**WOLLO UNIVERSITY**
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**SCHOOL OF CIVIL,ARCHITECTURE AND WATER ENGINEERING**

REINFORCED CONCRETE STRUCTURE-II

# Continuous beams

# Chapter One
# Continuous beams

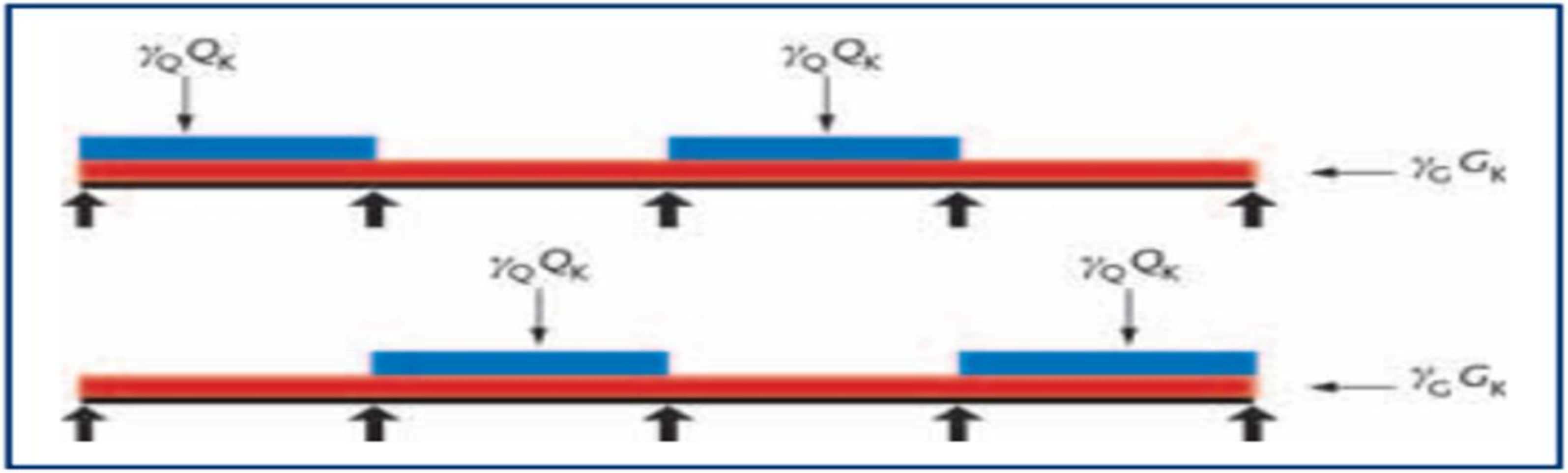
Most reinforced concrete structures are designed for internal forces found by elastic theory with methods such as

- Slope deflection,
- Moment distribution
- Matrix analysis.

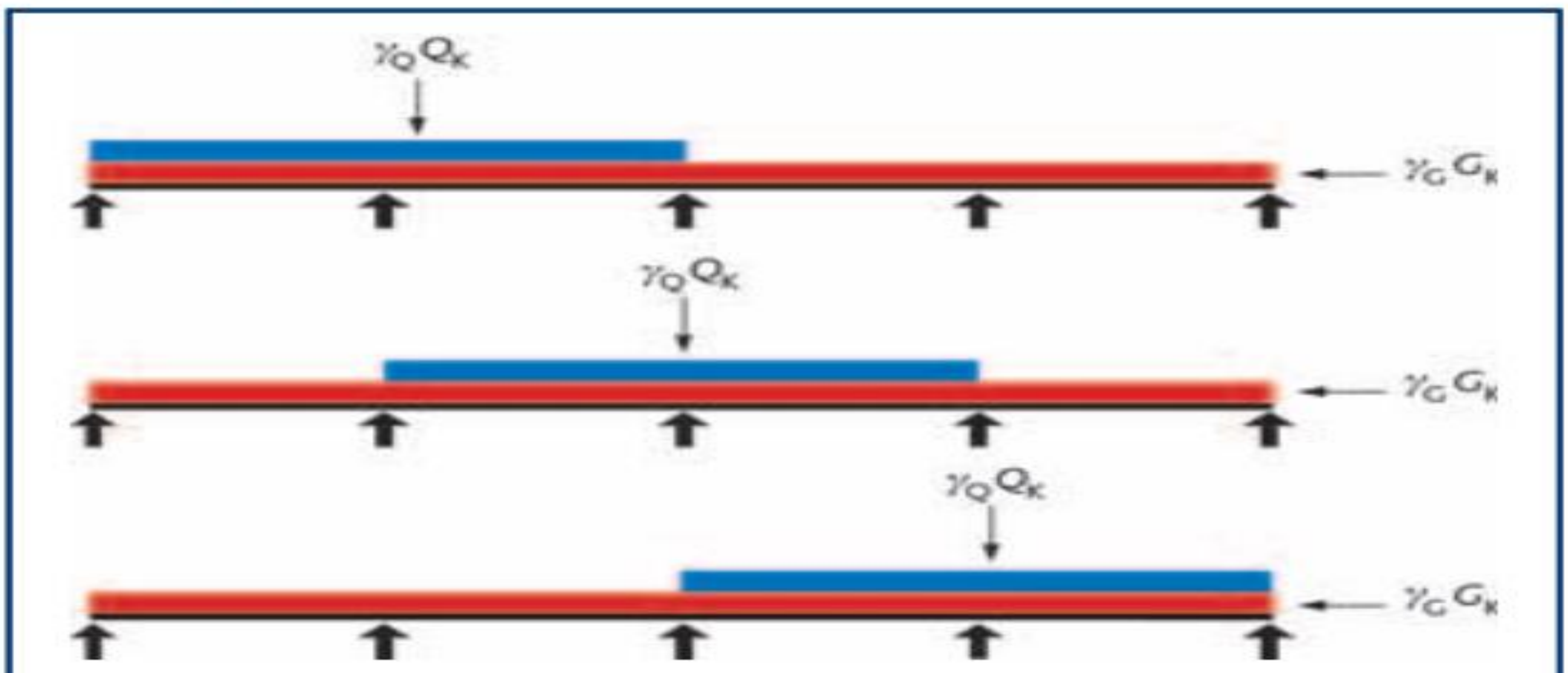
# Cont….

- -The term load arrangements refers to arranging of variable actions(e.g. imposed and wind loads) to give the most onerous forces in a member or structure .
- -Load set 1. Alternate or adjacent spans loaded The design values should be obtained from the more critical of:
  -Alternate spans carrying the design variable and permanent loads with other spans loaded with only the design permanent load.
- The value of γG should be the same throughout.
  - Any two adjacent spans carrying the design variable and permanent loads with other spans loaded with only the design permanent load. The value of γG should be the same throughout

**Alternate spans loaded**




**Adjacent spans loaded**



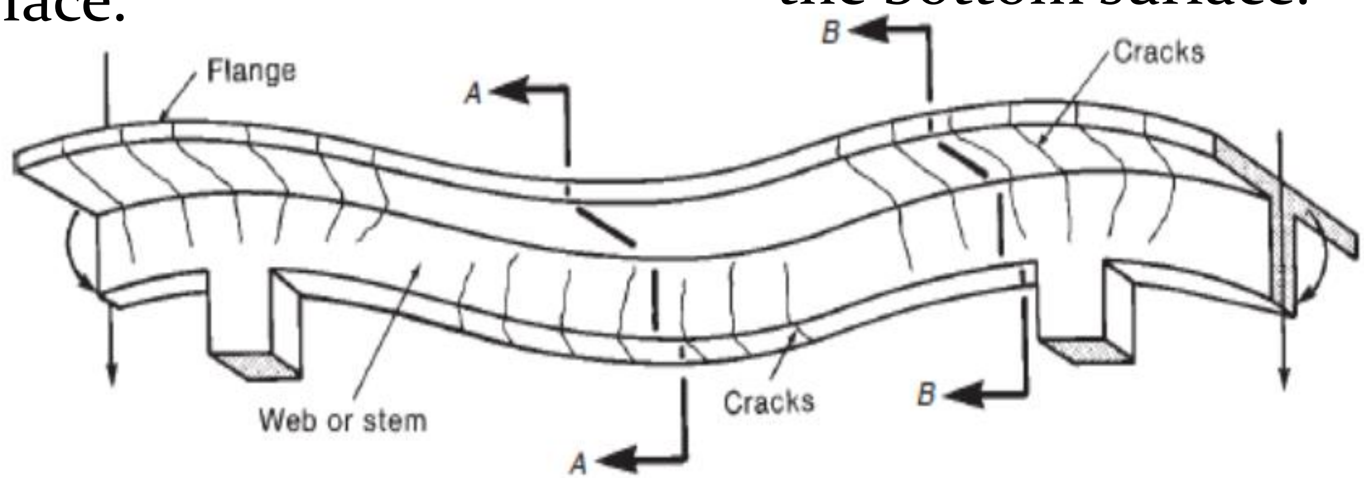
# Positive and Negative Moments

## Positive Moments

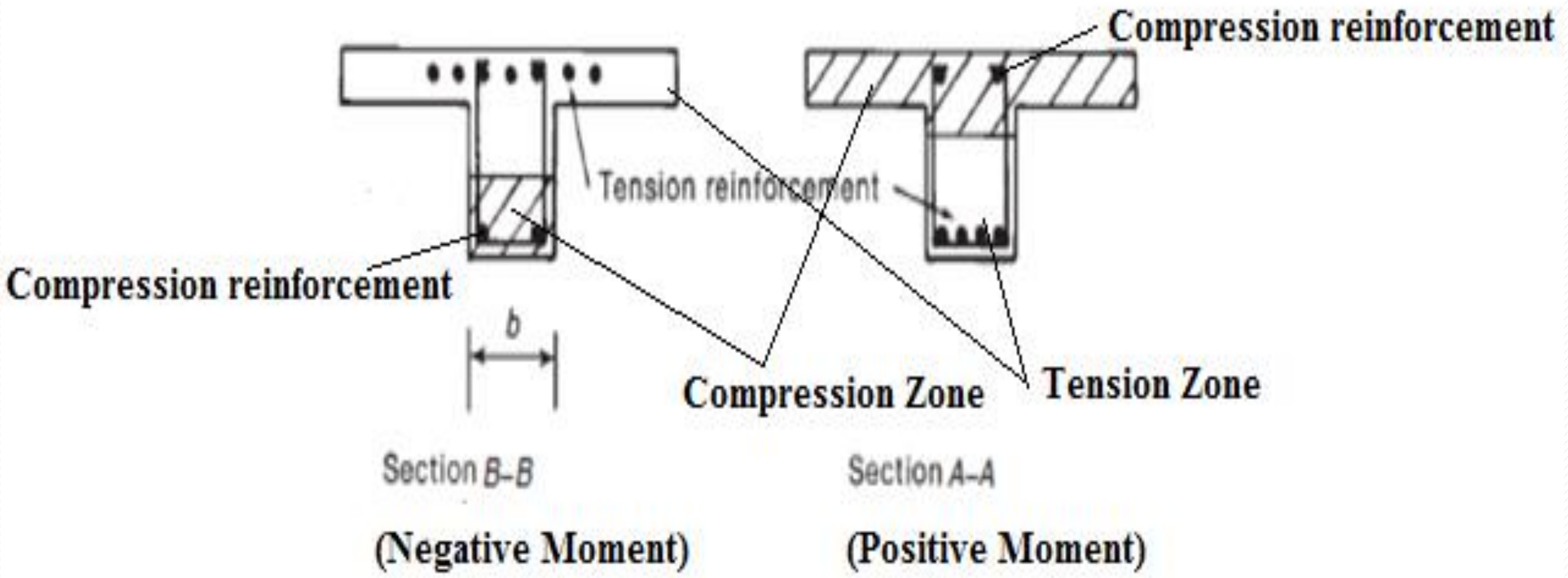
A moment that causes compression on the top surface of a beam and tension on the bottom surface.

## Negative Moments

A moment that causes tension on the top surface of a beam and compression on the bottom surface.



# Cont….




Positive and negative moment regions in a T-beam

# Moment redistribution

- For practical applications, linear elastic analysis with limited redistribution is a useful approach as it takes into account the advantages of **redistribution of internal forces** for verification of the load-carrying capacity at the ULS.

$$\delta = \frac{M_{red}}{M_{el}}$$ the redistribution coefficient $\delta$

where $M_{red}$ is the redistributed moment and $M_{el}$ is the elastic moment in the section of the structure under consideration.

# Linear elastic analysis with limited redistribution

- Suitable for ULS.
- The moments at ULS calculated using a linear elastic analysis may be redistributed, provided that the resulting distribution of moments remains in equilibrium with the applied loads.
- Redistribution of bending moments may be carried out without explicit check on the rotation capacity, provided that:

$0,5 \leq l_1 / l_2 \leq 2,0$

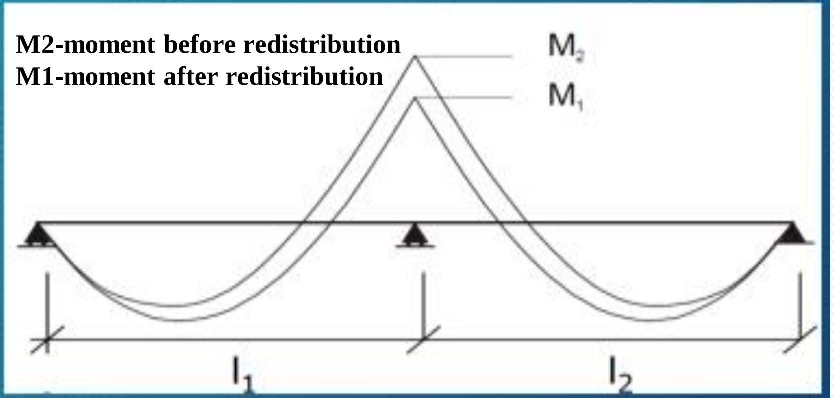
Ratio of redistribution $\delta = M_1 / M_2 < 1$, is

✓ $\delta \geq k_1 + k_2 x_u / d$ for $f_{ck} \leq 50$ MPa

✓ $\delta \geq k_3 + k_4 x_u / d$ for $f_{ck} > 50$ MPa

✓ $\delta \geq k_5$ for reinforcement class B & C

✓ $\delta \geq k_6$ for reinforcement class A




$x_u$ is the depth of the neutral axis at the ultimate limit state after redistribution.
recommended value for $k_1$ is 0,44, for $k_2$ is $1,25(0,6+0,0014/\varepsilon_{cu2})$, for $k_3 = 0,54$, for $k_4 = 1,25(0,6+0,0014/\varepsilon_{cu2})$, for $k_5 = 0,7$ and $k_6 = 0,8$

# Cont…

**Plastic Analysis**

- Suitable for ULS.
- Suitable for SLS if compatibility is ensured.

When a beam yields in bending, an increase in curvature does not produce an increase in moment resistance.

Analysis of beams and structures made of such flexural members is called Plastic Analysis.

This is generally referred to as limit analysis, when applied to **reinforced concrete framed structures**, and plastic analysis when applied to **steel structures**

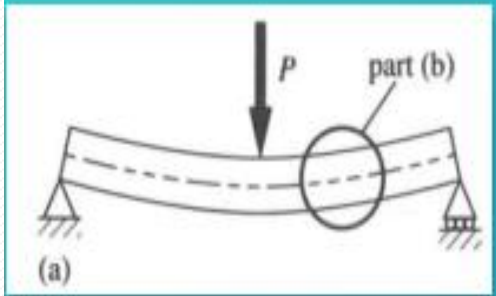
# Cont…

**Non-Linear Analysis**

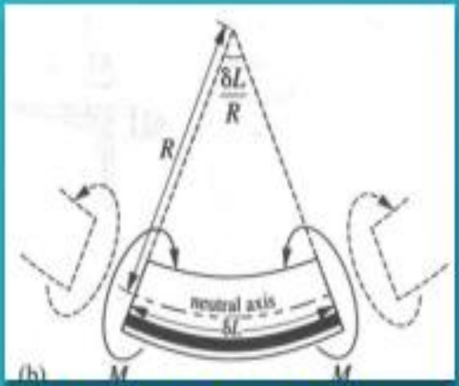
- Nonlinear analysis may be used for both ULS and SLS, provided that equilibrium and compatibility are satisfied and an adequate non-linear behavior for materials is assumed.
- The non-linear analysis procedures are more complex and therefore very time consuming.
- The analysis maybe first Or second order.

# Moment Curvature Relationship

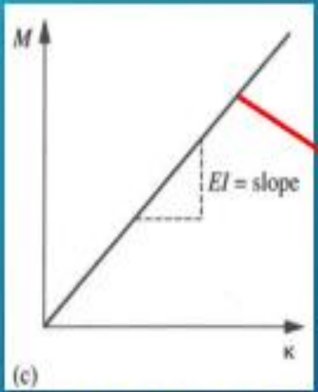
For a beam with homogeneous cross-section, which is loaded in bending is shown below.




Beam loaded in bending.




Segment of the beam loaded in bending.




but not linear for cracked section

Relationship between bending moment M and curvature K for beam with linear elastic homogeneous material.

$K = \frac{M}{E \cdot I}$ ...... From Elastic Theory

Where:

E= the modulus of elasticity

I=the moment of inertia of the cross-section

K=the local curvature=1/R

But is Concrete a Homogenous, elastic material?

Then how do we determine the moment curvature relationship for it?

Why do we even bother compute the M - K relationship in the first place?

# Rotation Capacity

- The designer adopting limit/plastic analysis in concrete must calculate the inelastic rotation capacity it undergoes at plastic-hinge locations.
- This is critical in situation where moment redistribution is going to be implemented.

One way to calculate this rotation capacity is making use of the moment-curvature relationship established for a given section.

But this plastic rotation is not confined to one cross section but is distributed over a finite length referred to as the hinging length. ($l_p$)

The total inelastic rotation $\theta_{pl}$ can be found by multiplying the average curvature by the hinging length:

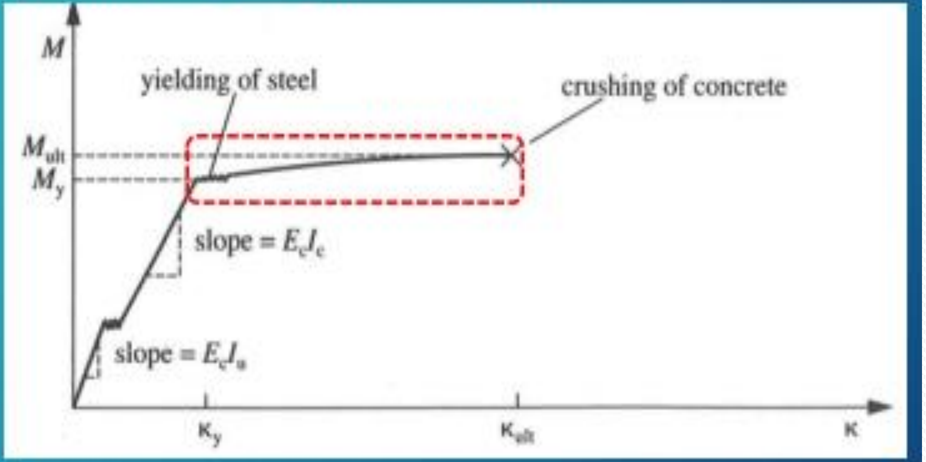
$$\theta_{pl} = \left(\kappa_u - \kappa_y \frac{M_u}{M_y}\right) l_p$$

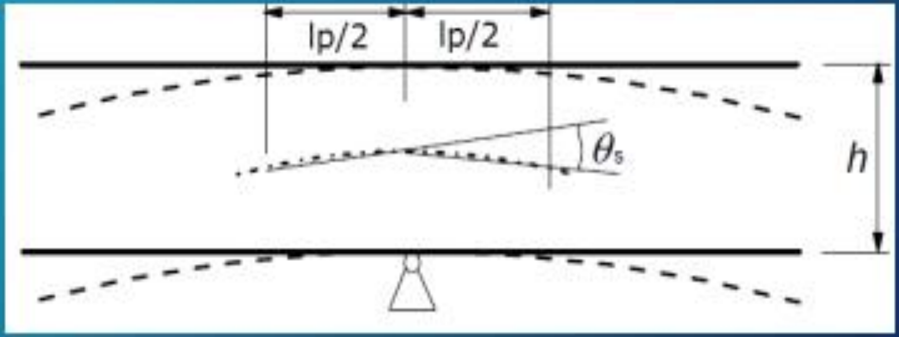
Mu,MyKu,Ky are expressed in moment kurvature relation above

where :

$l_p = 0.5d + 0.05z$

In which z is the distance from the point of maximum moment to the nearest point of zero moment



# Cont…

According to EC-2, verification of the plastic rotation in the ultimate limit state is considered to be fulfilled, if it is shown that under the relevant action the calculated rotation, $\theta_{pl,s}$, is less than or equal to the allowable plastic rotation, $\theta_{pl,d}$

In the simplified procedure, the allowable plastic rotation may be determined by multiplying the basic value of allowable rotation by a correction factor $k_\lambda$ that depends on the shear slenderness.

The recommended basic value of allowable rotation, for steel Classes B and C (the use of Class A steel is not recommended for plastic analysis) and concrete strength classes less than or equal to C50/60 and C90/105 are given

The values apply for a shear slenderness $\lambda = 3,0$. For different values of shear slenderness $\theta_{pl,d}$ should be multiplied by $k_\lambda$

$$k_\lambda = \sqrt{\lambda / 3}$$

where :

$\lambda$ is the ratio of the distance between point of zero and maximum moment after redistribution and effective depth, d.

As a simplification $\lambda$ may be calculated for the concordant design values of the bending moment and shear.

$$\lambda = M_{sd} / (V_{sd} \cdot d)$$

# Cont…

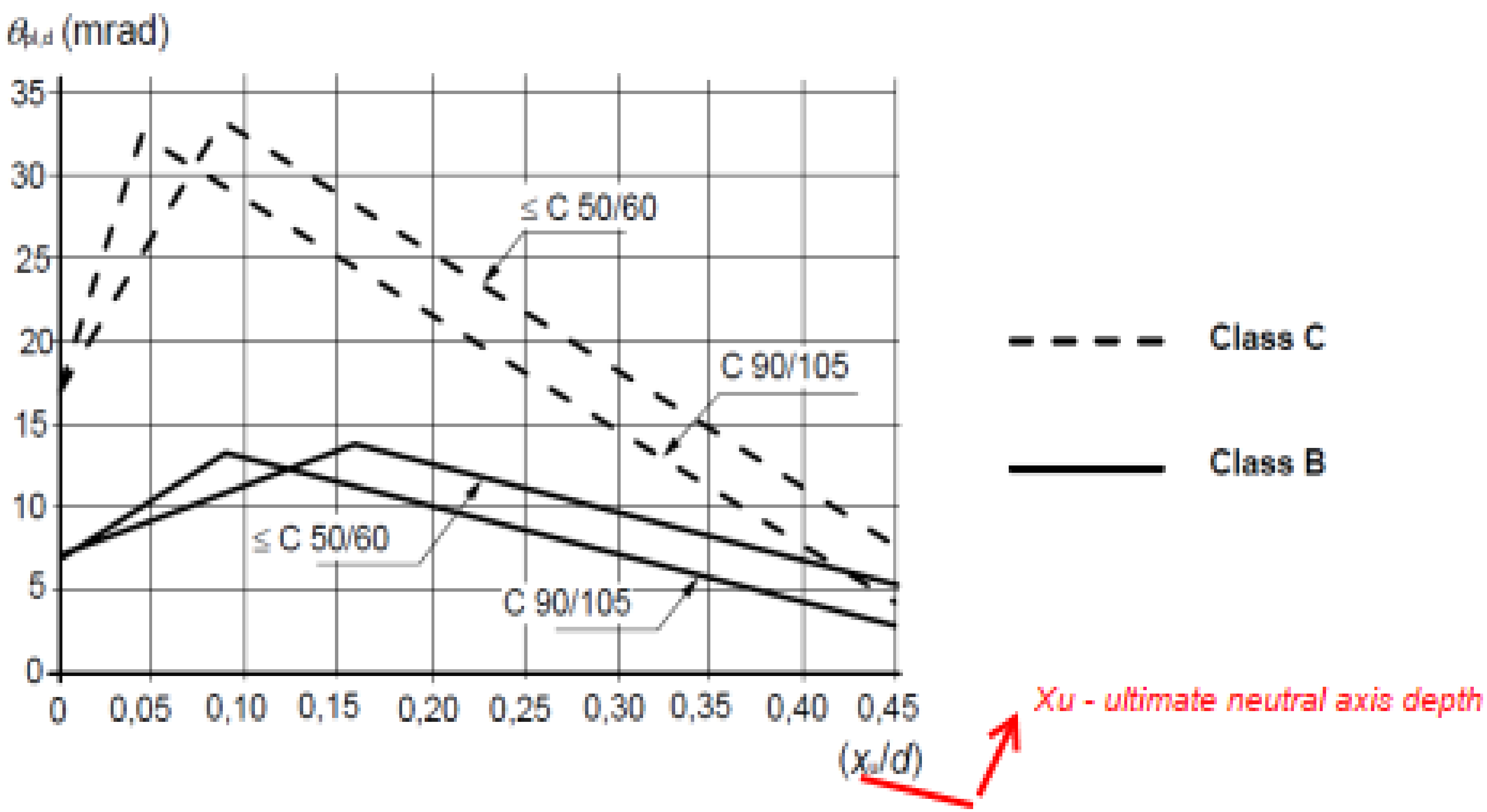



**Figure 5.6N: Allowable plastic rotation, $\theta_{pl,d}$, of reinforced concrete sections for Class B and C reinforcement. The values apply for a shear slenderness $\lambda = 3{,}0$**