d_b} = \frac{2.41 + 0.88}{1.41} = 2.33 < 2.5 \text{ ok}$$

$\Psi_t = 1.3$ Top bars

$\Psi_e = 1.0$ Not Epoxy coated

$\Psi_s = 1.0$ No. 7 and larger bars

$\alpha \times \beta = 1.3 \times 1.0 = 1.3 < 1.7$

$\lambda = 1.0$ Normal weight concrete

$d_b = 1.41\ in$

$$l_d = \left[\frac{3}{40}\frac{60{,}000}{1 \times \sqrt{4{,}000}}\frac{1.3 \times 1 \times 1}{(2.33)}\right] \times 1.41 = 56\ in$$

$$l_d = 56 \times \frac{2.9}{3.12} = 52\ in > 12\ in$$

Video Content / Details of website for further learning (if any):

1. https://www.youtube.com/watch?v=HiHJN4gDLXo
2. **https://www.youtube.com/watch?v=HiHJN4gDLXo**

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V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **III** **Date of Lecture:**

Topic of Lecture: Behavior of one way and two way slabs

Introduction : In **one way slab**, the **slabs** are supported by the beams on the **two** opposite sides. In **two way slab**, the **slabs** are supported on all the four sides. ... In **one way slab**, the ratio of Longer span to shorter span is equal or greater than 2.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ One way slab
- ✓ Two way slab

Detailed content of the Lecture:

- ✓ **Difference between One Way Slab and Two Way Slab**
- ✓ SLAB:
- ✓ **Slabs** are constructed to provide flat surfaces, usually horizontal, in **building floors**, roofs, **bridges**, and other types of structures. The slab may be supported by walls, by reinforced concrete beams usually cast monolithically with the slab, by structural steel beams, by **columns**, or by the ground.
- ✓ Slabs are classified into two types:

- ✓ One Way Slab
- ✓ Two Way Slab
- ✓ 1 One Way Slab:
- ✓ One way slab is a slab which is supported by beams on the two opposite sides to carry the **load** along one direction.The ratio of longer span (l) to shorter span (b) is equal or greater than 2, considered as One way slab because this slab will bend in one direction i.e in the direction along its shorter span

$$\frac{LongerSpan}{ShortSpan} \geq 2$$

- ✓ Due to the huge difference in lengths, load is not transferred to the shorter beams. Main reinforcement is provided in shorter span and distribution reinforcement in longer span.

- ✓ Example: Generally all the Cantilever slabs are one Way slab. Chajjas and verandahs are an practical example of one way slab.

- ✓
- ✓ #2 Two Way Slab:
- ✓ Two way slab is a slab supported by beams on all the four sides and the **loads** are carried by the supports along both directions, it is known as two way slab. In two way slab, the ratio of longer span (l) to shorter span (b) is less than 2.

$$\frac{LongerSpan}{ShorterSpan} = \frac{l}{b} < 2$$

- ✓
- ✓ In two way slabs, **load** will be carried in both the directions. So, main reinforcement is provided in both direction for two way slabs.
- ✓ Example: These types of slabs are used in constructing floors of multi storeyed building.

- ✓ Difference between One Way Slab and Two way slab:

✓ **One Way Slab**	✓ **Two Way Slab**
✓ Slabs are supported by the beams on the two opposite sides	✓ Slabs are supported by beams on all the four sides.
✓ Main reinforcement is provided on shorter span due to bending	✓ Main reinforcement is provided in both sides due to bending occurs on both sides
✓ Main Reinforcement is provided in only direction for one way slabs	✓ Main Reinforcement is provided along both the directions in two way slabs.

✓ Loads are carried along one direction in one way slab.	✓ Loads are carried along both the directions in two way slabs.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=ok-omRzPv9s
https://www.youtube.com/watch?v=SVC2BeqRKGc

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V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **III** **Date of Lecture:**

Topic of Lecture: Design of one way simply supported

Introduction : staircase. **stair·case**. a stairway, esp. one constructed for access between the floors of a building, and usually having a handrail or balustrade. MLA Style

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types ofstaircase
- ✓ Doglegged staircase

Detailed content of the Lecture:

subjected to live load of 3kN/m23kN/m2 and floor finish 1.25kN/m2.1.25kN/m2. Design flights from plinth beam to mid landing and mid landing to floor landing. Draw reinforcement details for both flig

It is a dog-legged staircase

Floor to floor height $= 3.2m$

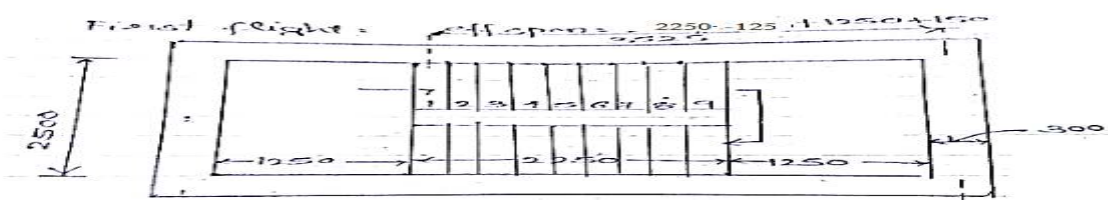
Height/flight $= (3.2/2) = 1.6m$

Assume Riser $= 160mm$

Tread $= 250mm$

No. of riser in one flight $= (1600/160) = 10$ Nos.

No. of tread in one flight $= R - 1 = 10 - 1 = 9$



s.

Trial depth= $\dfrac{\text{eff.span}}{S/D\ ratio \times M.F.}$

$$S/Dratio = 20, M.F. = 1.4$$

$$d_{reqd} = \frac{5050}{20 \times 1.4} = 180.35$$

Assume D = 250 mm

d= D-clear cover $-\phi/2$

$$= 250 - 25 - 20/2$$
$$d = 215mm.$$

Load calculation on step portion

a) D.L. of waist slab $= D \times 25 \times \dfrac{\sqrt{R^2 + T^2}}{T}$

$$= 0.3 \times 25 \times \frac{\sqrt{160^2 + 250^2}}{250}$$
$$= 8.9kN/m^2$$

b) D.L. of step $= R/2 \times 25$

$$= 0.16/2 \times 25 = 1.875kN/m^2$$

c) $F.F. = 1.25kN/m^2$

d) $L.L. = 3kN/m^2$

Total $= 8.9 + 1.875 + 1.25 + 3$
$= 15.025kN/m^2$

Factored Load $= 1.5 \times 15.025$
$= 22.53kN/m^2$

Load calculation on landing portion:

a) D.L. of slab $= D \times 25 = 0.25 \times 25 = 6.25kN/m^2$.

b) $F.F. = 1.25kN/m^2$

c) $L.L. = 3kN/m^2$

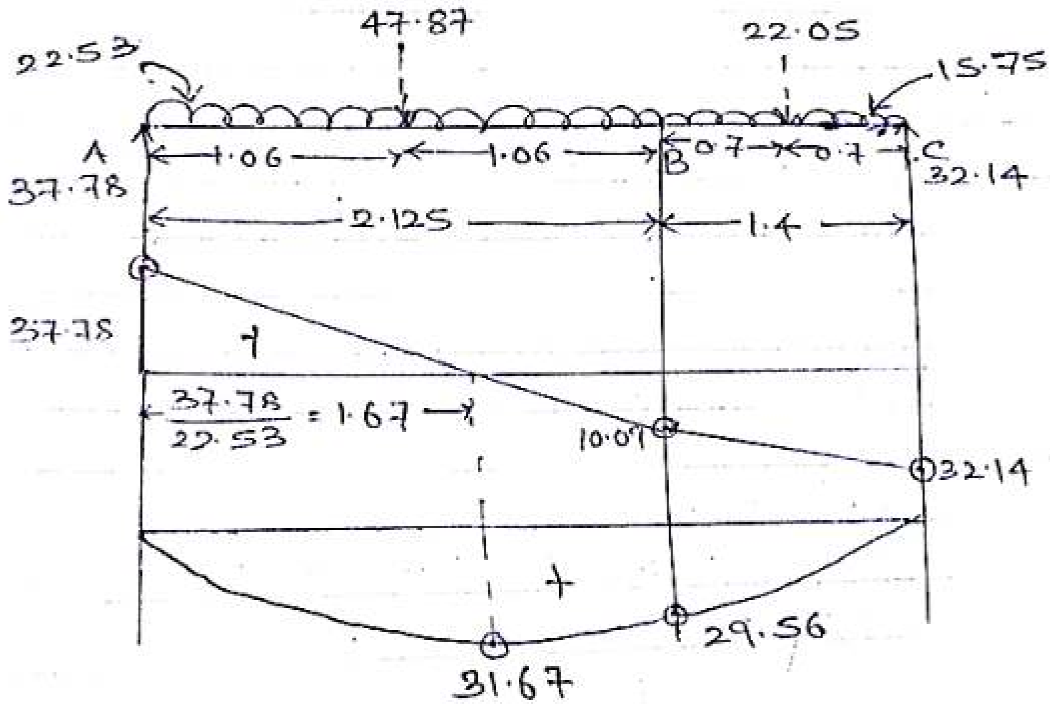
Total $= 6.25 + 1.25 + 3 = 10.5kN/m^2$

Factored Load $= 10.5 \times 1.5 = 15.75kN/m^2$

First Flight:

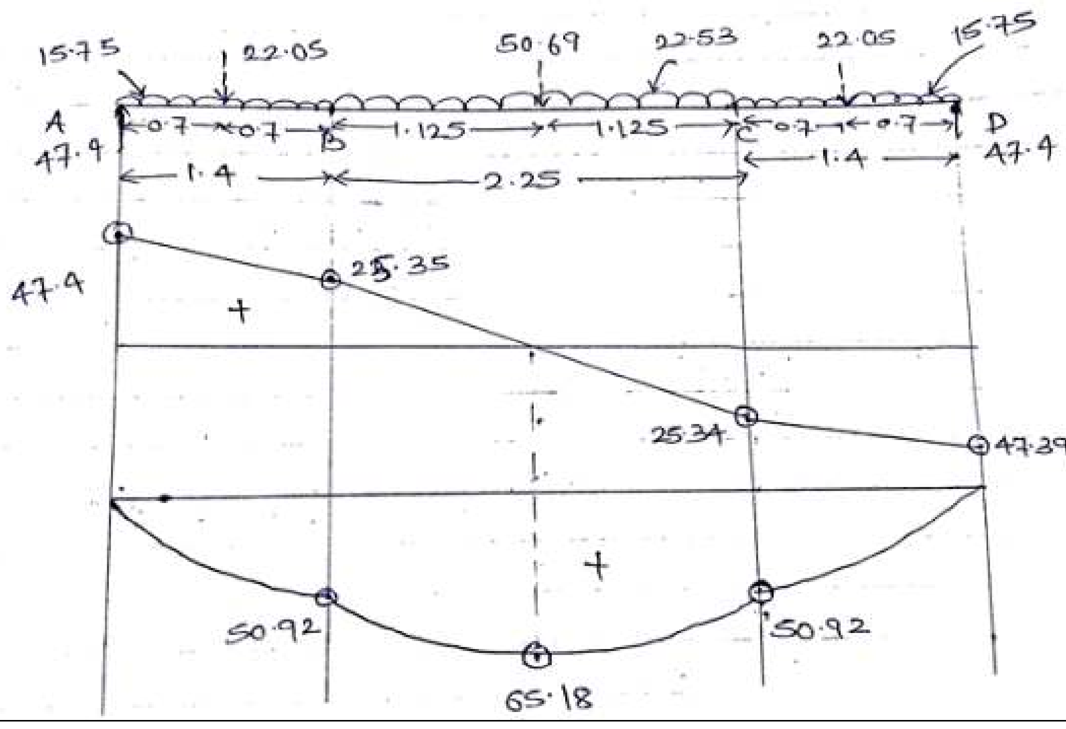
Calculations:

$$\sum M_{@C}=0$$
$$V_A\times 3.525-47.87\times(1.06+1.4)-22.05\times(0.7)=0$$
$$V_A=37.78kN$$
$$\sum Fy=0$$
$$V_A+V_C=47.87+22.05$$
$$V_C=32.14kN$$
$$B.M_{MAX}=37.78\times 1.67-\frac{22.53\times 1.67^2}{2}$$
$$=31.67kNm$$
$$B.M>_{@B}=32.14\times 1.4-22.05\times 0.7$$
$$=29.56kNm.$$



Calculations:

$$\sum M_{@C} = 0$$
$$V_A \times 3.525 - 47.87 \times (1.06 + 1.4) - 22.05 \times (0.7) = 0$$
$$V_A = 37.78kN$$
$$\sum Fy = 0$$
$$V_A + V_C = 47.87 + 22.05$$
$$V_C = 32.14kN$$
$$B.\,M_{MAX} = 37.78 \times 1.67 - \frac{22.53 \times 1.67^2}{2}$$
$$= 31.67kNm$$
$$B.\,M >_{@B} = 32.14 \times 1.4 - 22.05 \times 0.7$$
$$= 29.56kNm.$$



$$= \frac{5050}{20 \times 1.48} = 170.66 < 215mm$$

$safe$

Check for development length:

$$M_0 = M/2 = (65.18)/2 = 32.59kNm$$

$$V = 47.4kN.$$

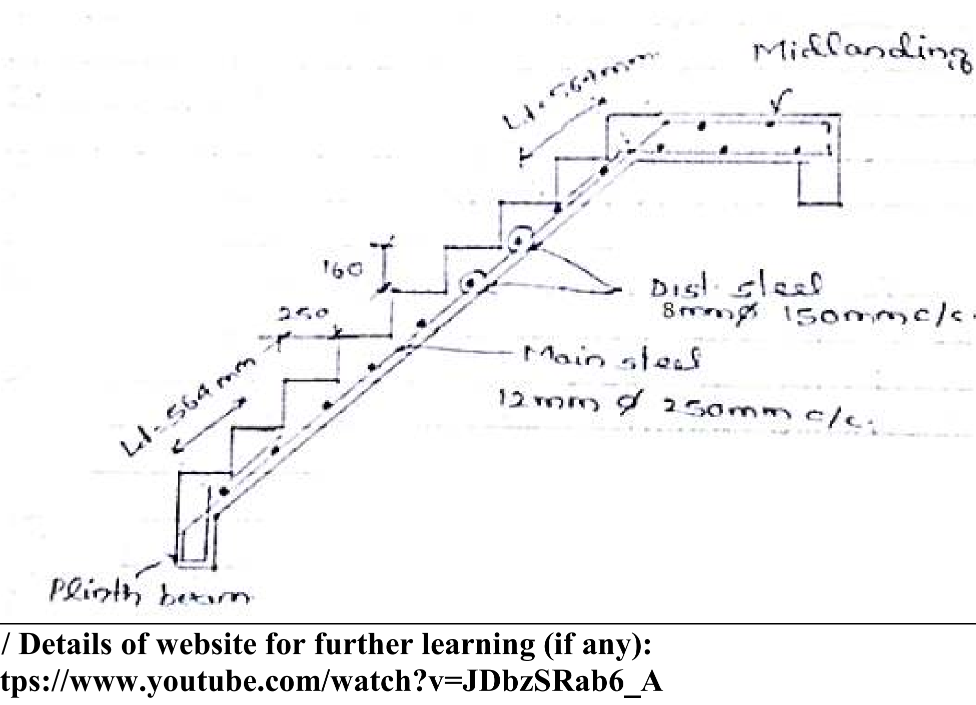
$$L_0 = (bs/2) - 25 + 3\phi = (300/2) - 25 + 3 \times 12 = 161mm.$$

$$L_d = \frac{0.87fy\phi}{4.Z_{bd}} = 47\phi = 47 \times 12 = 564mm$$

$$L_d \leq \frac{1.3M_0}{V} + L_0$$

$$564 \leq \frac{1.3 \times 32.59 \times 10^6}{47.4 \times 10^3} + 161$$

First flight:



Video Content / Details of website for further learning (if any):

1. **https://www.youtube.com/watch?v=JDbzSRab6_A**
2. **https://www.youtube.com/watch?v=d1r4jBc1FZE**

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CIVIL

V/III

Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : III **Date of Lecture:**

Topic of Lecture: Design of cantilever beams and slabs

Introduction :

- ✓ A **cantilever** is a rigid structural element such as a beam or a plate, anchored at one end to a (usually vertical) support from which it protrudes; this connection could also be perpendicular to a flat, vertical surface such as a wall. **Cantilevers** can also be constructed with trusses or **slabs**.
- ✓ A **slab** which is extended over three or more support beams in a given direction is called **continuous slab**. In **continuous slab** the **slab** is constructed as a single unit without a wall as a support we only able able to see a beam as a support.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ One way and two way slab
- ✓ One way simply supported

Detailed content of the Lecture:

4.3 DESIGN AND DETAILING OF CANTILEVER SLABS

Design and detailing of a cantilever slab is the same as that of a cantilever beam (Section 3.3) of unit width. Temperature and shrinkage reinforcement is provided along the direction perpendicular to the span. This is illustrated through the following example.

Example 4.1

Design the cantilever slab of a bus stand shown in Figure 4.1. Load data and design parameters are given below :

Load Data

Lime terrace topping of 100 mm thickness is provided over the slab.

Imposed load = 0.75 kN/m^2.

Figure 4.1 : Cantilever Roof Shade for Bus Stop

Solution

Effective Span (l_{ef})

$$l_{ef} = 3 + 0.3^* = 3.3 \text{ m}$$

> * Estimate of effective depths (d) :
> $$d \approx \frac{l_{ef}}{7} \approx \frac{300}{7} = 428.57 \text{ mm}$$
> $$\therefore \frac{d}{2} \approx 300 \text{ mm} = 0.3 \text{ m added}$$
> for evaluating l_{ef} (Cl. 22.2c).

Depth of Slab (D)

From Deflection Control

$\frac{l_{ef}}{d} \le k_B\, k_1\, k_2\, k_3\, k_4$, where $k_B = 7$; $k_1 = 1$ as $l_{ef} < 10$ m

For k_2, $f_s = 0.58\, f_y \dfrac{\text{Area of cross section of steel required}}{\text{Area of cross section of steel provided}}$

Assuming area of cross section of steel required = Area of cross section of steel provided = Area of balanced tensile steel for M 25 concrete and Fe 415 steel ($p_t\%$ = 1.19%). According to above assumptions

$$f_s = 0.58 \times f_y \times 1 = 0.58 \times 415 \approx 240 \text{ N/mm}^2$$

and $k_2 = 0.96$ (Figure 1.2)

$k_3 = k_4 = 1$ as the slab is singly reinforced and it is not a flanged section.

Substituting all these values

$$\frac{l_{ef}}{d} \le 7 \times 1 \times .96 \times 1 \times 1 = 6.72$$

or $$d \ge \frac{3.3 \times 10^3}{6.72} = 491 \text{ mm}$$

$\therefore$ $$D = d + \frac{\phi}{2} + \text{nominal cover} = 491 + \frac{10}{2} + 30 = 526 \text{ mm}$$

(assuming ϕ = 10)

Taking D = 550 mm

$\therefore$ $$d = D - \frac{\phi}{2} - \text{Nominal cover} = 550 - \frac{10}{2} - 30 = 515 \text{ mm}$$

res-II **From Moment of Resistance Consideration**

Loads

Self	= 1 × 1 × 0.550 × 25	= 13.75 kN/m^2
Lime Terrace	= 1 × 1 × 0.1 × 18.8	= 1.88 kN/m^2
Ceiling Plaster	= 1 × 1 × 0.01 × 20.4	= 0.204 kN/m^2
Total (Dead Load)		= 15.834 kN/m^2
Imposed Load (IL)		= 0.750 kN/m^2
Total Load, w		= 16.584 kN/m^2

$$\text{Maximum BM, } M_u = \frac{w_u l_{ef}^2}{2} = \frac{1.5 \times 16.584 \times 3.26^2}{2} = 132.2 \text{ kNm}$$

$$M_{u\text{-lim}} = 0.36 \frac{x_{u,\max}}{d}\left(1 - 0.42 \frac{x_{u,\max}}{d}\right) bd^2 f_{ck}$$

$$132.2 \times 10^6 = 0.36 \times 0.48 \times (1 - 0.42 \times 0.48) \times 1000 \times d^2 \times 25$$

or d = 195.8 mm

Hence, provided D = 550 mm and d = 515 mm as above.

Tensile Reinforcement (A_{st})

$$M_u = 0.87\, f_y\, A_{st}\, d \left(1 - \frac{A_{st}\, f_y}{bd\, f_{ck}}\right)$$

$$132.2 \times 10^6 = 0.87 \times 415 \times A_{st} \times 515 \times \left(1 - \frac{A_{st} \times 415}{1000 \times 515 \times 25}\right)$$

or, $$132.2 \times 10^6 = 185940.75\, A_{st} - 5.993\, A_{st}^2$$

Check for Shear

SF at critical section, i.e. at d from the face of support

$$= V_u = 1.5 \times 16.584 \times (3 - 0.515)$$

$$= 61.817 \text{ kN}$$

$$\tau_v = \frac{V_u}{bd} = \frac{61.817 \times 10^3}{1000 \times 515}$$

$$= 0.12 \text{ N/mm}^2$$

$\tau_{c,\min}$ for M 25 concrete

$$= 0.29 \text{ N/mm}^2 > 0.12 \text{ N/mm}^2$$

Hence, O.K.

Detailing of Reinforcement

As $A_{st,\min}$ (= 618 mm^2) is more than 50% of A_{st} (742.857 mm^2/m) provided, hence, all the tensile reinforcement shall be extended up to free end of the slab.

Development Length

$$L_d = \frac{\phi\sigma_s}{4\tau_{bd}} = \frac{10 \times 0.87 \times 415}{4 \times 1.6 \times 1.4} = 403 \text{ mm}$$

Value of a 90° bend is $8\,\phi = 8 \times 10 = 80$ mm.

$\therefore$ Length of bar required = 403 − 80 = 323 mm say 325 mm.

The detailing of the reinforcement has been shown in Figure 4.2.

Video Content / Details of website for further learning (if any):

1.https://www.youtube.com/watch?v=NblAoUtOKPM
2. https://www.youtube.com/watch?v=_NH4NozC8G8

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LECTURE HANDOUTS | **L22**

CIVIL | **V/III**

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **I** **Date of Lecture:**

Topic of Lecture: Design of cantilever beams and slabs

Introduction :

- ✓ A **cantilever** is a rigid structural element such as a beam or a plate, anchored at one end to a (usually vertical) support from which it protrudes; this connection could also be perpendicular to a flat, vertical surface such as a wall. **Cantilevers** can also be constructed with trusses or **slabs**.
- ✓ A **slab** which is extended over three or more support beams in a given direction is called **continuous slab**. In **continuous slab** the **slab** is constructed as a single unit without a wall as a support we only able able to see a beam as a support.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ One way and two way slab
- ✓ One way simply supported

Detailed content of the Lecture:

4.3 DESIGN AND DETAILING OF CANTILEVER SLABS

Design and detailing of a cantilever slab is the same as that of a cantilever beam (Section 3.3) of unit width. Temperature and shrinkage reinforcement is provided along the direction perpendicular to the span. This is illustrated through the following example.

Example 4.1

Design the cantilever slab of a bus stand shown in Figure 4.1. Load data and design parameters are given below :

Load Data

Lime terrace topping of 100 mm thickness is provided over the slab.

Imposed load = 0.75 kN/m^2.

Figure 4.1 : Cantilever Roof Shade for Bus Stop

Solution

> * Estimate of effective depths (d) :
>
> $$d \approx \frac{l_{ef}}{7} \approx \frac{300}{7} = 428.57 \text{ mm}$$
>
> $\therefore \frac{d}{2} \approx 300$ mm $= 0.3$ m added for evaluating l_{ef} (Cl. 22.2c).

Effective Span (l_{ef})

$$l_{ef} = 3 + 0.3^* = 3.3 \text{ m}$$

Depth of Slab (D)

From Deflection Control

$\frac{l_{ef}}{d} \leq k_B\, k_1\, k_2\, k_3\, k_4$, where $k_B = 7$; $k_1 = 1$ as $l_{ef} < 10$ m

For k_2, $f_s = 0.58\, f_y \dfrac{\text{Area of cross section of steel required}}{\text{Area of cross section of steel provided}}$

Assuming area of cross section of steel required = Area of cross section of steel provided = Area of balanced tensile steel for M 25 concrete and Fe 415 steel (p_t% = 1.19%). According to above assumptions

$$f_s = 0.58 \times f_y \times 1 = 0.58 \times 415 \approx 240 \text{ N/mm}^2$$

and $k_2 = 0.96$ (Figure 1.2)

$k_3 = k_4 = 1$ as the slab is singly reinforced and it is not a flanged section.

Substituting all these values

$$\frac{l_{ef}}{d} \leq 7 \times 1 \times .96 \times 1 \times 1 = 6.72$$

or $d \geq \dfrac{3.3 \times 10^3}{6.72} = 491$ mm

$\therefore$ $D = d + \dfrac{\phi}{2} + \text{nominal cover} = 491 + \dfrac{10}{2} + 30 = 526$ mm

(assuming $\phi = 10$)

Taking $D = 550$ mm

$\therefore$ $d = D - \dfrac{\phi}{2} - \text{Nominal cover} = 550 - \dfrac{10}{2} - 30 = 515 \text{ mm}$

res-II   **From Moment of Resistance Consideration**

Loads

Self	$= 1 \times 1 \times 0.550 \times 25$	$= 13.75$ kN/m^2
Lime Terrace	$= 1 \times 1 \times 0.1 \times 18.8$	$= 1.88$ kN/m^2
Ceiling Plaster	$= 1 \times 1 \times 0.01 \times 20.4$	$= 0.204$ kN/m^2
Total (Dead Load)		$= 15.834$ kN/m^2
Imposed Load (IL)		$= 0.750$ kN/m^2
Total Load, w		$= 16.584$ kN/m^2

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$$M_{u \cdot \lim} = 0.36 \frac{x_{u,\max}}{d}\left(1 - 0.42 \frac{x_{u,\max}}{d}\right) b d^2 f_{ck}$$

$$132.2 \times 10^6 = 0.36 \times 0.48 \times (1 - 0.42 \times 0.48) \times 1000 \times d^2 \times 25$$

or $d = 195.8$ mm

Hence, provided $D = 550$ mm and $d = 515$ mm as above.

Tensile Reinforcement (A_{st})

$$M_u = 0.87\, f_y\, A_{st}\, d \left(1 - \frac{A_{st}\, f_y}{bd\, f_{ck}}\right)$$

$$132.2 \times 10^6 = 0.87 \times 415 \times A_{st} \times 515 \times \left(1 - \frac{A_{st} \times 415}{1000 \times 515 \times 25}\right)$$

or, $132.2 \times 10^6 = 185940.75\, A_{st} - 5.993\, A_{st}^2$

Check for Shear

SF at critical section, i.e. at d from the face of support

$$= V_u = 1.5 \times 16.584 \times (3 - 0.515)$$

$$= 61.817 \text{ kN}$$

$$\tau_v = \frac{V_u}{bd} = \frac{61.817 \times 10^3}{1000 \times 515}$$

$$= 0.12 \text{ N/mm}^2$$

$\tau_{c,\min}$ for M 25 concrete

$$= 0.29 \text{ N/mm}^2 > 0.12 \text{ N/mm}^2$$

Hence, O.K.

Detailing of Reinforcement

As $A_{st,\min}$ (= 618 mm^2) is more than 50% of A_{st} (742.857 mm^2/m) provided, hence, all the tensile reinforcement shall be extended up to free end of the slab.

Development Length

$$L_d = \frac{\phi\sigma_s}{4\tau_{bd}} = \frac{10 \times 0.87 \times 415}{4 \times 1.6 \times 1.4} = 403 \text{ mm}$$

Value of a 90° bend is 8 ϕ = 8 × 10 = 80 mm.

∴ Length of bar required = 403 − 80 = 323 mm say 325 mm.

The detailing of the reinforcement has been shown in Figure 4.2.

Video Content / Details of website for further learning (if any):

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2. https://www.youtube.com/watch?v=_NH4NozC8G8

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LECTURE HANDOUTS

L23

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **III** **Date of Lecture:**

Topic of Lecture: Design of two -way slab various edge conditions

Introduction : If a **slab** is only supported on 2 opposite ends, obviously it has to span between them. If the **slab** is supported at all **edges** (which is most likely the case), it will behave as a 2-**way slab** the closer the supports are to being square. ... You may consider it a 1-**way slab** if the long span to short span ratio is 2 or more.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Cantilever slab
- ✓ Continuous slab

Detailed content of the Lecture:

- ✓ **Design of Two-way Slab by Coefficient Method**
- ✓ There are several methods by which two-way slabs can be designed. All methods are viable provided that the safety and serviceability of the elements are within the acceptable limits. The coefficient method may be the simplest, easiest and the quickest approach for the design of two-way slab supported by edge beam on all slab sides.
- ✓ This method was provided in the American Concrete Institute (ACI) in 1963 to design two-way slabs carried by steel beams, deep beam, or walls. Nonetheless, the coefficient method is not included in the current edition of the ACI code. This is because it is considered to be too conservative and more precise approaches can be employed. However, it should be known that the coefficient method is still applied for two-way slabs.

- ✓ Coefficient Method
- ✓ The coefficient method employs tables of moment coefficients for different slab edge conditions. The conditions are based on elastic analysis but inelastic redistribution is accounted for as well.
- ✓ As a result, the design moment on both directions is smaller by a specific amount than the ultimate elastic moment in that exclusive direction.
- ✓ According to the coefficient approach, the slab is divided into the middle strip and column strip in each direction. The width of the latter is equal to the one-quarter of the panel width whereas the width of the former is one-half the panel width, as illustrated in Fig.1.

Video Content / Details of website for further learning (if any):

1.https://www.youtube.com/watch?v=UseI8aJ_heI

2. https://www.youtube.com/watch?v=SLceJhNBltk

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LECTURE HANDOUTS

L24

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **III** **Date of Lecture:**

Topic of Lecture: Types of staircases

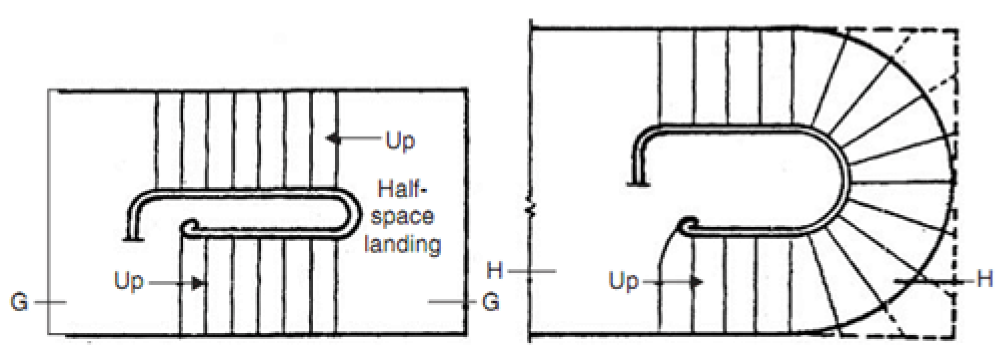
Introduction : staircase. **stair·case**. a stairway, esp. one constructed for access between the floors of a building, and usually having a handrail or balustrade. MLA Style.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Cantilever and continuous slab
- ✓ Various edge conditions

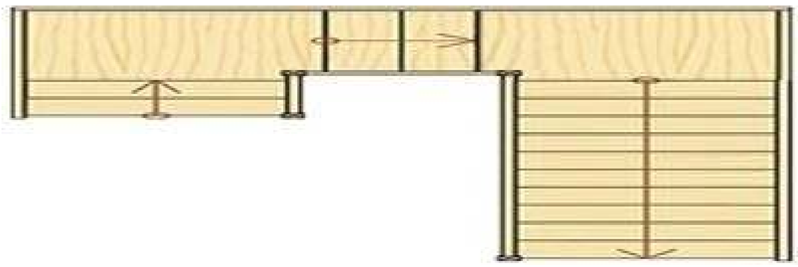
Detailed content of the Lecture:

In case of geometrical half turn stairs the stringers and the hand rails are continuous, without any intervening newel post. These stairs may contains either with half space landing or without landing.



5. Three quarter turn stairs

The direction of stairs changed three times with its upper flight crossing the bottom one in the case of three quarter turn stairs. These stairs are may either be newel or open newel type. This type stairs are generally used when the vertical distance between two floors is more and as well as length of the stair room is limited.



6. Bifurcated stairs

Bifurcated stairs are commonly used in public building at their entrance hall. This has a wider flight at the bottom, which bifurcates into two narrower flights, one turning to the left and other to the right, at landing.it may be either of newel type with a newel post or of geometrical type with continuous stringer and hand rails.

7. Continuous stairs

This type of stairs neither have any landing nor any intermediate newel post. They are geometric in shape. These are may be of following types.

- Circular stairs
- Spiral stairs
- Helical stairs

Circular stairs or spiral stairs are usually made either of R.C.C or metal, and is placed at a location where there are space limitations. Sometimes these are also used as emergency stairs, and are provided at the back side of a building. These are not comfortable because of all the steps are winders and provides discomfort.

A helical stair looks very fine but its structural design and construction is very complicated. It is made of R.C.C in which a large portion of steel is required to resist bending, shear and torsion.

Video Content / Details of website for further learning (if any): **1.https://www.acadiastairs.com/types-of-staircases/** **2.https://www.youtube.com/watch?v=_CQPR8vRzeg**
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LECTURE HANDOUTS

L25

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **III** **Date of Lecture:**

Topic of Lecture: Design of dog legged staircase

Introduction : Dog legged staircase is one of the simplest form of **staircases** in which a flight of stairs ascends to a half-landing before turning 180 degrees and continuing upwards. It is also **called** this because of its appearance in sectional elevation.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Various edge conditions
- ✓ Types of stair case

Detailed content of the Lecture:

- ✓ Dog Legged Staircases
- ✓ Dog legged staircase is one of the simplest form of staircases in which a flight of stairs ascends to a half-landing before turning 180 degrees and continuing upwards. It is also called this because of its appearance in sectional elevation.
- ✓ From a design point of view, the advantage of this staircase lies in its compact layout and better circulation. So it finds application in almost all types of buildings, be it residential, commercial, or institutional. One often encounters drafting such a staircase in architectural projects. The simplicity of the staircase is reflected while drafting too, as shown by the typical plan of a dog legged staircase in Fig 1.
- ✓ But such a simple staircase does not result in a smooth handrail which is one of the essential components of any staircase. Handrails are provided to afford assistance and a safeguard and should be fixed at a convenient height from floor level. They should be of a satisfactory size and shape to enable them being easily grasped by the hand. If we focus on the handrail in the staircase as shown in Fig 1, we find that kinks develop at junctions where it turns (Fig 2).
- ✓ This creates uncomfortable conditions for the person accessing it. In majority of the cases, this issue

gets identified on the verge of project execution. How can this problem be overcome?

- ✓ Note: Handrails on the stairwell side has been shown only for ease of explanation.

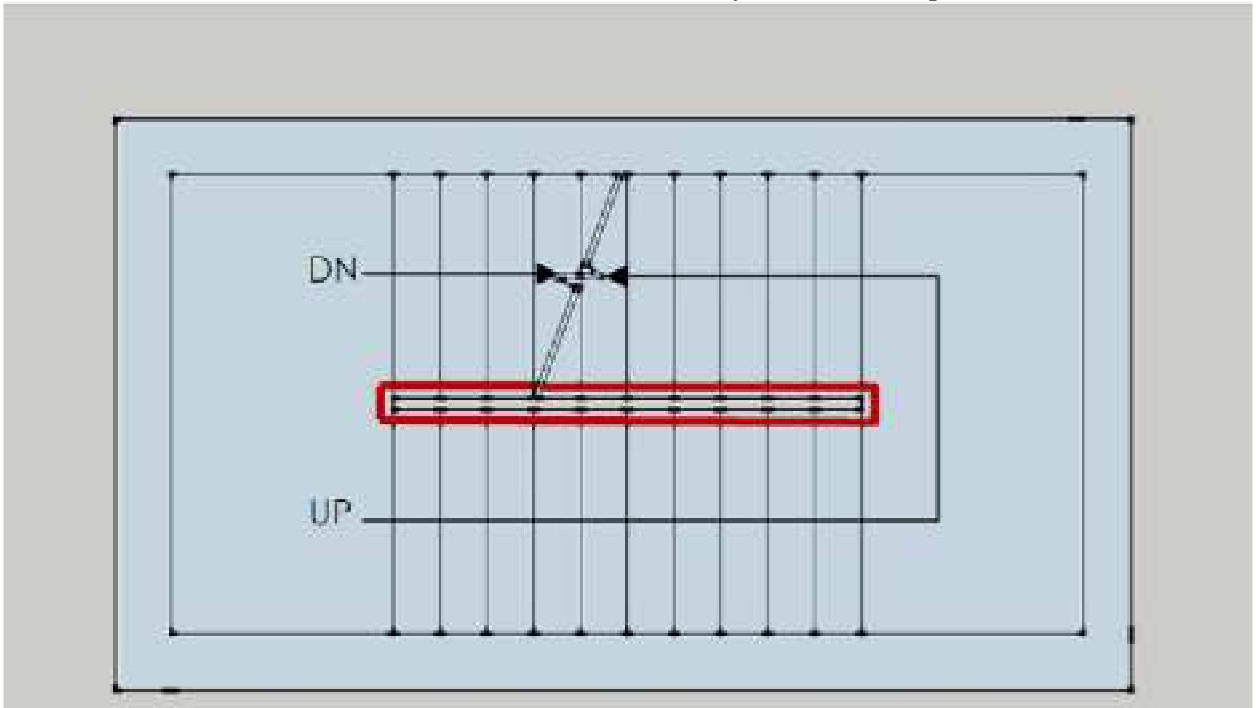

Fig. 1: TYPICAL PLAN OF A DOG LEGGED STAIRCASE

✓

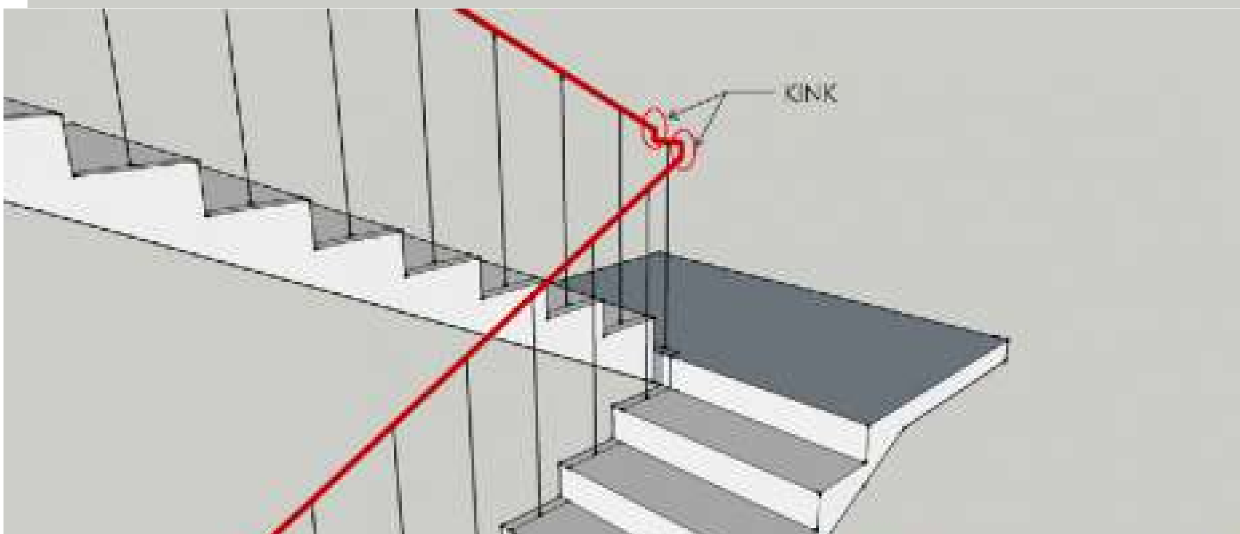

Fig. 2: TYPICAL HANDRAIL PROFILE

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=JDbzSRab6_A

https://www.youtube.com/watch?v=iZ_2xvOFKz4

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LECTURE HANDOUTS

L26

CIVIL

V/III

Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : III **Date of Lecture:**

Topic of Lecture: Open well staircase

Introduction : Open well staircase. This type of **stair** consists of two or more flights arranging a **well** or opening between the backward and forward flights. When all the steps are difficult to arrange in two flights, a short third flight of 3 to 5 steps may be provided along the direction perpendicular to the hall.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Staircase
- ✓ Types of staircase

Detailed content of the Lecture:

A staircase of 1.5 m width for an office building with slab supported on a beam at the top and and on the landing of the flight at right angles at the bottom is shown in **Figure 2**. The riser and goings of the stairs are 160 mm and 250 mm, respectively. The variable load is 3.0 kN/m^2 and the permenant action from finishes, baluster and railing about 1.0 kN/m^2. Materials used in this construction consist of concrete with characteristic strength, f_{ck} = 30 N/mm^2 and steel strength, f_{yk} = 500 N/mm^2. The thickness of the landing is 150 mm and waist thickness (h) is 150 mm. Design the stairs if the concrete cover = 25 mm and the main bar diameter, ϕ_{main} = 10 mm.

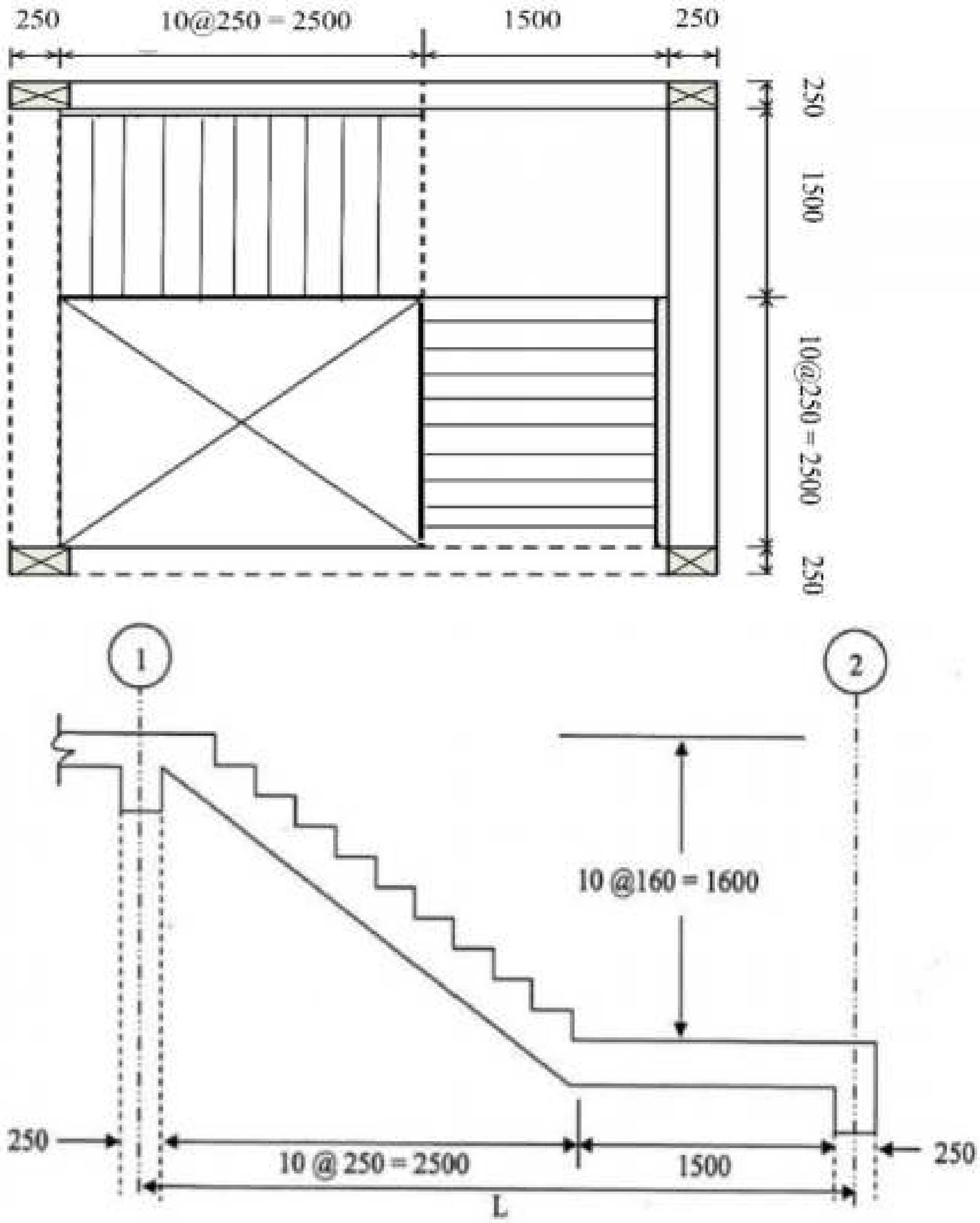


Figure 2 (continue)

Load Analysis

Average thickness, $y = h(G^2 + R^2)^{1/2}/G$

$= 150\ (250^2 + 160^2)^{1/2}/250$

= 178 mm

Average thickness, $t = [y + (y + R)]/2 = 258$ mm

Actions

Landing

Slab self-weight = 0.15 x 25 = 3.75 kN/m^2

Permanent load excluding self-weight = 1.00 kN/m^2

Characteristic permanent action = 4.75 kN/m^2

Characteristic variable action = 3.00 kN/m^2

Design action n_d = 1.35 (4.75) + 1.5 (3.0) = 10.91 kN/m^2

Flight

Slab self-weight = 0.258 x 25 = 6.45 kN/m^2

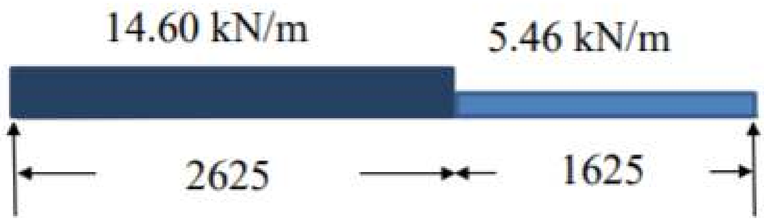
Permanent load excluding self-weight = 1.00 kN/m^2

Characteristic permanent action = 7.45 kN/m^2

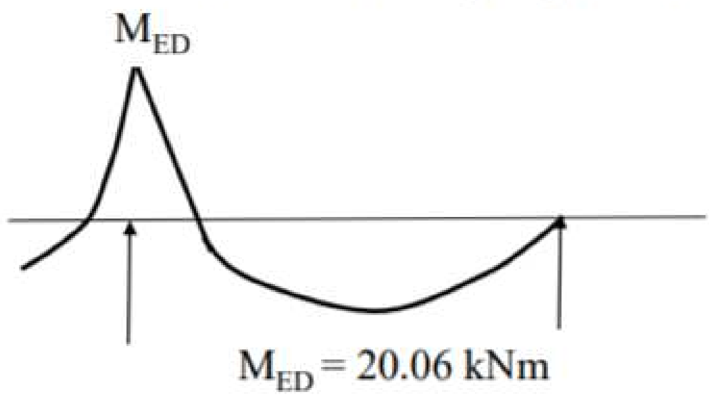
Characteristic variable action = 3.00 kN/m^2

Design action n_d = 1.35 (7.45) + 1.5 (3.0) = 14.60 kN/m^2

Analysis



Total action = (5.46 x 1.625) + (14.6 x 2.625) = 47.2 kN/m



M_{ED} = FL/10

= 47.2 (4.25)/10

= 20.06 kNm

Video Content / Details of website for further learning (if any):

1.https://www.youtube.com/watch?v=OBvn5meowIY

2. https://www.youtube.com/watch?v=uCOmTGCho2s

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LECTURE HANDOUTS

L27

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **III** **Date of Lecture:**

Topic of Lecture: Open well staircase

Introduction : Open well staircase. This type of **stair** consists of two or more flights arranging a **well** or opening between the backward and forward flights. When all the steps are difficult to arrange in two flights, a short third flight of 3 to 5 steps may be provided along the direction perpendicular to the hall.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Staircase
- ✓ Types of staircase

Detailed content of the Lecture:

A staircase of 1.5 m width for an office building with slab supported on a beam at the top and and on the landing of the flight at right angles at the bottom is shown in **Figure 2**. The riser and goings of the stairs are 160 mm and 250 mm, respectively. The variable load is 3.0 kN/m^2 and the permenant action from finishes, baluster and railing about 1.0 kN/m^2. Materials used in this construction consist of concrete with characteristic strength, f_{ck} = 30 N/mm^2 and steel strength, f_{yk} = 500 N/mm^2. The thickness of the landing is 150 mm and waist thickness (h) is 150 mm. Design the stairs if the concrete cover = 25 mm and the main bar diameter, ϕ_{main} = 10 mm.

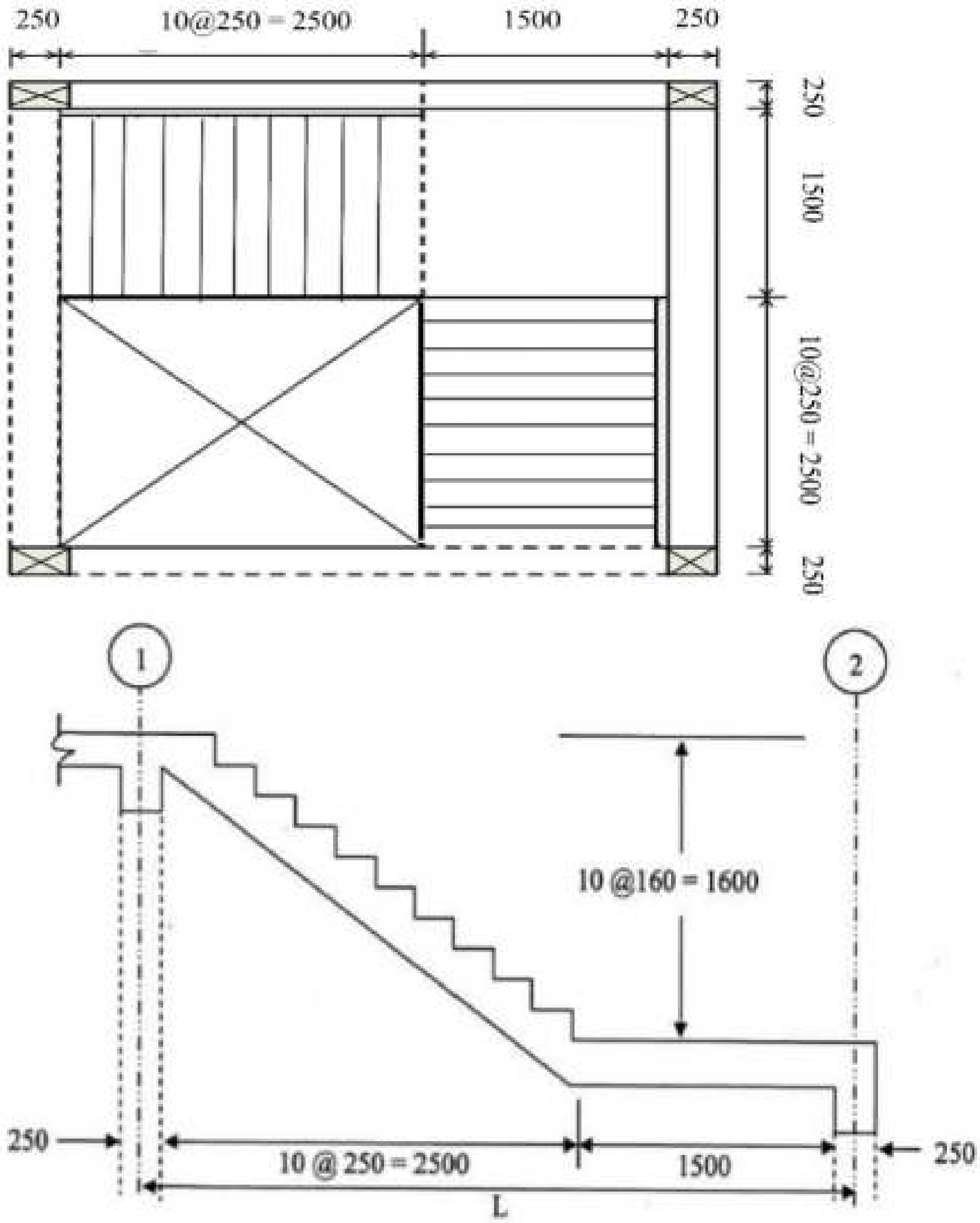

Figure 2 (continue)

Load Analysis

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$= 150\ (250^2 + 160^2)^{1/2}/250$

= 178 mm

Average thickness, $t = [y + (y + R)]/2 = 258$ mm

Actions

Landing

Slab self-weight = 0.15 x 25 = 3.75 kN/m^2

Permanent load excluding self-weight = 1.00 kN/m^2

Characteristic permanent action = 4.75 kN/m^2

Characteristic variable action = 3.00 kN/m^2

Design action n_d = 1.35 (4.75) + 1.5 (3.0) = 10.91 kN/m^2

Flight

Slab self-weight = 0.258 x 25 = 6.45 kN/m^2

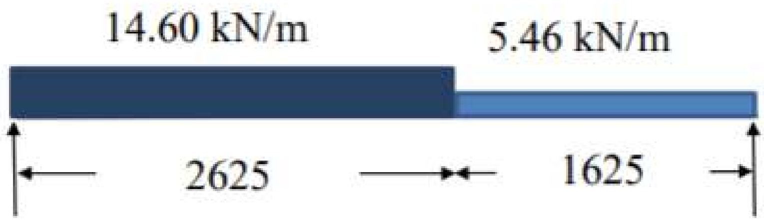
Permanent load excluding self-weight = 1.00 kN/m^2

Characteristic permanent action = 7.45 kN/m^2

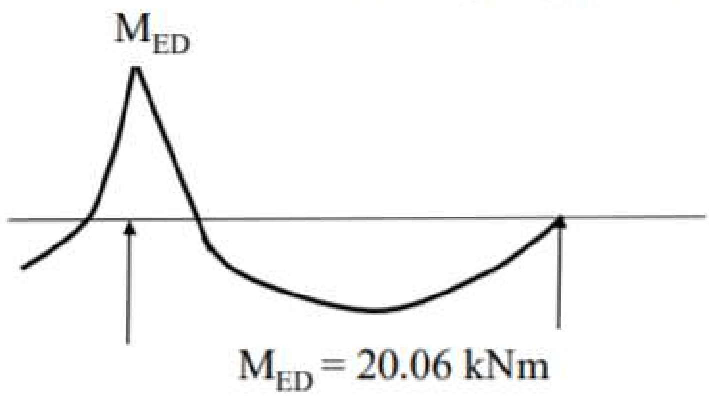
Characteristic variable action = 3.00 kN/m^2

Design action n_d = 1.35 (7.45) + 1.5 (3.0) = 14.60 kN/m^2

Analysis



Total action = (5.46 x 1.625) + (14.6 x 2.625) = 47.2 kN/m



$M_{ED} = FL/10$

$= 47.2\,(4.25)/10$

$= 20.06$ kNm

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CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Types of column

Introduction :

There are several **types of columns** which are used in different parts of structures. **Column** is a vertical structural member that carry loads mainly in compression.

...

Tied **Column**. ...

Spiral **Column**. ...

Composite **column**. ...

Axially Loaded **Column**. ...

Column with Uniaxial Eccentric Loading. ...

Column with Biaxial Eccentric Loading. ...

Short **Column**.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Slabs
- ✓ Staircase
- ✓ column

Detailed content of the Lecture:

INTRODUCTION:

A vertical member whose effective length is greater than 3 times Its least lateral dimension carrying compressive loads is called as a column. Columns transfer the loads from the beams or slabs to the footings or foundations. The inclined member carrying compressive loads as In the case of frames and trusses is called as struts. The pedestal is a vertical compression member whose effective length Is less than 3 times Its least lateral dimension. *(different types columns)*

Why we provide Columns?

Primarily, Columns carry Axial Loads and therefore are designed for compression. Other loads from snow, wind or other horizontal forces can cause bending in the columns. Columns then need to be designed for Axial Load and Bending.

Columns are classified into four types:-

1. Based on Shape
2. Based on a type of reinforcement
3. Based on type of loading
4. Based on slenderness ratio

Note: It's just a classification a column can be a combination of both types like a column can be Rectangular shape with tied column

Based on Shape: –

1. **Square or Rectangular Column:-**
   They are generally used in the construction of buildings., which are common in practice; these types of column are provided only if the shape of the room is a square or rectangular shape. It is way much easier to construct and cast rectangular or square columns than circular ones. This is primarily for the ease of working with the shuttering and to support it from it collapsing due to pressure while the concrete is still in flowable form. The square and rectangular ones are better and less costlier to cast.

Learn how to calculate quantity of Cement, Sand, and aggregate used in 1m3 of concrete

2. **Circular column:-**
   They are specially designed columns, they are mostly used in piling and elevation of the buildings. Why we use it in elevation? In order to avoid edges, we use this type of columns. they are also provided in sit out areas, auditoriums or fire assembly zones, where you have enough space for them not to hinder any movement of people or look bad with flat surfaces You can find circular columns as pillars of Bridges because there you don't need to flush them to anything. Also circular looks aesthetic there.

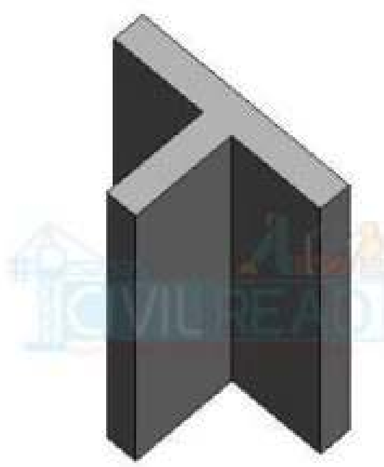
1. **L- Type Column:-**

They are generally used in the corners of the boundary wall and has same features of a rectangular or square column. These kind of columns are very less used.

L- Type Column

2. T- Type Column:

This kind of columns is used depending on design requirements and in the construction of bridges, etc. This has same features of a rectangular or square column.



T- TYPE COLUMN

3. V- Type Column:-

As a name itself, it showcasing the column is in V shape and generally used if the shape of the room is in trapezoidal. As it requires more amount of concrete when compared to the other columns.

V TYPE COLUMN

4. Hexagon Column:-

Hexagon columns are generally modified columns. It has six sides and it gives good pictorial view generally used in elevation. It is adopted to give a good look to the column. It is generally provided in open verandahs, Auditoriums, Cinema halls etc.

1. Arch type columns:

These type of columns are used when the room has a shape of an arch. It is adopted where there is a no chance of building square or rectangular or circular type of column. it is rarely used as it possess very difficulty in casting.

ARCH TYPE COLUMN

2. Y – Type Column:-

These types of columns are generally used in the construction of [bridges](), flyovers, etc.

Y TYPE COLUMN

3. **Y type Column with Arch:**

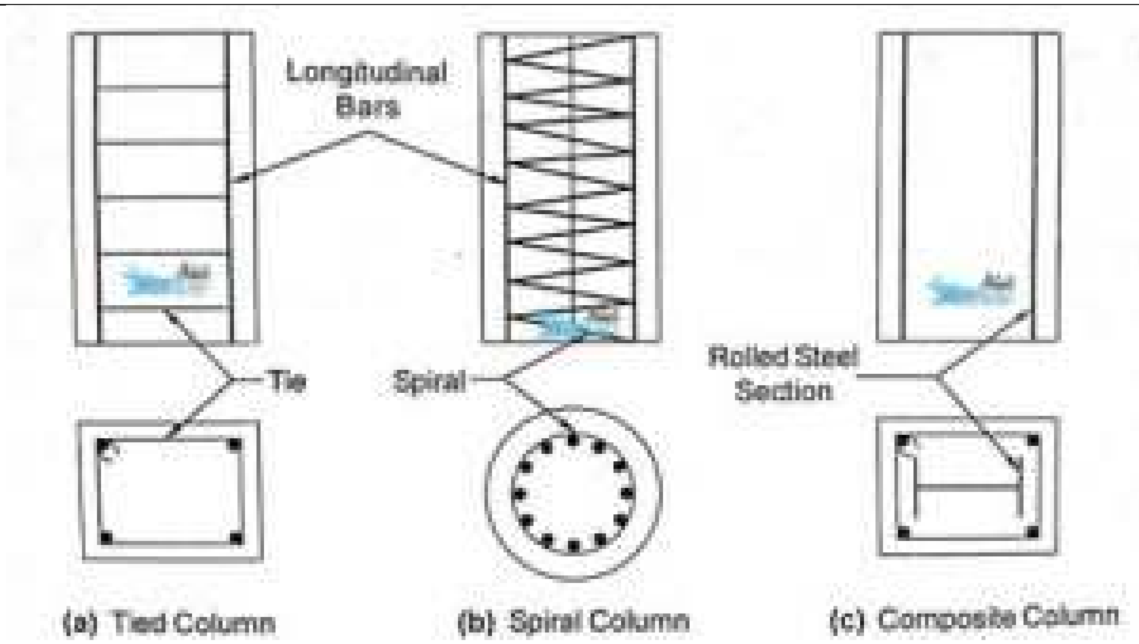
   As it is same as Y-type Column but it has curved edges or sides. These are generally provided below the bridges and flyovers where there is a congestion of building more columns to withstand heavy loads on top.

Y TYPE COLUMN WITH ARCH

Based on Type of Reinforcement:-

Depending upon the type of reinforcement used, reinforced columns are classified into following types:-

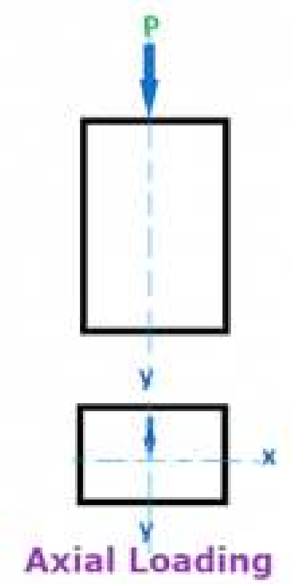
1. **Tied Column:**
   When the main longitudinal bars of the column are confined within closely spaced lateral ties, it is called as tied column.
2. **Spiral Column:**
   When the main longitudinal bars of the column are enclosed with in closely spaced and continuously wound spiral reinforcement, it is called as a spiral column.
3. **Composite Column:**
   When the longitudinal reinforcement is in the form of structural steel section or pipe with or without longitudinal bars, it is called as a composite column.



Based on the type of loading:-

Depending on the type of loading on columns are classified into three types:

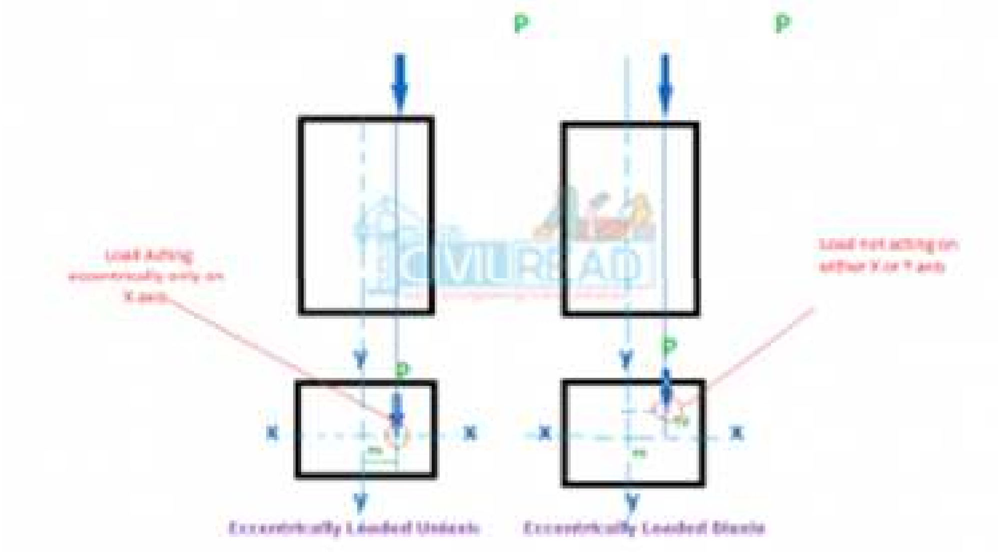
1. **Axially loaded Column: –**
   When the line of action of the compressive force coincides with the center of gravity of the cross-section of the column, it is called axially loaded column. (The total load from top is acted on the centroid of the column.) How to design Learn more



2. **Eccentrically loaded column (Uniaxial or Biaxial):**
   When the line of action of compressive force doesn't coincide with the center of gravity of the cross-section of the column, it is called as the eccentrically loaded column.
   Uniaxial:
   We know the X-Axis and Y-axis if load is acted eccentrically either on X or Y axis (anyone) then it is called as Eccentrically loaded column (uniaxial)

Biaxial:

If load is not acting eccentrically on both the axis, that mean load won't act on either X or Y axis is called Eccentrically loaded column (Biaxial)



Video Content / Details of website for further learning (if any):

1.https://www.youtube.com/watch?v=_KRbx-1lxPc

2. https://www.youtube.com/watch?v=cGYfxquZRLU

Important Books/Journals for further learning including the page nos.: REINFORCED CONCRETE DESIGN,N.Krishna raju and R.N.Pranesh,**Page no:**

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LECTURE HANDOUTS

L29

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Braced columnsand unbraced columns

Introduction : A **braced column** is defined as follows: "A **column** may be considered **braced** in a given plan if lateral stability to the structure as a whole is provided by walls or **bracing designed** to resist all lateral forces in that plane. It should otherwise be considered as **unbraced**"

Prerequisite knowledge for Complete understanding and learning of Topic:

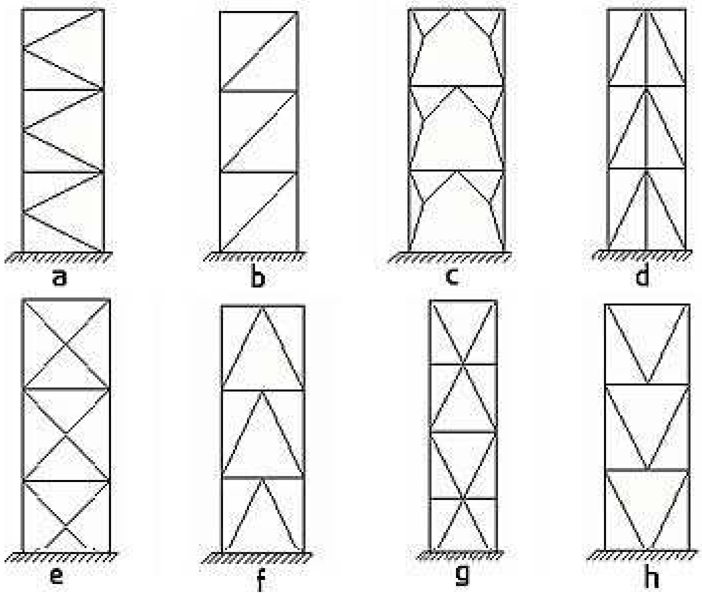
- ✓ Columns
- ✓ Types of columns

Detailed content of the Lecture:

- ✓ Braced Column
- ✓ A column may be considered braced in a given plan if lateral stability of the structure as a whole is provided by walls or bracing.
- ✓ These columns are not designed to resist lateral loads.
- ✓ These columns have zero value of sway.
- ✓ Unbraced column
- ✓ A column may be considered unbraced in a given plan if lateral stability of the structure as a whole is provided by columns only.
- ✓ These columns are subjected to sway.
- ✓ **Braced Column**

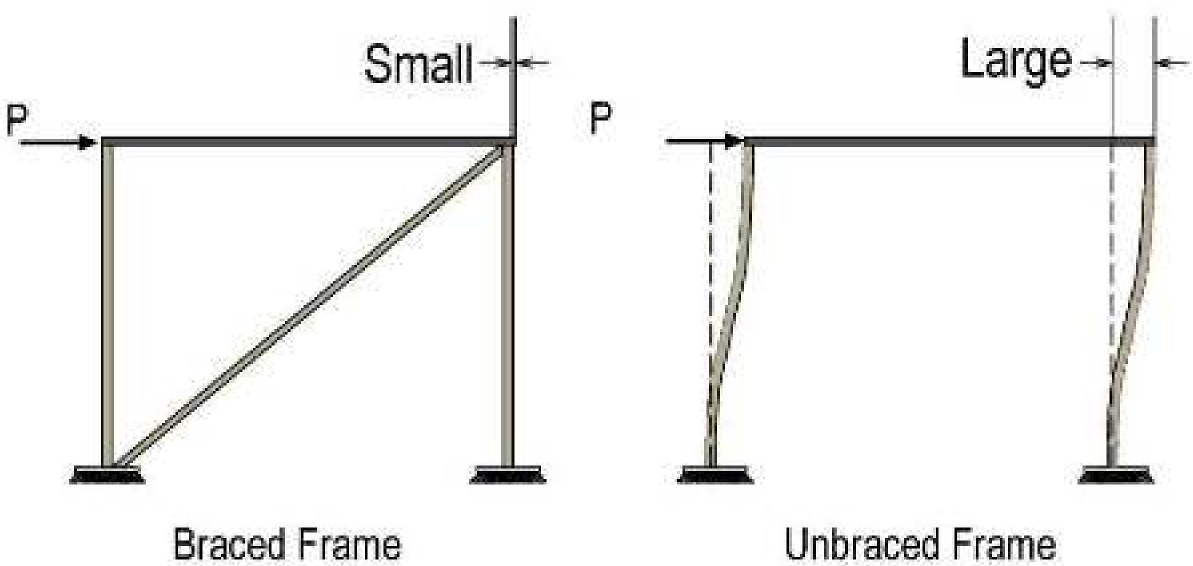
  A column may be considered braced in a given plan if lateral stability of the structure as a

whole is provided by walls or bracing.
These columns are not designed to resist lateral loads.
These columns are more resistant to Earthquake than unbraced column.



- ✓
- ✓ **Unbraced Column**

A column may be considered unbraced in a given plan if lateral stability of the structure as a whole is provided by columns only.
These columns are designed to resist lateral loads.
These columns are less resistant to Earthquake than braced column.



Video Content / Details of website for further learning (if any): 1. https://www.youtube.com/watch?v=uoB9kOYYL8c 2. https://www.youtube.com/watch?v=GS4if18iTII
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LECTURE HANDOUTS

L30

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Design of rectangular and circular columns for axial load

Introduction : Circular columns are symmetric about any centroidal axis. ... If you compare a square **column** with a **circular column** having the same diameter as the side of the square **column**, **circular column** has a smaller cross section area (0.785 times the square **column**) but larger second moment of area (1.178 times the square **column**).
Rectangular column should reinforced with minimum 4 bars; circular **column** should reinforced with minimum 6 bars. 2. The area of longitudinal reinforcement should lie in the limits: 3. Spacing of reinforcement – the minimum distance between adjacent bars should not be less than the diameter of the bar or hagg + 5 mm

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Column
- ✓ Types of column

Detailed content of the Lecture:
Circular column:-
They are specially designed columns, they are mostly used in piling and elevation of the buildings. Why we use it in elevation? In order to avoid edges, we use this type of columns. they are also provided in sit out areas, auditoriums or fire assembly zones, where you have enough space for them not to hinder any movement of people or look bad with flat surfaces You can find circular columns as pillars of Bridges because there you don’t need to flush them to anything. Also circular looks aesthetic

there.

CIRCULAR COLUMN

Example#1 Design a circular tie column to support an axial dead load of 250 kip and an axial live load of 305 kip. Begin with 2% Ast and take fc' = 4ksi , fy = 60 ksi

Design solution

Design load = 1.2D.L + 1.6 L.L

Pu = 1.2(250) + 1.6(305)

Pu = 788 kip

Size of column=?

ØPu= Øα[0.85 fc' (Ag-Ast) + fy Ast]

α=0.80 , Ø=0.65

788= 0.65(0.80) [0.85 (4)(Ag - 0.02Ag) +(60 x 0.02Ag)]

788= 2.35664 Ag

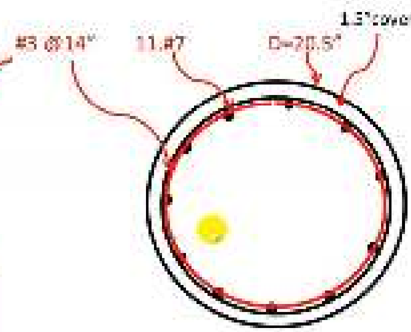
Ag = 334.374 in^2

$$Ag = \frac{\pi D^2}{4}$$

$$\frac{4 \times 334.374}{\pi} = \frac{\pi D^2}{\pi 4} \times 4$$

$$\sqrt{D^2} = \sqrt{425.738}$$

D = 20.5 in



The principle of this tutorial lies in designing a circular tie column to support an axial dead load of 250 kips and an axial live load of 305 kips. First of all, the design begins with 2% Ast also fc' = 4ksi , fy = 60 ksi .Inside the provided video below you will find the solution of the column design. Basically the solution has been gone through in six steps which are described below:

1- By determining the design axial load = pu.

2- Reinforcement ratio should not be less than 1% not more than 8%.

3- Measure the section size or gross area = Ag.

4- By the help of gross area calculate the quantity of reinforcement = Ast.

5- The concrete cover should be assumed as 1.5 in.

6- Finally, perform a detailing check.

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=yFBXYlJmbZc
2.https://www.youtube.com/watch?v=wR0k2AgYTjg

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LECTURE HANDOUTS | **L31**

CIVIL | **V/III**

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Provisions of IS-456 & SP16 code for the analysis of Column subjected to axial load

Introduction : An **axial loading** is a **force** directed over the line of axis. If the object is loaded with **force**, the **axial loads** act along the object's axis. Alternatively, the **axial force** is seen as passing through the neutral axis of a considered section, which is normal to the plane of the section.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Braced columns
- ✓ Unbraced columns

Detailed content of the Lecture:

Along with the axial load, a 'radial load' also acts on an object, and the combination of these two loads is known as 'combined load'.

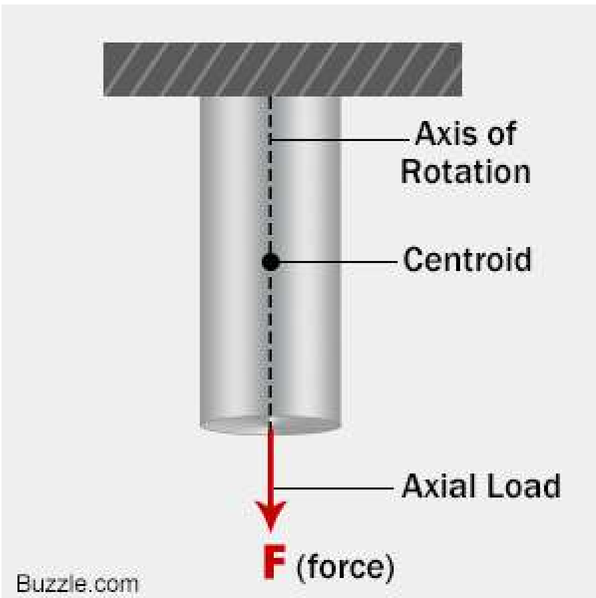
A load, when applied to an object, subjects it to some force. This can cause deformations in the object, which are a result of the stress caused by the load. There are various locations at which a load can act on an object. The force which will be acting on the object is a result of the load, and such a load has two components – radial and axial.

Explanation of Axial Load

The strength of a material can be known with the help of axial load. The axial load of an object is responsible for the force which passes through the center of the object, is parallel to its axis of rotation, and perpendicular to the plane of cross-section. The force owing to the axial load acts on the central axis of the object, and it can be a compressing or stretching force. The central axis, or the axis of rotation of an object, is that axis around which the object can spin.

Axial load is also known as 'thrust load'. The image below will help in better understanding of what axial load actually is.

Diagram for Axial Load



Axial Load Diagram

The axial load 'f', which is along the axis of rotation of the object, and passing through the centroid, is due to the mass 'm' of the load on top.

Axial Load Calculation

The formula to calculate the stress due to axial load is,

$\sigma = F/A$

Here,
σ = The stress caused by the axial load.
F = The force generated by the axial load.
A = The area of the cross-section.

The force generated (F) is,

F = ma

Where ‘m’ is the mass of the load, and ‘a’ is its acceleration.

The axial load will also result in deflection, which is,

$$\delta = FL/AE$$

Here,
F = The force generated by the load.
L = Length of the object.
A = Area of cross-section.
E = Young’s Modulus.

The tendency of an elastic to overcome the deformation it faces is its stiffness, and Young’s modulus is the measure of this stiffness.

Example

In the above diagram, assume that the cylinder is made of stainless steel, the Young’s Modulus value of which is 180 GPa, having a radius of 0.25 m, and a length 1 m. The gravitational acceleration acts on the load, the value of which is $9.8 m/s^2$. Assume that the mass of the load acting on it is 10 Kg. Now, the force created by the load can be calculated as,

$$F = m \times a$$
$$= 10 \times 9.8$$
$$= 98 \text{ N}$$

Thus, the force generated by the load is 98 N. The area of the cross-section is,

$$A = 3.14 \times 0.25^2 = 0.196 \text{ m}^2$$

The stress due to this axial load can be calculated as,

$$\sigma = 98/0.196$$

Thus, the value of the stress caused by the axial load is 500 Pa.

The deflection is,

$\delta = (98 \times 1)/(0.196 \times 180)$

Thus, the deflection caused by the load is 0.28 m.

The radial load is completely opposite to the axial load, and it acts along the radius of the object. This load is parallel to the surface of the object, i.e., it is perpendicular to the axis of rotation of the object, and also the axial load, if any.

Both these loads—radial and axial—are important when studying the motion of a spinning object. When a load is introduced in a perfectly balanced way on a spinning object, it will not hamper its motion. Even slight variations in balance can affect the functioning of the object, which when used for longer periods will reduce the lifespan of the object. If the balance is not maintained, it will lead to more wear and tear of the spinning object, resulting in its failure.

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=jURuwHdliYs
2. https://www.youtube.com/watch?v=i611fex4O10

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LECTURE HANDOUTS

L32

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Column subjected to uniaxial bending

Introduction : Bending comes in one direction that may be along strong axis or weak axis we called it **uniaxial bending**. While when **bending** comes in both strong as well as along weak axis we called it biaxial **bending**, and we use interaction diagram for calculation in biaxial **bending**.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Column
- ✓ Axial load

Detailed content of the Lecture:

Design of columns uniaxial load as per IS 456-2000

1. 1. Design of Compression members- Uniaxial Bending
2. 2. Based on Type of Loading a) Columns with axial loading (applied concentrically) b) Columns with uniaxial eccentric loading c) Columns with biaxial eccentric loading 2
3. 3. ► The occurrence of 'pure' axial compression in a column (due to concentric loads) is relatively rare.
4. ► Generally, flexure accompanies axial compression — due to 'rigid frame' action, lateral loading and/or actual(or even, unintended/accidental) eccentricities in loading.
5. ► The combination of axial compression (P) with bending moment (M) at any column section is statically equivalent to a system consisting of the load P applied with an eccentricity e = M/P with respect to the longitudinal centroidal axis of the column section.
6. ► In a more general loading situation, bending moments (Mx and My) are applied simultaneously on the axially loaded column in two perpendicular directions — about the major axis (XX) and minor axis (YY) of the column section. This results in biaxial eccentricities ex=

Mx/P and ey= My/P, as shown in [Fig.(c)]. 3

7. 4. ► Columns in reinforced concrete framed buildings, in general, fall into the third category, viz. columns with biaxial eccentricities.
8. ► The biaxial eccentricities are particularly significant in the case of the columns located in the building corners
9. . ► In the case of columns located in the interior of symmetrical, simple buildings, these eccentricities under gravity loads are generally of a low order (in comparison with the lateral dimensions of the column), and hence are sometimes neglected in design calculations.
10. ► In such cases, the columns are assumed to fall in the first category, viz. columns with axial loading. ► The Code, however, ensures that the design of such columns is sufficiently conservative to enable them to be capable of resisting nominal eccentricities in loading 4
11. 5. Column under axial compression and Uni-axialColumn under axial compression and Uni-axial Bending
12. ► Let us now take a case of a column which is subjected to combinedLet us now take a case of a column which is subjected to combined action of axial load (Paction of axial load (Puu) and Uni-axial Bending moment (M) and Uni-axial Bending moment (Muu).).
13. ► This case of loading can be reduced to a single resultant load PThis case of loading can be reduced to a single resultant load Puu acting at an eccentricity e such that e= Mat an eccentricity e such that e= Muu / P/ Puu ..
14. ► The behavior of such column depends upon the relative magnitudes ofThe behavior of such column depends upon the relative magnitudes of Muu and Pand Puu , or indirectly on the value of eccentricity e., or indirectly on the value of eccentricity e.
15. ► For a column subjected to load PFor a column subjected to load Puu at an eccentricity e, the location ofat an eccentricity e, the location of neutral axis (NA) will depend upon the value of eccentricity e.neutral axis (NA) will depend upon the value of eccentricity e.
16. ► Depending upon the value of eccentricity and the resulting position (XDepending upon the value of eccentricity and the resulting position (Xuu)) of NA., We will consider the following cases.of NA., We will consider the following cases. 5
17. 6. ♣ Case ICase I :: Concentric loading: Zero Eccentricity or nominalConcentric loading: Zero Eccentricity or nominal eccentricity (Xeccentricity (Xuu =∞)=∞) ♣ Case ICase II :: Moderate eccentricity (XModerate eccentricity (Xuu > D)> D) ♣ Case IIICase III :: Moderate eccentricity (XModerate eccentricity (Xuu = D)= D) ♣ Case IVCase IV :: Moderate eccentricity (XModerate eccentricity (Xuu < D)< D) Case I (e=0 and e<eCase I (e=0 and e<eminmin)) 6
18. 7. 7 Case II (Neutral axis outside the sectionCase II (Neutral axis outside the section)
19. 8. 8 Case III (Neutral axis along the edge)Case III (Neutral axis along the edge)
20. 9. 9 Case IV (Neutral Axis lying within the section)Case IV (Neutral Axis lying within the section)
21. 10. Modes of Failure in Eccentric CompressionModes of Failure in Eccentric Compression ► The mode of failure depends upon the relative magnitudes ofThe mode of failure depends upon the relative magnitudes of eccentricity e. (e = Meccentricity e. (e = Muu / P/ Puu)) 10 Eccentricity Range Behavior Failure e = Mu / Pu Small Compression Compression e = Mu / Pu Large Flexural Tension e = Mu / Pu In between two Combination Balanced
22. 11. Column Interaction DiagramColumn Interaction Diagram ► A column subjected to varying magnitudes of P and M will act with itsA column subjected to varying magnitudes of P and M will act with its neutral axis at varying points.neutral axis at varying points. 11
23. 12. Method of Design of Eccentrically loaded short columnMethod of Design of Eccentrically

loaded short column 12 The design of eccentrically loaded short column can be done by two methods I) Design of column using equations II) Design of column using Interaction charts

24. 13. Design of column using equationsDesign of column using equations 13
25. 14. 14
26. 15. 15 Design of column using Interaction chartsDesign of column using Interaction charts

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=miPwo-Y1GGQ
https://www.youtube.com/watch?v=YBk_vGNXUAg

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LECTURE HANDOUTS

L33

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Design of short column

Introduction : SHORT COLUMN. The **column**, whose lateral dimension is very small when compared to its length (or height), is called as long **column**. The **column**, whose lateral dimension is very large when compared to its length (or height), is called as **short column**. It is generally fails by buckling

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Axial load
- ✓ Uniaxial bending

Detailed content of the Lecture:

SHORT COLUMN UNDER AXIAL COMPRESSION

The factored axial load, P_u is given by the equation ,

$$P_u = 0.4\sigma_{ck}A_c + 0.67\sigma_y A_{sc}$$

Where A_c = area of concrete and, A_{sc} = area of longitudinal reinforcement of columns.

This equation can be recast as

$$\frac{P_u}{\sigma_{ck}bD} = 0.446 + \frac{P}{100\sigma_{ck}}\left(\sigma_y - 0.446\sigma_{ck}\right)$$

Where P = percentage of reinforcement. Design charts are prepared based on this equation.

REINFOCEMENT

There are two kinds of reinforcement in a column, longitudinal and transverse reinforcement. The purpose of transverse reinforcement is to hold the vertical bars in position, providing lateral support so that individual bars can not buckle outward and split the concrete.

1. Longitudinal Reinforcement in columns (as per IS 456:2000)

a) The cross-sectional area of longitudinal reinforcement shall be not less than 0.8 percent nor more than 6 percent of the gross cross-sectional area of the column.

Note: the use of 6 percent reinforcement may involve practical difficulties in placing and compacting of concrete, hence lower percentage is recommended. Where bars from the columns below have to be lapped with those in the column under consideration, the percentage of reinforcement steel shall usually not exceed 4 percent.

b) In any column that has a larger cross-sectional area than that required to support the load, the minimum percentage of steel shall be based upon the area of concrete required to resist the direct stress and not upon the actual area.

c) The minimum number of longitudinal bars provided in a column shall be four in rectangular columns and six in circular columns.

d) The bars shall not be less than 12mm in diameter.

e) A reinforced concrete column having helical reinforcement shall have at least six bars of longitudinal reinforcement within the helical reinforcement.

f) In a helically reinforced columns, the longitudinal bars shall be in contact with the helical reinforcement and equidistant around its inner circumference.

g) Spacing of longitudinal bars measured along the periphery of the column shall not exceed 300mm.

h) In case of pedestals in which the longitudinal reinforcement is not taken into account in strength calculations, nominal reinforcement not less than 0.15 percent of the cross-sectional area shall be provided.

Note: Pedestal is a compression member, the effective length of the which does not exceed three times the least lateral dimension.

(2) Transverse Reinforcement in columns:

(a) A reinforced compression member shall have transverse reinforcement or helical reinforcement so disposed that every longitudinal bar nearest to the compression face has effective lateral support against buckling subject to provisions in (b) below. The effective lateral support is given by transverse reinforcement either in the form of circular rings capable of taking up circumferential tension or by polygonal links (lateral ties) with internal angles not exceeding 135°. The ends of the transverse reinforcement shall be properly anchored.

(b) Arrangement of transverse reinforcement:

1. If the longitudinal bars are not spaced more than 75mm on either side, transverse reinforcement need only to go round corner and alternate bars for the purpose of providing effective lateral supports. (figure 2)
2. If the longitudinal bars spaced at a distance of not exceeding 48 times the diameter of the tie are effectively tied in two directions, additional longitudinal bars in between these bars need to be tied in one direction, by open ties (figure 3)
3. Where the longitudinal reinforcing bars in a compression member are placed in more than one row, effective lateral support to the longitudinal bars at the inner rows may be assumed to have been provided, if
    1. Transverse reinforcement is provided for the outer row and
    2. No bar of the inner row is closer to the nearest compression face than three times the diameter of the largest bar in the inner row (figure 4)
4. Where the longitudinal bars in a compression member are grouped (not in contact) and each group adequately tied with transverse reinforcement, the transverse reinforcement for the compression member as a whole may be provided on the assumption that each group is a single longitudinal bar for purpose of determining the pitch and diameter of the transverse reinforcement. The diameter of such transverse reinforcement need not however exceed 20mm (figure 5).

(c) Pitch and diameter of lateral ties (as per IS 456:2000)

1. Pitch – The pitch of transverse reinforcement shall be not more than the least of the following distances:

a. The least lateral dimension of the compression member

b. Sixteen time the smallest diameter of the longitudinal reinforcement bar to be tied

c. Forty-eight times the diameter of the transverse reinforcement.

1. Diameter – The diameter of the polygonal links or lateral ties shall be not less than one-fourth of the diameter of the largest –longitudinal bar, and in no case less than 5mm.

(d) Helical Reinforcement (as per IS 456: 2000)

1. Pitch – Helical reinforcement shall be of regular formation with the turns of the helix spaced evenly and its ends shall be anchored properly by providing one and a half extra turns of the spiral bar. Where an increased load on the column on the strength of helical reinforcement is allowed for, the pitch of helical turns shall be not more than 77 mm nor more than one-sixth of the core diameter of the column, nor less than 25mm, nor less than 3 times the diameter of the steel bar forming the helix. In other cases, the requirements of transverse reinforcement shall be complied with.
2. Diameter – The diameter of the helical reinforcement shall be in accordance with para (c) above.

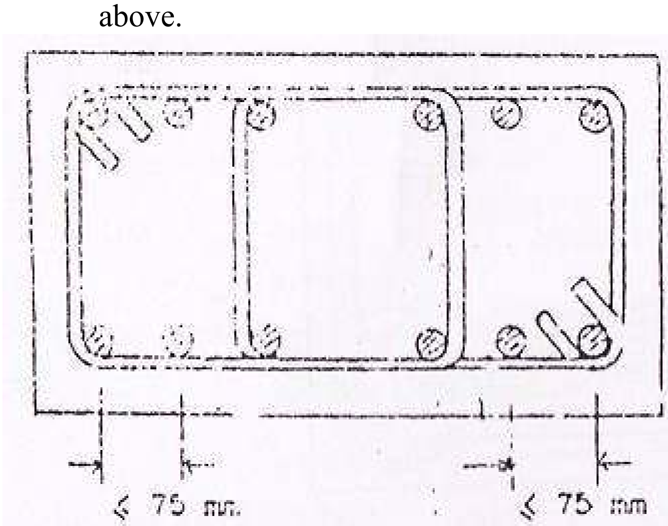

Figure 2

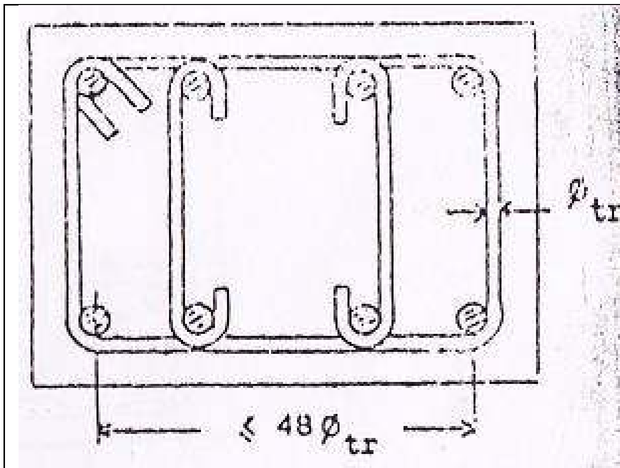

Figure 3

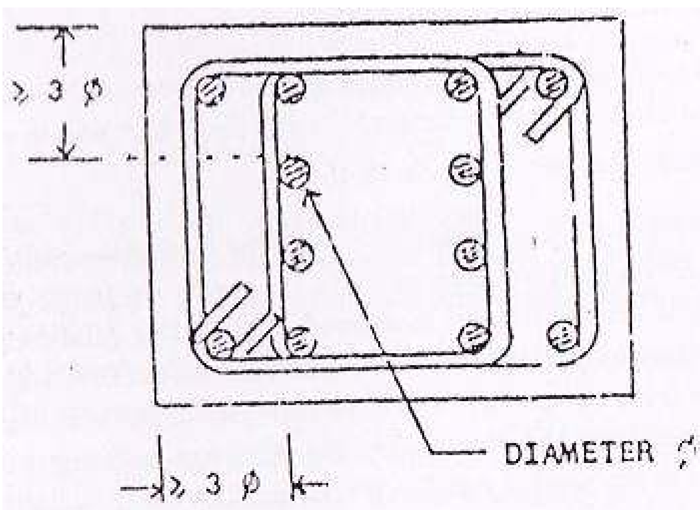

Figure 4

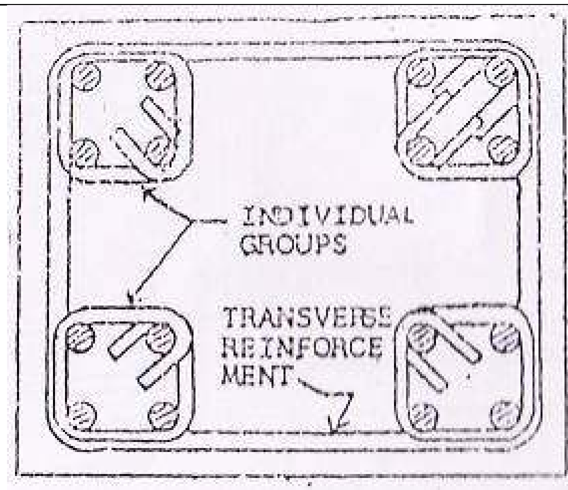

Figure 5

Short Columns with Helical Reinforcement:

The permissible load for columns with helical reinforcement satisfying the following shall be 1.05 times the permissible load for similar member with lateral ties or rings.

Ratio of the volume of helical reinforcement to the volume of the core should not be less than

$$0.36\left[\frac{A_g}{A_c}-1\right]\frac{f_{ck}}{f_y}$$

Where A_g = gross area of the section

A_c = area of the core of the helically reinforced column measured to the outside diameter of the helix.

f_{ck} = characteristic compressive strength of the concrete

f_y = characteristic strength of the helical reinforcement but not exceeding 415 N/mm^2.

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=H-yAGV2Hh7g
2.https://www.youtube.com/watch?v=DxK4gfEraYk

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LECTURE HANDOUTS

L34

CIVIL

V/III

Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : IV **Date of Lecture:**

Topic of Lecture: Design of long column

Introduction : A short steel column is one whose slenderness ratio does not exceed 50; an intermediate length steel column has a slenderness ratio ranging from about **50 to 200**, and are dominated by the strength limit of the material, while a long steel column may be assumed to have a slenderness ratio greater than 20..

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Column
- ✓ Axial load
- ✓ Uniaxial bending

Detailed content of the Lecture:

Effective Length of Column Members (IS 456:2000)

No.	Degree of end restraint of member	Effective
1	Effectively held in position and restrained against rotation at both ends	0.65L

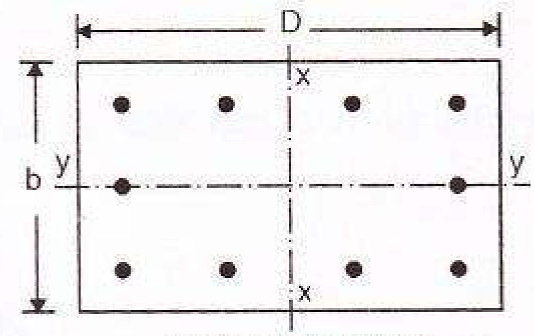
2	Effectively held in position at both ends and restrained against rotation at one end.	0.80 L
3	Effectively held in position at both ends but not restrained against rotation.	L
4	Effectively held in position and restrained against rotation at one end and at the other end, restrained against rotation but not held in position.	1.20 L
5	Effectively held in position and restrained against rotation at one end and at the other end, partially restrained against rotation but not held in position.	1.50 L
6	Effectively held in position but not restrained against rotation at one end and at the other end, restrained against rotation but not held in position.	2.0 L
7	Effectively held in position and restrained against rotation at one end and at the other end, neither restrained against rotation nor held in position.	2.0 L

Where L is the unsupported length of a compression member

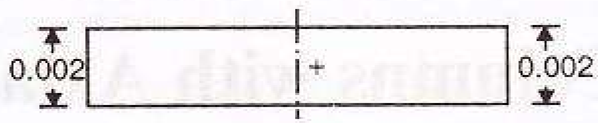
DESIGN ASPECT

The relationship between stress and strain in concrete is assumed to be parabolic. Maximum compressive stress is equal to $\left(\frac{0.67\sigma_{ck}}{1.5}\right)$ or 0.446 σ_{ck} . The tensile strength of concrete is ignored.

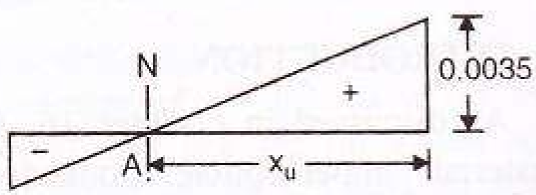
The stress in reinforcement is derived from the representative stress-strain cure for the type of steel.



(a) Column section



(b) Strain diagram for pure axial compression



(c) Strain diagram for N.A. within the section

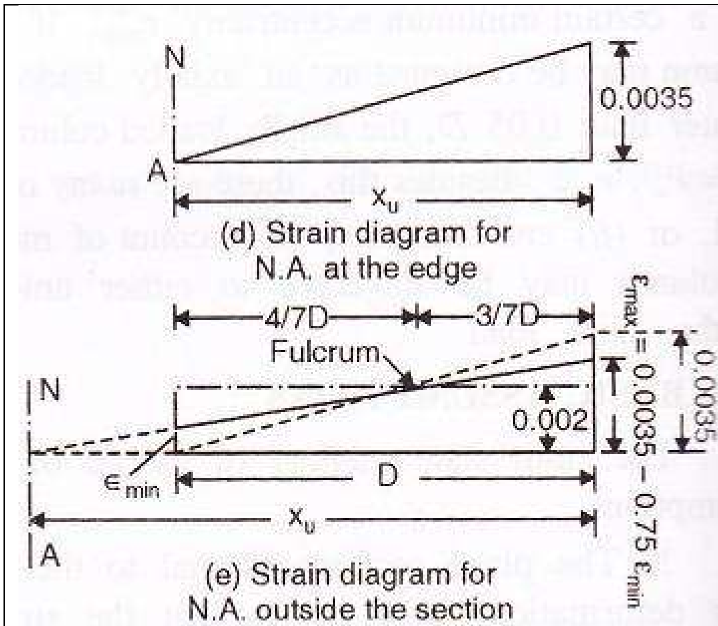


Figure 1: Stress distribution across the cross section of a column The stress distribution lines for purely axial compression case and for limiting case when the strain varies from 0.0035 at one edge to zero at the opposite edge as shown in figure (1). These lines intersect each other at a depth of $\frac{3}{7}D$ from the highly compressive edge. The point is assumed to act as a fulcrum for the strain distribution line when the neutral axis lies above the section as shown in figure (1). This leads to the assumption that the maximum compressive strain at the highly compressed extreme fibre in concrete is 0.002 minus 0.75 times the strain at the least compressed fibre

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=y9LI6x0GY5Q
2.https://www.youtube.com/watch?v=vLRZoWV8SSU

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CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Design of short and long columns subjected to axial load and Biaxial bending moment

Introduction : **Biaxial bending** is the **bending** of the beam about both axes (the x–x and y–y axes). ... Pure **biaxial bending** occurs when the loads to each axis are applied directly through the shear center which is the point within a member such that when loads are applied through that point, twisting will not occur

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Short columns
- ✓ Long columns

Detailed content of the Lecture:

- ✓ **Biaxial bending**

- ✓ A column is a vertical structural member designed to transfer a compressive load. For example, a column might transfer loads from a ceiling, floor or roof slab or from a beam, to the foundations.
- ✓ Columns also carry the bending moment about one or both axes of their cross-section.
- ✓ Biaxial bending affects columns where the load is eccentric about both the axes in the plane of the column (eccentric load is a force placed upon a portion of a column which is not symmetric with its central axis, thereby producing bending).
- ✓ For both rectangular and square columns, there are situations in which axial compression is accompanied by simultaneous bending about both principal axes of the section.
- ✓ **Bending** comes in one direction that may be along strong axis or weak axis **we** called it **uniaxial bending**. While when **bending** comes in both strong as well as along weak

axis **we** called it **biaxial bending**, and **we** use interaction diagram for calculation in **biaxial bending**
Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=miPwo-Y1GGQ** **2.https://www.youtube.com/watch?v=pnuzDARgqN0**
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CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Design of short and long column subjected to axial load and biaxial bending moment
Introduction : Biaxial bending is the **bending** of the beam about both axes (the x–x and y–y axes). ... Pure **biaxial bending** occurs when the loads to each axis are applied directly through the shear center which is the point within a member such that when loads are applied through that point, twisting will not occur
Prerequisite knowledge for Complete understanding and learning of Topic: ✓ Column ✓ Biaxial bending
Detailed content of the Lecture:

Example 1: A 12 feet span simply supported beam of shape W21 × 68. Lateral support of the compression flange is provided only at the ends. Loads act through the shear center, producing moments about the x and y axes. The service load moments about the x axis are M_{Dx} = 48 ft-kips and M_{Lx} = 144 ft-kips. Service load moments about the y axis are M_{Dy} = 6 ft-kips and M_{Lx} = 18 ft-kips. If A992
steel is used, does this beam satisfy the provisions of the AISC Specification? Assume that all moments are uniform over the length of the beam.

Solution

1- compute the nominal flexural strength for *x*-axis bending. $L_b = 12$ ft , $F_y = 50$ ksi

From AISC Manual for W21 × 68 from the Z_x Table.

$L_p = 6.36$ ft , $L_r = 18.7$ ft , $Z_x = 160, S_x = 140$

$Z_y = 24.4 , S_y = 15.7$

The shape is compact (no footnote to indicate otherwise)

For Compact shape and $L_p < L_b \le L_r \rightarrow$

$$M_{nx} = C_b\left[M_{px} - (M_{px} - 0.7 F_y S_x)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \le M_{px}$$

$M_{px} = F_y Z_x = 50 * 160 = 8000$ kips.in

$C_b = 1.0$ due to bending moment is uniform

$$M_{nx} = 1.0\left[8000 - (8000 - 0.7 * 50 * 140)\left(\frac{12 - 6.36}{18.7 - 6.36}\right)\right]$$

$$= 6583 \text{ kips.in} = 548.6 \text{ kips.ft} \quad < M_{px} = 8000 \rightarrow OK$$

1- compute the nominal flexural strength for *y*-axis bending.

For the *y* axis, since the shape is compact, there is no flange local buckling and

$$M_{ny} = M_{py} = F_y Z_y = 50 * 24.4 = 1220 \text{ k.in} = 101.7 \text{ k.ft}$$

Check the upper limit

$$\frac{Z_y}{S_y} = \frac{24.4}{15.7} = 1.55 < 1.6 \rightarrow M_{ny} = M_{py} = 101.7 \text{ k.ft}$$

$$M_{ux} = 1.2 M_{Dx} + 1.6 M_{Lx} = 1.2*48 + 1.6*144 = 288.0 \text{ k/ft}$$

$$M_{uy} = 1.2 M_{Dy} + 1.6 M_{Ly} = 1.2*6 + 1.6*18 = 36.0 \text{ k/ft}$$

$$\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}$$

$$\frac{288.0}{0.9*548.6} + \frac{36.0}{0.9*101.7} = 0.977 < 1.0 \rightarrow OK$$

Video Content / Details of website for further learning (if any):

1.https://www.youtube.com/watch?v=miPwo-Y1GGQ

2.https://www.youtube.com/watch?v=pnuzDARgqN0

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V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **V** **Date of Lecture:**

Topic of Lecture: Classification of foundation

Introduction : Shallow **foundation**. Individual footing or isolated footing. Combined footing. Strip **foundation**. Raft or mat **foundation**.
Deep **Foundation**. Pile **foundation**. Drilled Shafts or caissons

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Columns
- ✓ foundations

Detailed content of the Lecture:

Types of Foundation

- ✓ In general, all foundations are divided into two categories, such as SHALLOW FOUNDATIONS and DEEP FOUNDATIONS.
- ✓ The terms Shallow Foundation and Deep Foundation refer to the depth of the soil at which the foundation is placed.
- ✓ Generally, if the width of the foundation is greater than the depth of the foundation it is labeled as “Shallow Foundation” and if the width of the foundation is smaller than the depth of the foundation it is called as “Deep Foundation.” However, shallow and deep foundations can be further classified as shown in the following chart.

Main aspects of different types of foundation along with their images are given below. As economic feasibility is one of the main factors in foundation type selection, it is also discussed briefly with each type of foundation To know other factors which affect the selection of foundation read: Factors Considered for Selection of Foundation.

Shallow Foundations

Several types of shallow foundations are discussed below:

1. Isolated Spread Footing

This is the most common and simplest type of foundation as this is the most economical type of foundation. They are generally used for ordinary buildings (Generally up to five stories).

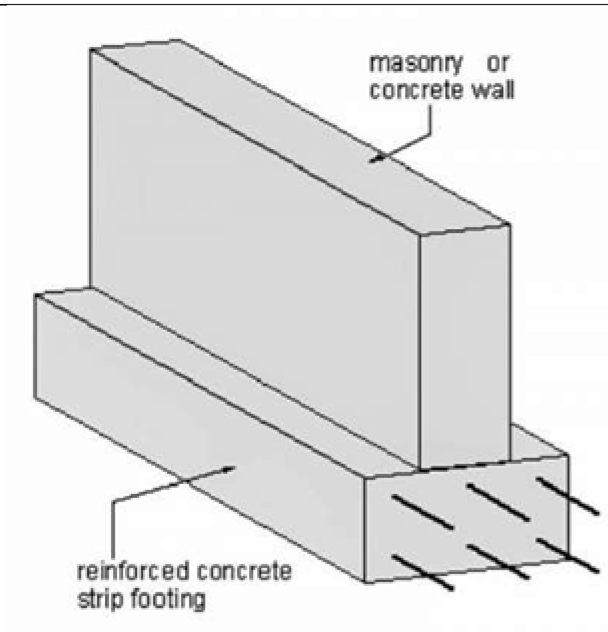
Isolated footing type foundation consists of footing at the base of the column. This type of foundations is independent footings. Usually, each column has its own footing. The footing directly transfers the loads form the column to the soil. The footings may be rectangular, square or circular in shape. The size of the footing can be roughly calculated by dividing the total load at the column base by the allowable bearing capacity of the soil.

Isolated Spread Footing is economical when:

- The load of the structure is relatively low.
- Columns are not closely placed.
- Bearing capacity of the soil is high at a shallow depth.

2. Wall Footing or Strip footing

This type of footing is used to distribute loads of structural load-bearing walls to the ground. Wall foundation runs along the direction of the wall. The width of the wall foundation is generally 2-3 times of the width of the wall.



The wall footing is a continuous slab strip along the length of the wall. Stone, brick, reinforced concrete etc. is used for the construction of wall foundations.

Wall footing is economical when:

- Loads to be transmitted are of small magnitude.
- The footing is placed on dense sand and gravels.

3. Combined Footing

The combined footing is very similar to the isolated footing. When the columns of the structure are closely placed, or the bearing capacity of the soil is low and their footing overlap each other, combined footing is provided.

The foundations which are made common to more than one column are called *combined footings*. They may be rectangular, tee-shaped or trapezoidal in shape. The main objective is the uniform distribution of loads under the entire area of footing. For this is necessary to coincide the center of gravity of the footing area with the center of gravity of the total loads.

- The columns are placed close to each other.
- When the column is close to the property line and the isolated footing would cross the property line or become eccentric.
- Dimensions of one side of the footing are restricted to some lower value.

4. Cantilever or Strap Footing

Strap footings are similar to combined footings and reasons for considering or choosing strap footing is similar to the combined footing.

In *strap footing*, the footings under the columns are built individually and connected by strap beam. Generally, when the edge of the footing cannot be extended beyond the property line the exterior

footing is connected by strap beam with interior footing
Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=AFLuAKGhanw** **2.https://www.youtube.com/watch?v=_hqSWYxPQq0**
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Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **V** **Date of Lecture:**

Topic of Lecture: Design guidelines- codal provisions

Introduction : A **guideline** is a statement by which to determine a course of action. A **guideline** aims to streamline particular processes according to a set routine or sound practice

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Foundations
- ✓ footings

Detailed content of the Lecture:

A **guideline** is a statement by which to determine a course of action. A guideline aims to streamline particular processes according to a set routine or sound practice.[1] Guidelines may be issued by and used by any organization (governmental or private) to make the actions of its employees or divisions more predictable, and presumably of higher quality. A guideline is similar to a rule.

List of guidelines

Examples of guidelines are:

- Code of practice
- EASE Guidelines for Authors and Translators of Scientific Articles
- Federal Sentencing Guidelines
- Guidelines for Examination in the European Patent Office
- The Guidelines for Japan-U.S. Defense Cooperation
- Medical guidelines
- Human interface guidelines

• Publicly Available Specification • Programming style guidelines • UNGEGN Toponymic Guidelines
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V/III

Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : V **Date of Lecture:**

Topic of Lecture: Design of wall footing

Introduction : A **wall footing** or strip **footing** is a continuous strip of concrete that serves to spread the weight of a load-bearing **wall** across an area of soil. It is the component of a shallow foundation

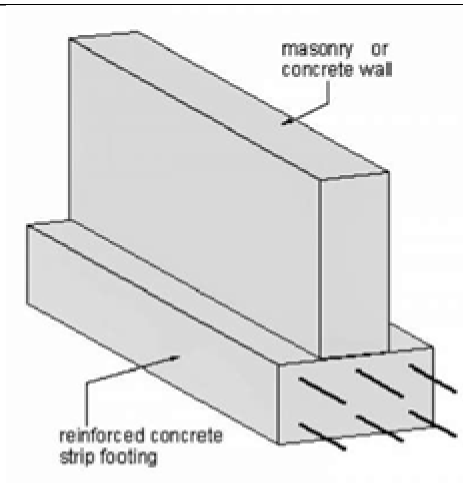
Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Foundations
- ✓ footings

Detailed content of the Lecture:

. Wall Footing or Strip footing

This type of footing is used to distribute loads of structural load-bearing walls to the ground. Wall foundation runs along the direction of the wall. The width of the wall foundation is generally 2-3 times of the width of the wall.



The wall footing is a continuous slab strip along the length of the wall. Stone, brick, reinforced concrete etc. is used for the construction of wall foundations.

Wall footing is economical when:

- Loads to be transmitted are of small magnitude.
- The footing is placed on dense sand and gravels.

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=bn3g0p2yUps
2.https://www.youtube.com/watch?v=fdCTxmY6csA

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V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **V** **Date of Lecture:**

Topic of Lecture: Design of axially and eccentrically loaded Square footing

Introduction : SQUARE FOOTING. CONTINUOUS **FOOTING**. Provided to support the load on a single column. Provided to support a load bearing wall. It is similar to a block or cube.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Foundations
- ✓ footings

Detailed content of the Lecture:

Design of a square footing

The procedure for designing a square footing is as follows:
Service load design:

1. Determine size of footing.

Reinforced concreter design:

2. Determine depth of footing for punching shear and direct shear
3. Determine footing reinforcement for bending moment.
4. Determine column dowel to transfer column load.

Example: Design of a square footing
Given:

- Column loads:
- Live load: 80 kips

- Dead load: 120 kips
- Footing uplift: 0 kips
- Column size: 1 ft. x 1 ft.
- Soil information:
- Allowable soil bearing capacity: 4000 psf
- Soil cover above footing: 1 ft
- Unit weight of soil: 120 pcf
- Materials used:
- Concrete strength at 28 day = 3000 psi
- Yield strength of rebars = 60 ksi

Design code: ACI 318-05

Requirement: Determine size, depth, and reinforcement for a square footing.

Solution:

Service load design:

1. Determine footing sizes:

1. Assume a footing depth of 18",net soil bearing capacity ,
2. Q_{net} = 4000 – 150*18/12-120*1 = 3655 psf
3. Required footing are, A = (100+100) (1000) / 3655 = 54.7 ft^2
4. Use 7'-6" by 7'-6" square footing. The footing area is 56.3 ft^2.

Reinforced concrete design:

2. Determine footing depth

The factored footing pressure can be calculated as

Q_u = (1.2 x 120 + 1.6 x 80) / 56.3 = 4.83 psf

a. Check punching shear

1. Assume the reinforcements are #6 bars, the effective depth
2. d = 18" - 3" (cover) - 0.75" (one bar size) = 14.3 " = 1.2'
3. The punch shear stress can be calculated as
4. $v_u = 4.83\ [7.5^2-(1+1.2)^2]*1000/[4 \times 1.2 \times (1+1.2) \times 144] = 163.3$ psi
5. The shear strength of concrete is fv_c = 0.75 x 4 x (3000)1/2 = 164 psi O.K.

b. Check direct shear:

1. The distance from the critical section of direct shear to the edge of the footing,
2. l = 7.5/2 - 1/2 – 1.2 = 2.05'
3. The direct shear stress is
4. v_u = (4.83)(1000)(2.05) / (12)(14.3) = 57.7 psi per foot width of footing.
5. The shear strength of concrete for direct shear is
6. $f\,v_c = 0.75 \times 2 \times (3000)^{1/2}$ = 82 psi > 57.7 psi O.K.

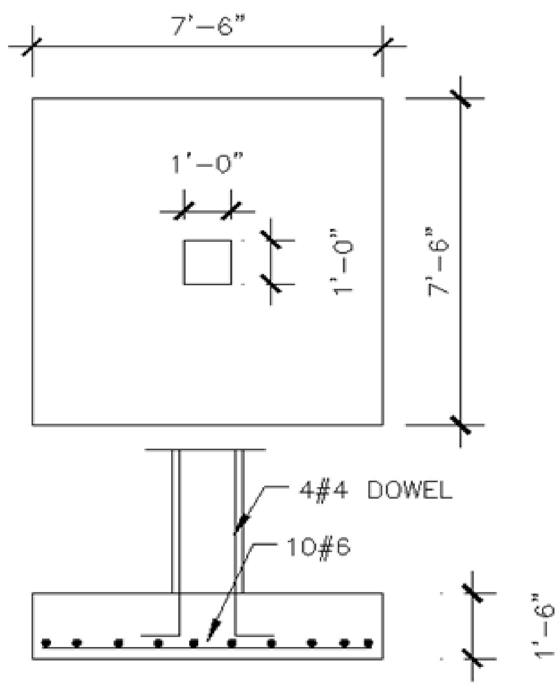
3. Determine footing reinforcement

1. The distance from face of column to the edge of the footing is
2. l = 7.5/2 – 1/2 = 3.25'
3. The factored moment at the face of the column is
4. $M_u = (4.83)(3.25)^2/2$ = 25.5 k-ft. per foot width of footing
5. Factor $R_n = (25.5)(1000)(12)/[(0.9)(12)(14.3^2)]$=139.5 psi
6. Factor m = 60000/[(0.85)(3000)] = 23.5
7. The reinforcement ratio is r = (1/23.5){1-Ö[1-(2)(23.5)(139.5)/60000]} = 0.0024

8. Minimum reinforcement ratio, r = 0.0033 or r = (4/3)*0.0024 =0.0032
9. A_s = (0.0032)(7.5)(12)(14.3) = 4.1 in^2.
10. Use 10 - #6 bars in both directions, A_s = 4.4 in^2.

4. Designing column dowels:

1. The bearing capacity of concrete at column base is
2. P_c = (0.65)(0.85)(3)(12)(12) = 238.7 kips
3. The factor column load is
4. P_u = (1.2)(120)+ (1.6)(80) = 272 kips
5. The required area of column dowels is
6. A_s = (272 - 238.7) / 60 = 0.56 in^2
7. The minimum dowel area is
8. $A_{s,min}$ = (0.0005)(12)(12) = 0.72 in^2
9. Use 4 - #4 dowels A_s = 0.8 in^2
10. The footing is shown in below



Video Content / Details of website for further learning (if any): **1.https://www.youtube.com/watch?v=OH1PzEb2Wco** **2.https://www.youtube.com/watch?v=U4G-H3W9feY**
Important Books/Journals for further learning including the page nos.: REINFORCED CONCRETE DESIGN,N.Krishna raju and R.N.Pranesh,**Page no:**

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LECTURE HANDOUTS | **L41**

CIVIL | **V/III**

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **V** **Date of Lecture:27.8.2019**

Topic of Lecture: Design of axially and eccentrically loadedRectangular footings

Introduction : Rectangular Footing

The purpose of the **footing**. The **footing** provides a stable flat supportive base that distributes the weight of the load of the structure into the surrounding soil. The weight distribution is spread out through the soil as the distance increases from the **footing**

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Footings
- ✓ foundations

Detailed content of the Lecture:

Design of rectangular footings

Designing procedure:

Service load design:

1. Determine required footing size from required footing area and limitation of footing width.

Reinforced concreter design:

2. Determine footing depth for punching shear and direct shear in the longitudinal direction.
3. Determine footing reinforcement for longitudinal direction.
4. Determine footing reinforcement for transverse direction. Distribute reinforcement based on length to width aspect ratio.
5. Determine column dowel to transfer column load.

Example 9: Design of a rectangular footing

Given:

- Column loads:
- Live load: 60 kips
- Dead load: 100 kips
- Footing uplift: 0 kips
- Column size: 1 ft 6 in. x 1 ft.
- Footing information:
- One side of footing is limited to 5’ due to property line
- Soil information:
- Allowable soil bearing capacity: 3500 psf
- Soil cover above footing: 1 ft
- Unit weight of soil: 100 pcf
- Materials used:
- Concrete strength at 28 day = 3000 psi
- Yield strength of rebars = 60 ksi

Design code: ACI-318-05, 08, 11

Requirement: Determine size, depth, and reinforcement for a square footing.

Solution:

Service load design

1. Determine footing sizes

1. Assume a footing depth of 18”,net soil bearing capacity ,
2. Q_{net} = 3500 – 150*18/12-100*1 = 3175 psf
3. Required footing are, A = (60+100) (1000) / 3175 = 50.4 ft^2
4. Since one side of the footing is limited to 5', the length of footing is
5. L = 50.4/5 = 10.1'   Use 10’, the footing area is 50 ft^2.

Reinforced concrete design:

2. Determine footing depth

The factored footing pressure can be calculated as

Q_u = (1.2 x 100 + 1.6x 60) / 50 = 4.32 psf

a. Check punching shear

Assume the reinforcements are #8 bars, the effective depth

d = 18" - 3" (cover) - 1" (one bar size) = 14" = 1.16'

The punch shear stress can be calculated as

v_u = (4.32)[50-(1.5+1.6)(1+1.16)](1000)/[(2)(1.16)(1.5+1.16+1.16)(144)]= 118 psi

The shear strength of concrete is $f\, v_c$ = 0.75 x 4 x (3000)$^{1/2}$ = 164 psi   O.K.

b. Check direct shear:

1. The distance from the critical section of direct shear to the edge of the footing,
2. l = (10– 1.5)/2 – 1.16 = 3.09'
3. The direct shear stress is v_u = (4.32)(1000)(3.09) / (12)(14) = 79.4 psi   per foot width of footing.
4. The shear strength of concrete for direct shear is $f\, v_c$ = 0.75 x 2 x (3000)$^{1/2}$ = 82 psi   > 79.4

psi O.K.

3. Determine footing reinforcement.

Longitudinal direction

The distance from face of column to the edge of the footing is

$l = (10 – 1.5)/2 = 4.25$ '

The factored moment at the face of the column is

$M_u = (4.32)(4.25)^2/2 = 39$ k-ft. per foot width of footing

Factor $R_n = (39)(1000)(12)/[(0.9)(12)(14^2)] = 221.1$ psi

Factor m = 60000/[(0.85)(3000)] = 23.5

The reinforcement ratio is r = (1/23.5){1-Ö[1-(2)(23.5)(221.1)/60000]} = 0.00386

Minimum reinforcement ratio,

r = 0.0033 < r = 0.00386

Use calculated reinforcement

$A_s = (0.00386)(5)(12)(14) = 3.24$ in^2.

Use 5#8, $A_s = 0.79*5 = 3.95$ in^2.

4. Transverse direction

The distance from face of column to the edge of the footing is

$l = (5 – 1)/2 = 2$'

The factored moment at the face of the column is

$M_u = (4.32)(2)^2/2 = 8.6$ k-ft. per foot width of footing

Factor $R_n = (39)(1000)(12)/[(0.9)(12)(14^2)] = 48.8$ psi

Factor m = 60000/[(0.85)(3000)] = 23.5

The reinforcement ratio is r = (1/23.5){1-Ö[1-(2)(23.5)(48.8)/60000]} = 0.00082

Minimum reinforcement ratio,

r = 0.0033 or r_{min} =(4/3)*0.00082=0.001

Use r_{min} =0.0011

A_s = (0.0011)(10)(12)(14) = 1.9 in^2.

Use 11 #4 bars, A_s = 0.2*11=2.2 in^2.

Distribute reinforcements

1. The aspect ratio, b = 10/5=2
2. The distribution ratio, g = 2/(2+1) = 0.67
3. The reinforcement in the 5' width center band is
4. N=11*0.67=7.4
5. Use 7 #4 in the center 5' band, spacing = 5*12/7 = 8.6 in. O.K.
6. Use 2#4 each side
7. Maximum spacing = [(10*12-5*12)/2 –3 (cover)]/2=13.5 in. O.K.

5. Designing column dowels.

1. The bearing capacity of concrete at column base is
2. $P_c = (0.65)(0.85)(3)(18)(12) = 359.1$ kips
3. The factor column load is

4. P_u = (1.2)(100)+ (1.6)(60) = 216 kips < 359.1 kips
5. Use minimum dowel area ,
6. $A_{s,min}$ = (0.0005)(18)(12) = 1.08 in^2
7. Use 4 - #5 dowels As = 1.2 in^2
8. The footing is shown in below

Video Content / Details of website for further learning (if any):

1. **https://www.youtube.com/watch?v=vluusPAgLGU**
2. **https://www.youtube.com/watch?v=x6m2jr-qMGMa**

Important Books/Journals for further learning including the page nos.: REINFORCED CONCRETE DESIGN,N.Krishna raju and R.N.Pranesh,**Page no:**

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LECTURE HANDOUTS

L42

CIVIL

V/III

Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : V **Date of Lecture:**

Topic of Lecture: Design of axially and eccentrically loaded Circular footings

Introduction : These kind of **footings** are generally square or rectangular or **circular** in shape which are provided under each column independently. ... It is **circular**, square or rectangular slab of uniform thickness

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Footings
- ✓ foundations

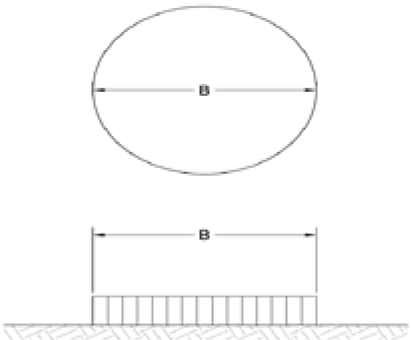
Detailed content of the Lecture:

Terzaghi's Bearing Capacity - Circular Foundation

More Cases

These kind of **footings** are generally square or rectangular or **circular** in shape which are provided under each column independently. ... It is **circular**, square or rectangular slab of uniform thickness

The above formulas may be used with both imperial and metric units. As with all calculations care must be taken to keep consistent units throughout with examples of units which should be adopted listed below:



Circular Foundation

$$q_u \ldots\ldots = 1.3c'N_c + qN_q + 0.3\gamma B N_\gamma$$

Bearing Capacity Factors

$$N_c \ldots\ldots = \cot\phi'\,(N_q - 1)$$

$$N_q \ldots\ldots = \frac{\left[e^{\pi\left(\frac{3}{4}-\frac{\phi'}{2}\right)\tan\phi'}\right]^2}{2\cos^2\left(\frac{\pi}{4}+\frac{\phi'}{2}\right)}$$

$$N_\gamma \ldots\ldots = \frac{1}{2}\left(\frac{K_{p\gamma}}{\cos^2\phi'} - 1\right)\tan\phi'$$

Terzaghi's Bearing Capacity Factors							
ϕ'	N_c	N_q	N_γ	ϕ'	N_c	N_q	N_γ
0	5.70	1.00	0.00	**26**	27.085	14.210	9.84
1	6.00	1.10	0.01	**27**	29.236	15.896	11.60
2	6.30	1.22	0.04	**28**	31.612	17.808	13.70
3	6.62	1.35	0.06	**29**	34.242	19.981	16.18
4	6.97	1.49	0.10	**30**	37.162	22.456	19.13
5	7.34	1.64	0.14	**31**	40.411	25.282	22.65
6	7.73	1.81	0.20	**32**	44.036	28.517	26.87
7	8.15	2.00	0.27	**33**	48.090	32.230	31.94
8	8.60	2.21	0.35	**34**	52.637	36.504	38.04
9	9.09	2.44	0.44	**35**	57.754	41.440	45.41
10	9.60	2.69	0.56	**36**	63.528	47.156	54.36
11	10.16	2.98	0.69	**37**	70.067	53.799	65.27
12	10.76	3.29	0.85	**38**	77.495	61.546	78.61
13	11.41	3.63	1.04	**39**	85.966	70.614	95.03
14	12.11	4.02	1.26	**40**	95.663	81.271	115.31
15	12.86	4.45	1.52	**41**	106.807	93.846	140.51
16	13.68	4.92	1.82	**42**	119.669	108.750	171.99
17	14.56	5.45	2.18	**43**	134.580	126.498	211.56
18	15.52	6.04	2.59	**44**	151.950	147.736	261.60
19	16.56	6.70	3.07	**45**	172.285	173.285	325.34
20	17.69	7.44	3.64	**46**	196.219	204.191	407.11
21	18.92	8.26	4.31	**47**	224.549	241.800	512.84
22	20.27	9.19	5.09	**48**	258.285	287.855	650.67
23	21.75	10.23	6.00	**49**	298.718	344.636	831.99
24	23.36	11.40	7.08	**50**	347.509	415.146	1072.80
25	25.13	12.72	8.34				

Notation

B = width of strip foundation, ft or m
c' = effective cohesion of soil, lb/ft^2 or kN/m^2
D_f = depth of ground foundation measured from ground surface, ft or m
K_p = passive pressure coefficient
N_c, N_q, N_γ = bearing capacity factors
q = effective unit weight of soil (refer modification for a water table), lb/ft^3 or kN/m^3
q_u = ultimate bearing capacity, lb/ft^2 or kN/m^2 (kPa)
γ = unit weight of soil, lb/ft^3 or kN/m^3
ϕ' = effective angle of internal friction, degrees

Video Content / Details of website for further learning (if any): **1.https://civilblog.org/2014/11/09/what-are-different-types-of-footings/** **2.https://www.youtube.com/watch?v=IkxJlK5s4Gw**
Important Books/Journals for further learning including the page nos.: REINFORCED CONCRETE DESIGN,N.Krishna raju and R.N.Pranesh,**Page no:**

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LECTURE HANDOUTS

L43

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **V** **Date of Lecture:**

Topic of Lecture: Design of Combined footings

Introduction : Whenever two or more columns in a straight line are carried on a single spread **footing**, it is called a **combined footing**. Isolated **footings** for each column are generally the economical. Proximity of building line or existing building or sewer, adjacent to a building column

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Footings
- ✓ foundations

Detailed content of the Lecture:

3. Combined Footing

The combined footing is very similar to the isolated footing. When the columns of the structure are closely placed, or the bearing capacity of the soil is low and their footing overlap each other, combined footing is provided.

The foundations which are made common to more than one column are called *combined footings*. They may be rectangular, tee-shaped or trapezoidal in shape. The main objective is the uniform distribution of loads under the entire area of footing. For this is necessary to coincide the center of gravity of the footing area with the center of gravity of the total loads.

Figure: Combined Footing

Combined foundations are economic when:

- The columns are placed close to each other.
- When the column is close to the property line and the isolated footing would cross the property

line or become eccentric.

- Dimensions of one side of the footing are restricted to some lower value.

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=w9AsZ8PHNRU
2.https://civilblog.org/2014/11/09/what-are-different-types-of-footings/

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LECTURE HANDOUTS

L44

CIVIL

V/III

Course Name with Code : 19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS

Course Faculty : Dr.M.Harikaran

Unit : V **Date of Lecture:**

Topic of Lecture: Rectangular and trapezoidal footing

Introduction : Footings are an important part of foundation **construction**. They are typically made of concrete with rebar reinforcement that has been poured into an excavated trench. The purpose of footings is to support the foundation and prevent settling. ... A **footing** is placed below the frost line and then the walls are added on top.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Footings
- ✓ foundations

Detailed content of the Lecture:

Design a rectangular combined footing to support two columns shown above. The edge column on the left has a section of 16” x 16” and carries dead & live load of 175 kips & 110 kips respectively. The interior column has a section of 20” x 20” & carries dead & live load of 220 kips & 120 kips respectively. The allowable soil pressure is 5.5 ksf (kips per square foot) and the bottom of footing is 5 ft. below the final grade. Using f’c = 4 ksi & Fy = 60 ksi. Design the footing using ACI Strength design method.

COMBINED FOOTING PROBLEM SOLUTION :

STEP 1: LOCATE THE RESULTANT OF LOADS ‘R’.

Taking moments about center line of left column. The distance of resultant from property line.

$\bar{x}.R=(200+120)\times 16$

x¯(175+110+220+120)=(340)×16
[bar{x} = frac{340*16}{625}]

x¯=340×16625
The distance of resultant from property line is;

= 2+ 8.704 = 10.704′

In order to have resultant at the middle of footing, the length of footing should be;

L= 10.704 x 2 = 21.41′
Now resultant of applied loads coincides with resultant of upward soil pressure.
STEP 2 : DETERMINE THE TOTAL AREA OF FOOTING

First find the **effective dept**h of footing
Assume a total depth of footing = 36"

d = Total Depth – Concrete cover – bar dia
d = 36-3 -1.5 = 31.5"
Total applied load = 175 +110 + 220 + 120 = **625 kips.**
Net Upward Soil Pressure
Net Upward Pressure=5500 –3612×150+2412×120

Net Upward Soil Pressure = 4810 psf = 4.810 ksf
Required Area of footing = 628/4.810 = 130 ft^2
Width of footing = 130 / Length of footing = 130 / 21.41
Width of footing = 6.07′ take 6.5′
We have chosen a footing with the length of 21.41′ and width of 6.5′, giving an area of 139.165 sq.ft .

STEP 3 : DETERMINE FACTORED UPWARD PRESSURE

Pu (Left Column) = 1.2 x 175 + 1.6 x 110 = 210 + 176
Pu (Left Column) =386 Kips

Pu (Right Column) = 102 x 220 + 1.6 x 120 = 264 +176
Pu (Right Column) = 456 Kips

Net Factored soil pressure = q_u = (386 +456)/139.16 = 6.05 ksf

STEP 4: DRAW FACTORED SHEAR FORCE DIAGRAM & BENDING MOMENT DIAGRAM

Considering the footing as a beam of 21.4′ span supported on two columns and subjected to a uniform upward pressure of

6.05 x 6.5 = 39.325 k/ft

Va + Vb = 39.325 x 21.41 = 841.95 Kips

∑Ma = 0 Vb x 16 = 39.325 x 21.41 x[(21.41/2) – 2)]
Vb = 458.07 Kips *(look at shear force diagram i.e. already plotted)*
Va = 841.95 – 458.07 = 383.87 Kips (As shown in the below diagram)

Vu (at outer face of left column) = 39.325 x (2 – 0.66)
Vu = – 52.69 Kips

Vu(at inner face of left column) = 39.325x(2+0.66) – 383.87
Vu = +279.26 Kips

Vu(at outer face of right column) = 39.325x(3.41- 0.833)
Vu(at outer face of right column) = + 101.34 kips

Vu(at inner face of right column) = 39.325 x (3.41 + 0.833) – 458.07
Vu(at inner face of right column) = – 291.22 Kips

So, Shear force diagram can be plotted. Now locate a point of zero shear. Compare similar triangles or write a generalized shear force expression for mid span and set it to zero.

279.26x=291.2214.51−x

X = 7.10′

STEP 5: DRAW FACTORED BENDING MOMENT DIAGRAM

Moment at the outer face of left column;

M = 39.325x[(2-0.66)/2]^2 = – 35.306 k-ft

Moment at the outer face of right column;

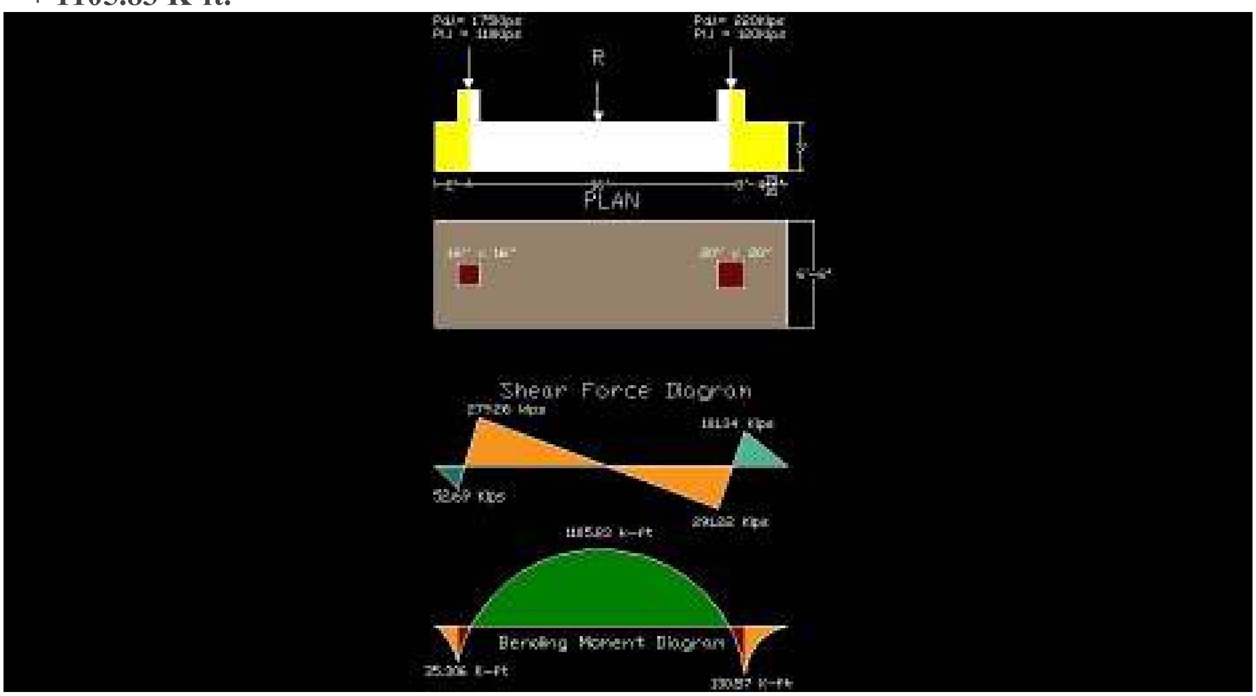
$M = 39.325x[(3.41 - 0.833)/2]^2$ = -130.57 k-ft

Maximum Positive Moment;

$M = -39.325 \times [(2+7.1+0.66)/2]^2 + 383.87 \times (7.1 + 0.66)$

$M = -1873 + 2978.83$

M = + 1105.83 K-ft.



Now we will check the depth of footing for one way shear and two way shear.

STEP 6: CHECK DEPTH OF FOOTING FOR ONE WAY SHEAR

From shear force diagram, maximum shear occurs at the critical sections, located at a distance "d" from the interior face of right column, as shown in the loading diagram above.

Vu (at critical Section) = 291.22 – 39.325 x (31.5/2)
Vu(at critical section) = 188 Kips

d =Vu/Φ2b√f'c = 188×1000/0.75x2x6.5×12*√4000
d = 25.4"< 31.5 "
Hence, depth of footing is adequate against one way shear.

STEP 7: CHECK FOR TWO WAY SHEAR

Two way shear or punching shear can be determined from critical perimeter b0.
FOR INTERIOR COLUMN;

b0 = 4x(c + d) = 4 x (20 + 31.5)

b0 = 17.17 ft. C + d = (20 + 31.5) / 12 = **4.29 ft.**
Shear at d/2 from all sides of this column is;
Vu = Pu – qu (C + d)^2

Vu = 456 – 6.05(4.29)^2

Vu = 344.65 Kips

d =Vu/Φ(4√f'c)b0 = (344 x 1000)/0.75(4x√4000)x 17.17x 12

d = 8.81" <31.5" →ok

The Depth of footing is adequate with respect to two way shear or punching shear.
STEP 8: CHECK THE DEPTH OF MOMENT & CALCULATE REQUIRED MOMENT:

From Bending moment diagram:
Maximum bending moment = 1105.83 k-ft
The depth would be adequate

$Mu/\Phi bd^2$ = (1105.83 x 1000)/ (0.9 x 6.5 x 12 x 31.5^2) = 190.51 psi.
ρ = (0.85xf'c)/fy[1- √1 – (2Mu)/Φbd^2/0.85f'c)]
ρ = (0.85 x 4)/60 [1 – √1 – (2 x 190.5)/ 0.85 x 4000]

ρ = 0.00322 As = ρbd = 0.00322 x 6.5 x 12 x 31.5

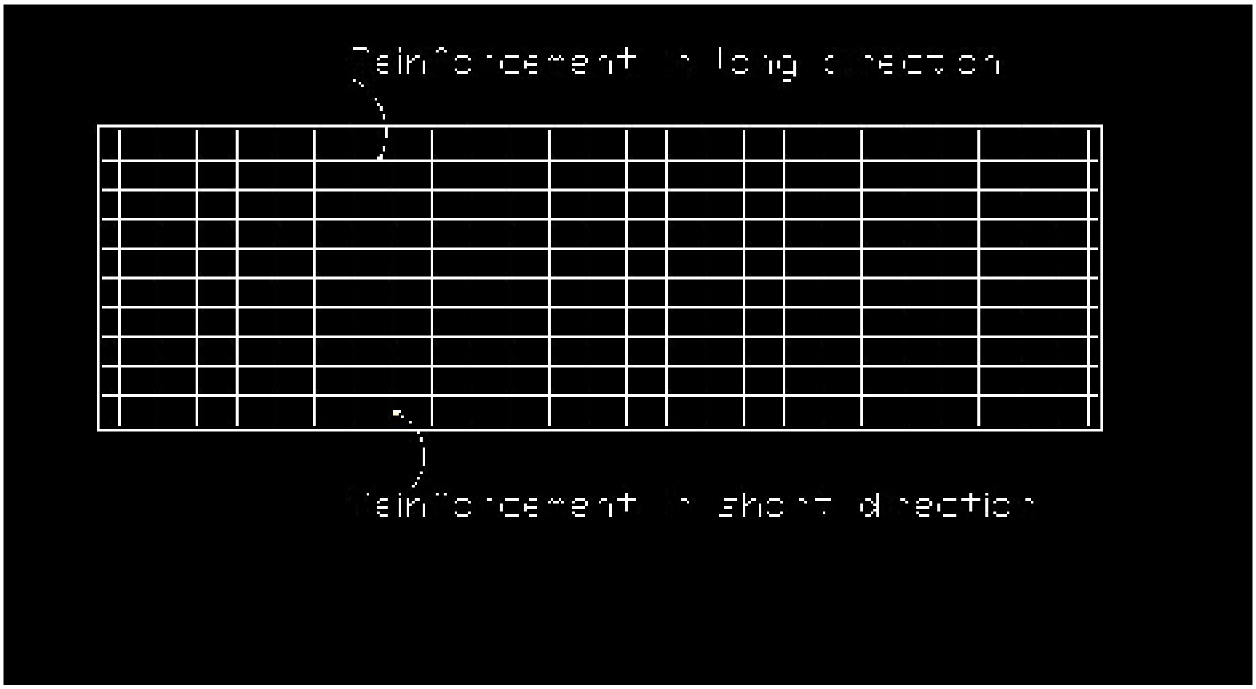
As = 7.91 in^2

ρmin = 0.0018

As min = ρmin x bd = 0.0018 x 6.5 x 12 x 36

As min = 5.05 in.

Choose 8 #9- bars (As = 7.91 in²)



BAR SPACING:

____

S = **(6.5 x12 – 2 x3)**/ 8 ***S = 10.28”***

These bars are extended between the columns at top of footing with concrete cover of 3” as place minimum reinforcement corresponding to temperature and shrinkage reinforcement, corresponding to minimum area of 5.5 in². Use (7 #8 bars) they provide an area (As = 5 in²).

Place this reinforcement at the bottom of projecting ends of footings beyond columns to take care of positive moments (see the bending moment diagram). Extend these bars by a development length beyond sides of the columns.

DEVELOPMENT LENGTH (LD) FOR TOP BARS = ***1.3 LD = 1.3 X 54 LD = 70"***

Reinforcement in the short direction.

Now calculate the bending moment in shorter direction. The reinforcement under each column is to placed within a maximum band width equal to column width plus twice the effective depth of footing.

Use full width of 6.5 ft as band width for concentrating reinforcement under;

LEFT COLUMN

Net Upward Pressure = Pu1/ width of footing = 386/6.5

Net Upward Pressure = 59.38 k/ft

Distance from free end to the face of left column. 2 – 8/12 = 1.33′

Mu at the face of left column. = 59.38 x $(1.33)^2/2$ = 52.51 K-ft.

Assume jd = 0.9d d = 31.5″

Mu = ΦTjd = ΦAsfy jd As = Mu/ Φfyjd = (52.51 x 12000)/(0.9 x 60,000 x 0.9 x 31.5")

As = 0.411 in^2 → Provide (As)min = 7 #8 bars (5.05 in^2)

RIGHT COLUMN

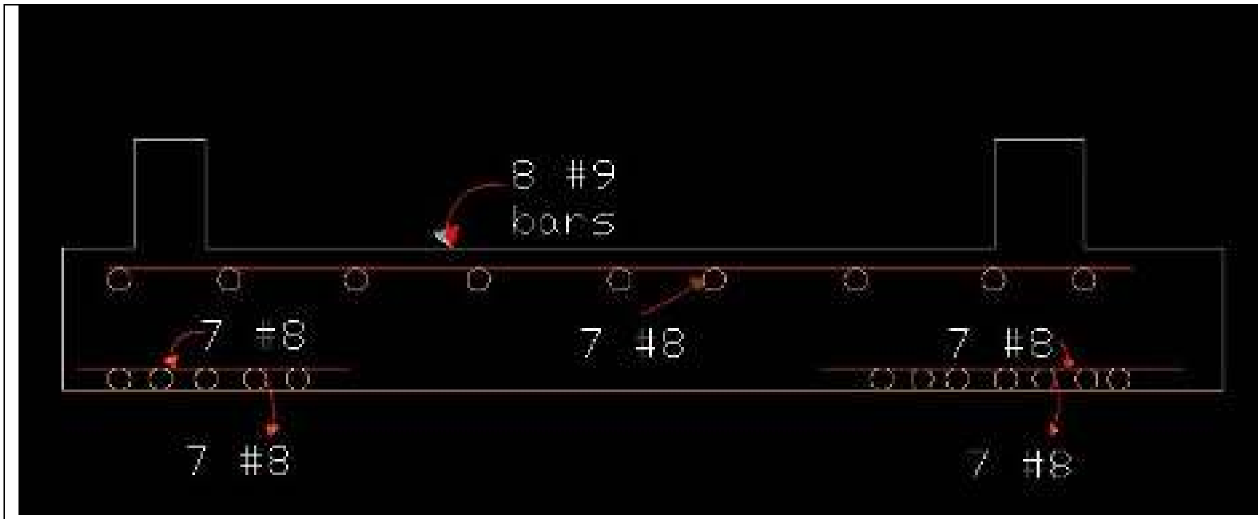
Net Upward Pressure under Right column = Pu2/ Width of footing = 456 / 6.5

Net Upward Pressure = 70.15 K/ft

Mu at face of right column = 70.15 x $(2.57)^2/2$ = 231.66 k-ft.

As = (231.66 x 12000)/(0.9 x 60,000 x 28.35)

As = 1.81 in^2 → Provide minimum As = 7 # 8 bars (5.5 in^2)



Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=i-oRSbTLm6I
2. https://www.youtube.com/watch?v=JvkJavV55I4

Important Books/Journals for further learning including the page nos.: REINFORCED CONCRETE DESIGN,N.Krishna raju and R.N.Pranesh,**Page no:**

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LECTURE HANDOUTS

L45

CIVIL

V/III

Course Name with Code : **19CEC09 / DESIGN OF REINFORCED CONCRETE ELEMENTS**

Course Faculty : **Dr.M.Harikaran**

Unit : **V** **Date of Lecture:**

Topic of Lecture: Design of RC footings

Introduction : RCC foundation - Reinforced Cement Concrete- concrete **Foundation** or **footing** of superstructure using concrete and reinforcement steel bars. These are like a base of the structure above to distribute the load evenly from the superstructure. ... Then pour desinged concrete over it .

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Footings
- ✓ foundations

Detailed content of the Lecture:

There are mainly two types of R.C.C. footings:
1. One way reinforced footings.
2. Two way reinforced footings.

1. **One Way Reinforced Footing**: These footings are for the walls. In these footings main reinforcements are in the transverse direction of wall. In longitudinal directions there will be only nominal reinforcement.

2. **Two Way Reinforced Footings**: For columns two way reinforced footings are provided.

The following types of the footings are common:
(i) Isolated Column Footings: If separate footings are provided for each column, it is called isolated column footing. Figure 7.3 shows a typical isolated column footing. The size of footing is based on the area required to distribute the load of the columns safely over the soil . These footings are provided

over a 100 to 150 mm bed concrete. Required reinforcements and thickness of footing are found by the design engineers. Thickness may be uniform or varying.

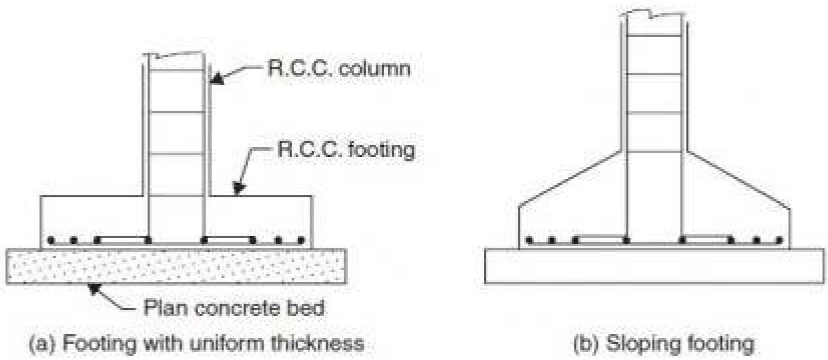

Fig. 7.3. Isolated R.C.C. footing

(ii) Combined Footings: Common footings may be provided for two columns. This type of footing is necessary when a column is very close to the boundary of the property and hence there is no scope to project footing much beyond the column face. Figure 7.4 shows a typical combined footing. The footing is to be designed for transferring loads from both columns safely to the soil. The two columns may or may not be connected by a strap beam.

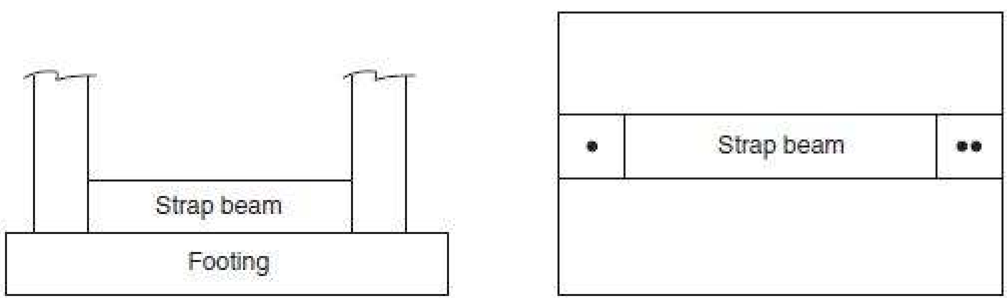

Fig. 7.4. Combined footing [Strap beam may or may not be provided]

(iii) Continuous Footings: If a footing is common to more than two columns in a row, it is called continuous footing. This type of footing is necessary, if the columns in a row are closer or if SBC of soil is low. Figure 7.5 shows this type of footing.

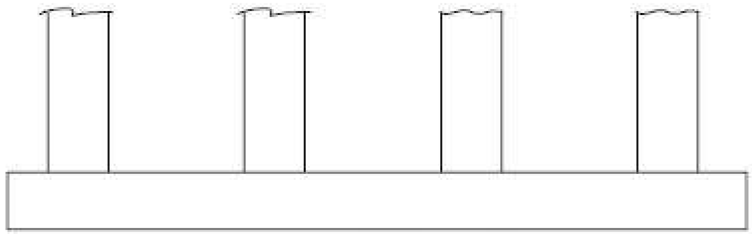

Fig. 7.5. Continuous footing

(iv) Mat Footing/Raft Footing: If the load on the column is quite high (Multistorey columns) or when the SBC of soil is low, the sizes of isolated columns may work out to be to such an extent that they overlap each other. In such situation a common footing may be provided to several columns as shown in Fig. 7.6. Such footings are known as raft footings. If the beams are provided in both directions over the footing slab for connecting columns, the raft foundations may be called as grid foundation also. The added advantage of such footing is, settlement is uniform and hence unnecessary stresses are not produced

Video Content / Details of website for further learning (if any):
1.https://www.youtube.com/watch?v=wHCKhTG_DRA
2.https://www.youtube.com/watch?v=ZTKETIvSys4

Important Books/Journals for further learning including the page nos.: REINFORCED CONCRETE DESIGN,N.Krishna raju and R.N.Pranesh,**Page no:**

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