Lecture 9

STR403 - Metallic Bridges

“Composite Plate-Girder Bridges”

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Lecture 9: Composite Plate-Girder Bridges

Topics

1 – Introduction

2 – Composite Simple Beam Design

3 – Composite Continues Beam Design

4 – Shear Connector.

5 – Composite Deck.

1. Introduction

❖ In Civil Engineering constructions, the merits of a material are based on:

Availability, Structural Strength, Durability, and Workability

❖ Improving material utilization (cost-effective) can be done two ways:

1. Composite Material
2. Composite Structure:

1. Introduction

Composite Material:

Use appropriate materials to form a new product with desired properties [e.g. glass fibers, cement, additives]

Tensile Strength

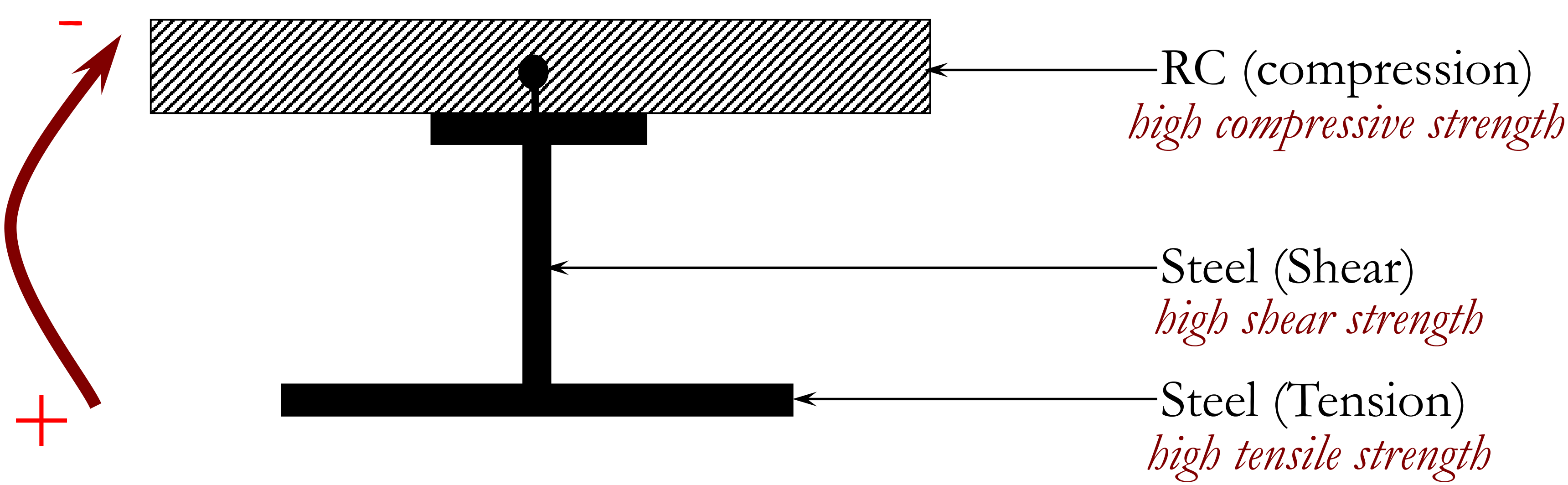
Compressive Strength

Durability

1. Introduction

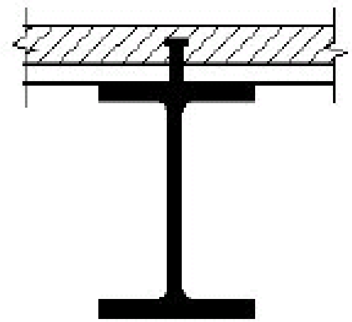
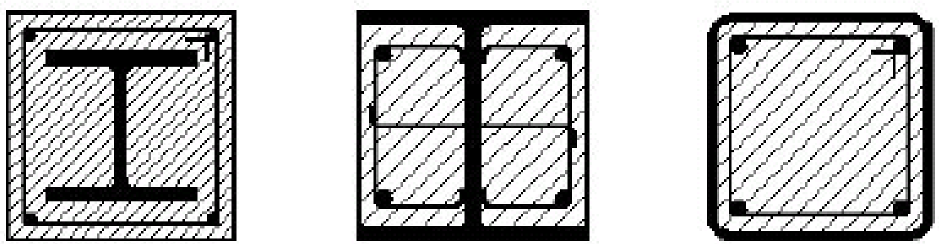
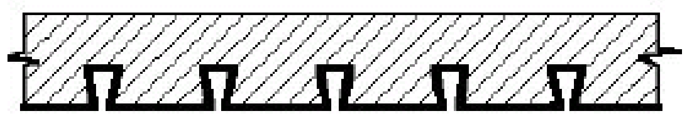
Composite Structure:

use different materials arranged in an optimum geometric configuration, correspond to the best material utilization



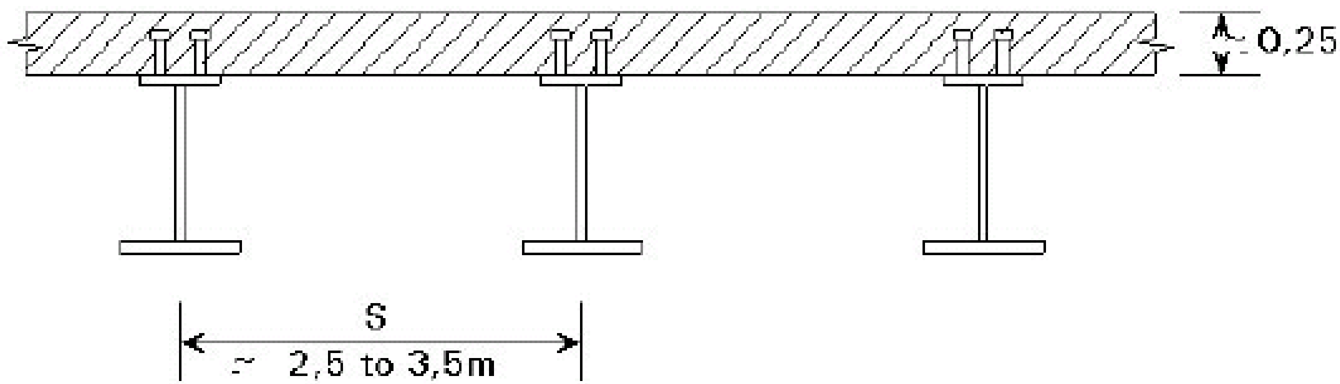
1. Introduction

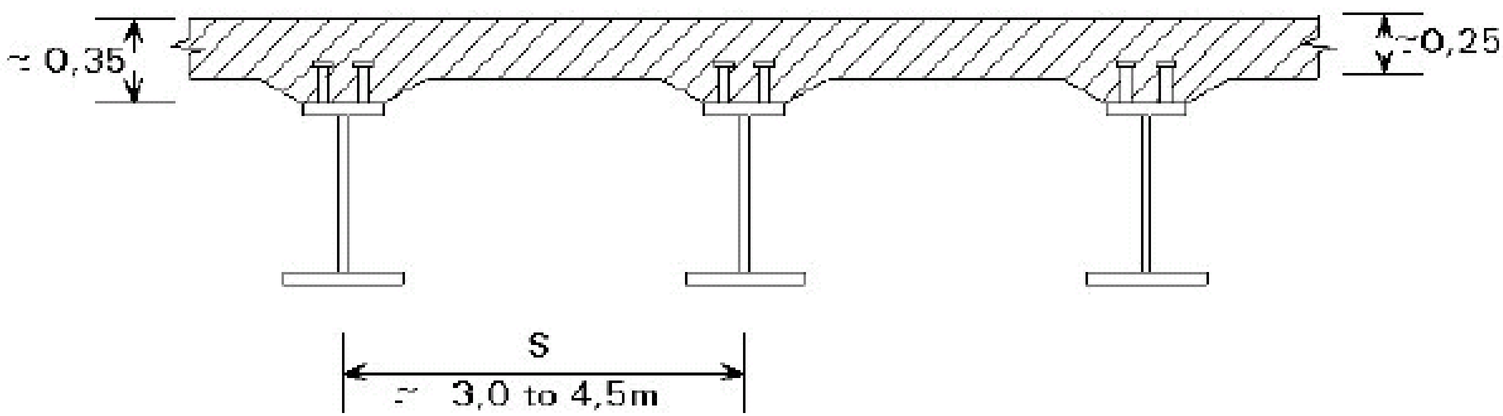
Composite Structure - Buildings:

Composite girder		Steel-beam composite slab or RC-slab
Composite column		Steel profiles embedded in or filled with concrete
Composite slab		Holorib ® sheeting + concrete

1. Introduction

Composite Structure - Bridges:

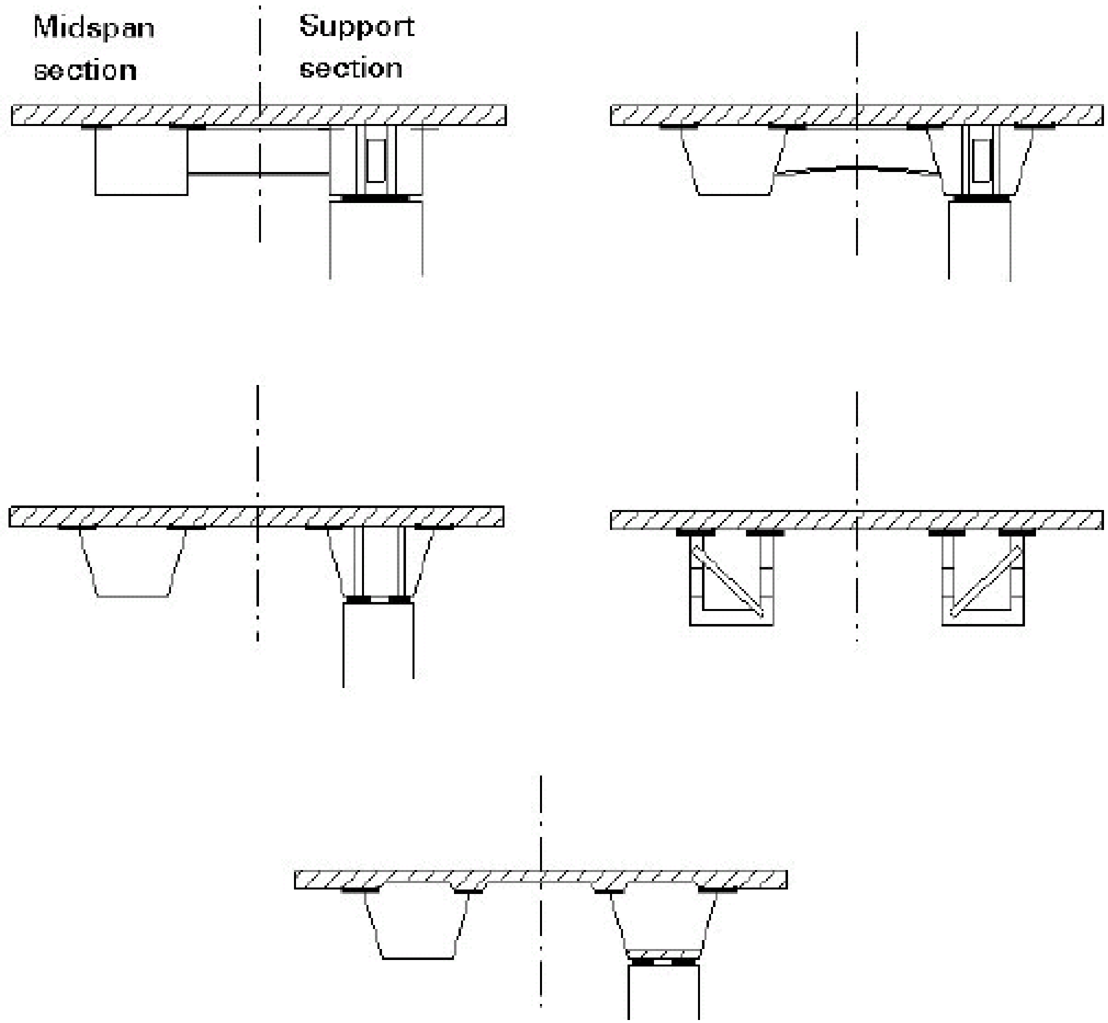




Multiple Plate Girders

1. Introduction

Composite Structure - Bridges:

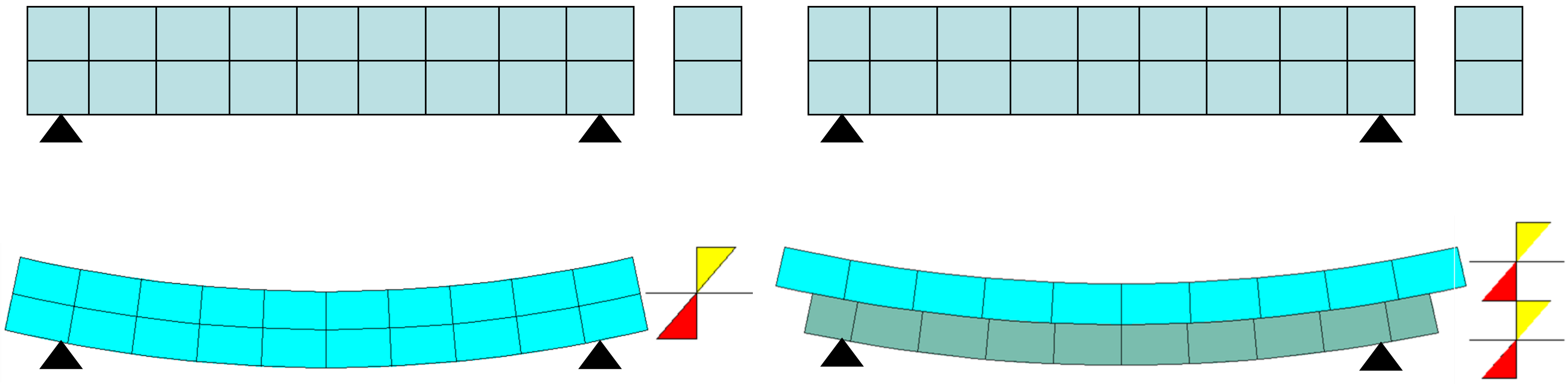


Twin Box Girders

1. Introduction

❖ Composite Action:

It requires different components to act as a single unit



Composite Action

Non-Composite Action

Δ=1mm ε = 100e-6

Δ=5mm ε = 300e-6

1. Introduction

❖ Advantages & Disadvantages:

Advantages:

Greater Stiffness, Higher Load Capacity, and Higher Collapse Capacity

Material Saving, Weight Saving, Shallow Sections, Reduce Live Load Deflection & Vibration

Disadvantages:

The need to provide shear connectors, and Higher Labor Cost.

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4 – Shear Connector.

5 – Composite Deck.

2. Composite Simple Beam Design:

10.1.3 Methods of Construction

Two different methods of construction are to be considered:

10.1.3.1 Without Shoring (Case I)

When no intermediate shoring is used under the steel beams or the concrete slab during casting and setting of the concrete slab, the steel section alone supports the dead and construction loads. The composite section supports the live loads and the superimposed dead loads (flooring, walls, etc.) after the slab has reached 75% of its required characteristic strength, f_{cu}.

10.1.3.2 With Shoring (Case II)

When an effective intermediate shoring system is utilized during casting and setting of the concrete slab, the composite section supports both the dead and live loads. Shoring shall not be removed until the concrete has attained 75% of its required characteristic strength, f_{cu}.

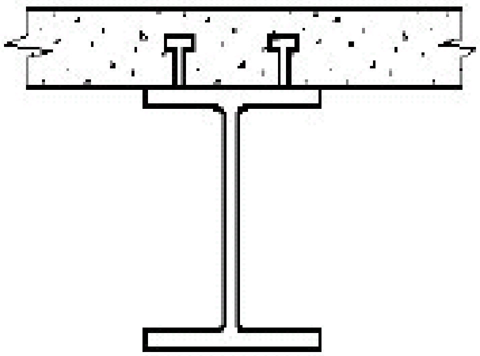
2. Composite Simple Beam Design:

Concrete Slab:

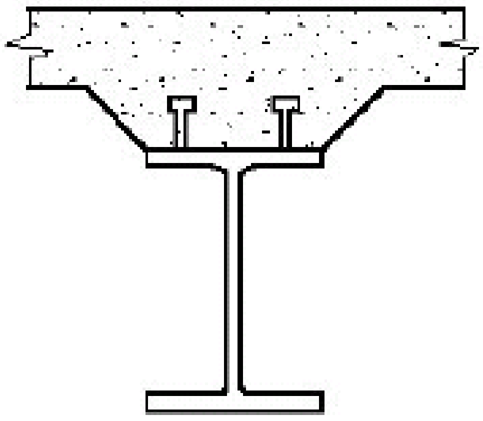
- Comply with the Egyptian Code for Reinforced Concrete.
- Minimum acceptable value for **Fcu**:
  - 300 kg/cm^2 for bridges.
  - Typically 400 kg/cm^2 (slab without wearing surface)
- May be placed on formed steel deck.
- May have constant thickness or haunch.
- Minimum Thickness t = 160mm.
- Minimum Thickness t = 200mm (slab without wearing surface)

2. Composite Simple Beam Design:

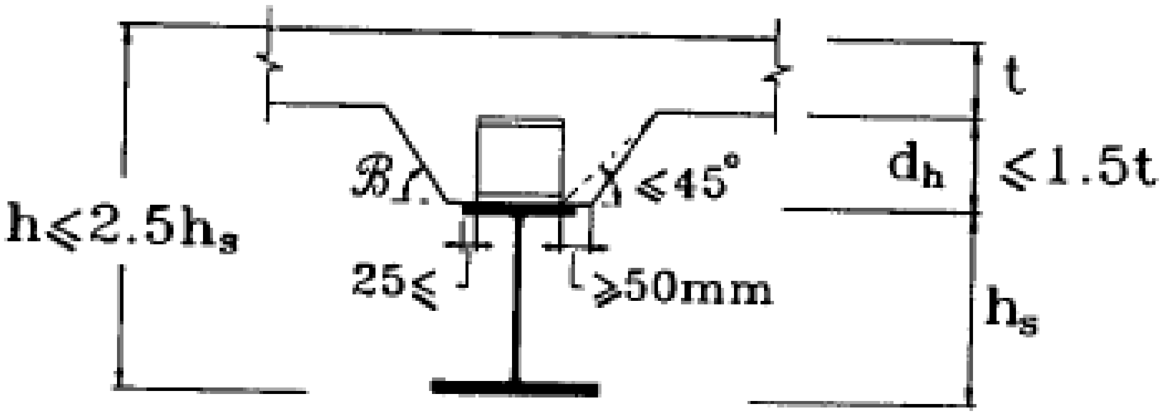
Concrete Slab



T - Beam



Haunched slab



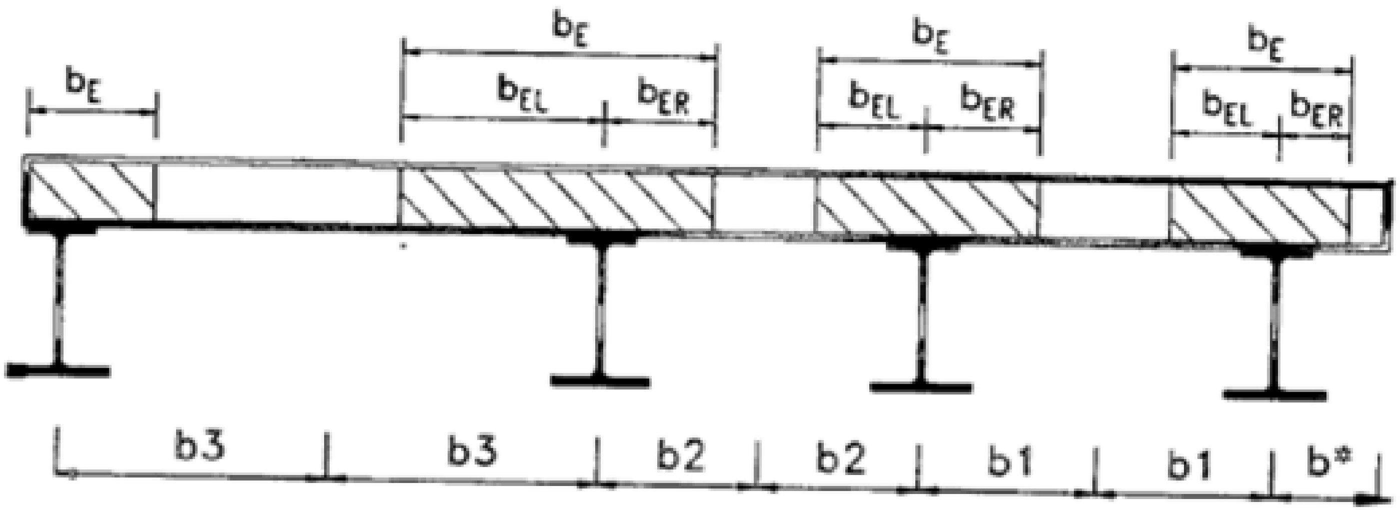
$d_h \leq 1.5t$

$h \leq 2.5h_s$

2. Composite Simple Beam Design:

Effective Width of Concrete Slab ($b_E = b_{EL} + b_{ER}$)

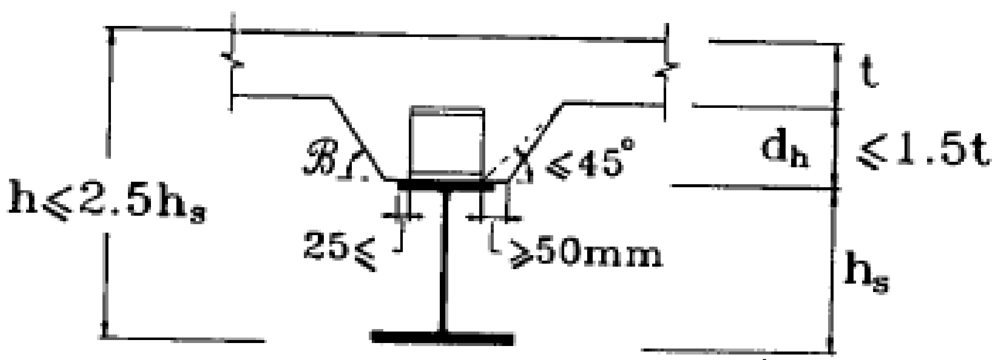
- b_{EL} or b_{ER} = the smallest of:
  - L/8
  - Half the center-to-center spacing.
  - 6 t (t = slab thickness).
  - Distance to slab edge.



2. Composite Simple Beam Design:

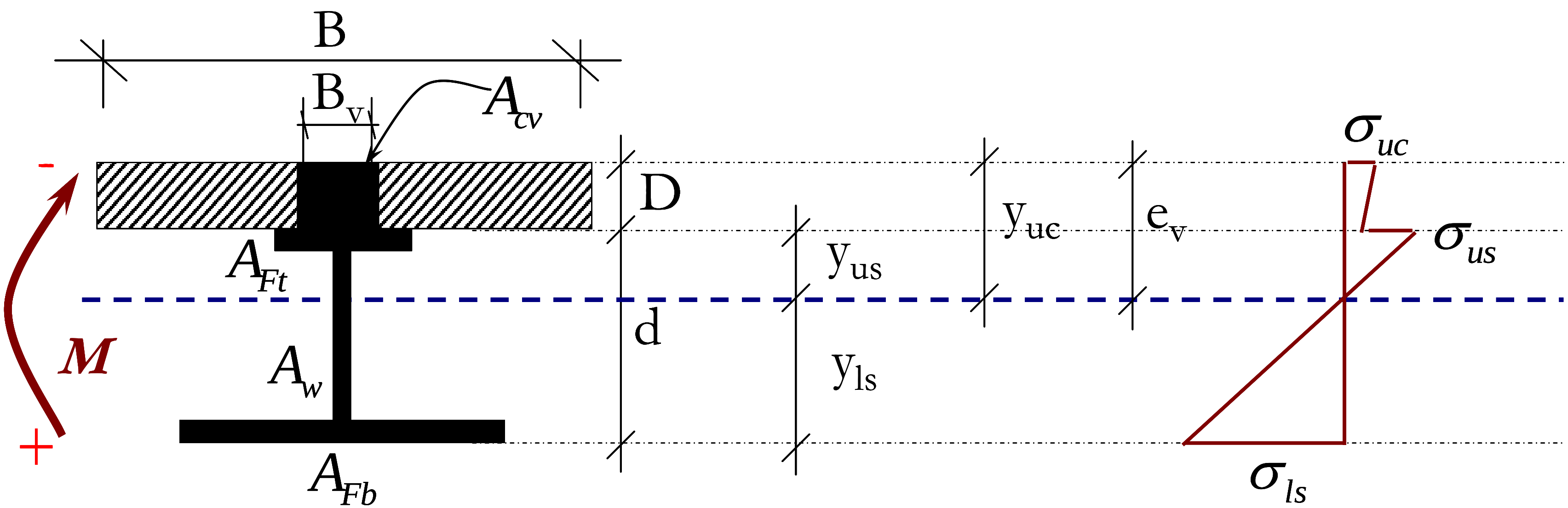
Beam Span to Depth Ratio (L/h)

- Preliminary dimensioning:
  - The ratio of the beam span, L, to the beam overall depth including the concrete slab, h, ranges from L/h = 16 to L/h =22.
  - If the span-to-depth limit is exceeded, limitation of deflection as defined by the Code must be satisfied.



2. Composite Simple Beam Design:

Calculation of Stresses



Stress Distribution

Check of Stresses:

$$\sigma_{uc} = \frac{M}{n \cdot I_v} y_{uc}, \quad \sigma_{us} = \frac{M}{I_v} y_{us}, \quad \sigma_{ls} = \frac{M}{I_v} y_{ls}$$

2. Composite Simple Beam Design:

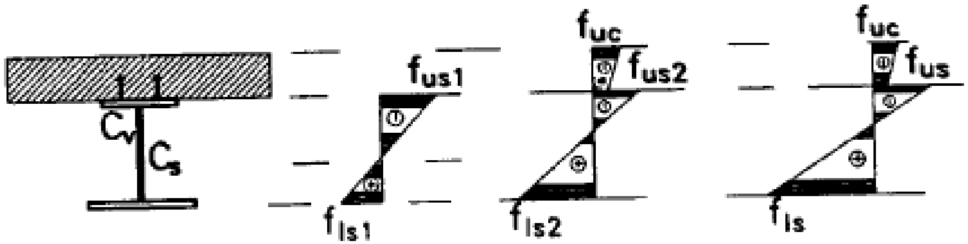
- Recommended Values of Modular Ratio, n

Concrete characteristic cube strength, F_{cu} (kg/cm^2)	Modulus of elasticity of concrete, E_c (t/cm^2)	Modular ratio, n
250	220	10
300	240	9
400	280	8
$\geq$ 500	310	7

- If the composite section is in the positive moment zone, and where the neutral axis falls inside the concrete slab, the tensile stresses shall not exceed the values:

Fcu (kg/cm^2)	250	300	400	$\geq$500
Tensile stress (kg/cm^2)	17	19	23	27

2. Composite Simple Beam Design:



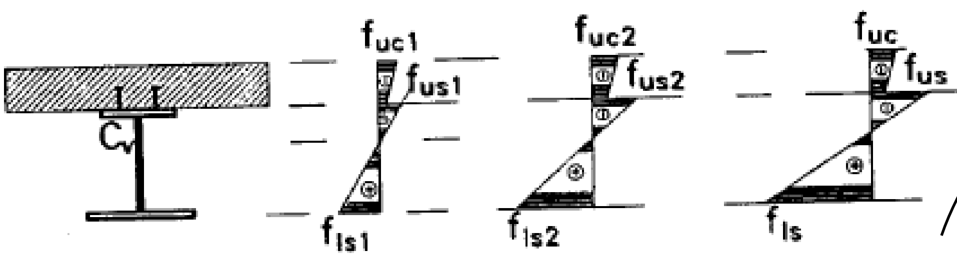
D.L₁ + (D.L₂ + L.L) = (D.L₁ + D.L₂ + L.L)

(a) Without Shoring (Case I)

$$\sigma_{uc} = \frac{M_{DL_2+LL}}{n \cdot I_v} y_{uc},$$

$$\sigma_{us} = \frac{M_{DL_1}}{Z_x} + \frac{M_{DL_2+LL}}{I_v} y_{us},$$

$$\sigma_{ls} = \frac{M_{DL_1}}{Z_x} + \frac{M_{DL_2+LL}}{I_v} y_{ls}$$



D.L₁ + (D.L₂ + L.L) = (D.L₁ + D.L₂ + L.L)

(b) With Shoring (Case II)

$$\sigma_{uc} = \frac{M_{DL_1+DL_2+LL}}{n \cdot I_v} y_{uc},$$

$$\sigma_{us} = \frac{M_{DL_1+DL_2+LL}}{I_v} y_{us},$$

$$\sigma_{ls} = \frac{M_{DL_1+DL_2+LL}}{I_v} y_{ls}$$

D.L.₁ = Dead Loads,

D.L.₂ = Super Imposed Dead Loads

L.L. = Live Loads

The steel web alone shall resist the vertical shear stresses of the composite beam, neglecting any concrete slab contribution

2. Composite Simple Beam Design:

Deflection

If the construction is shored during construction, Case II, the composite section will support both the dead load and the live load deflections. However, if the construction is not shored, Case I, the total deflection will be the sum of the dead load deflection of the steel girder and the live load deflection of the composite section. The deflection allowable limit due to live load without impact is equal to L/800.

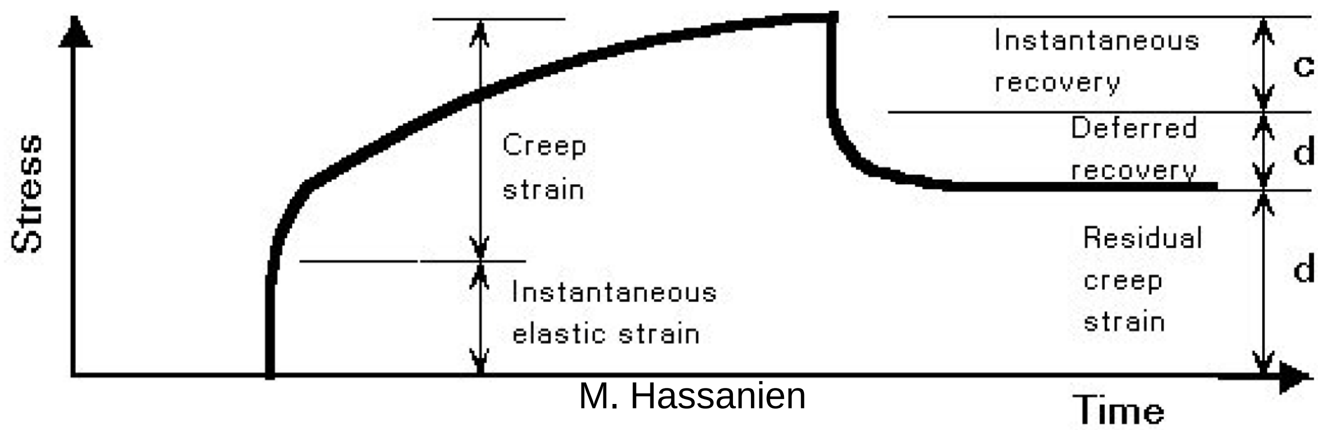
$$\delta_{Case-1} = \frac{5L^4}{384E}\left[\frac{W_{DL_1}}{I_x} + \frac{W_{DL_2+LL}}{I_v}\right];$$

$$\delta_{Case-2} = \frac{5L^4 W_{DL_1+DL_2+LL}}{384EI_v}$$

$$Allowable\ Deflection = Span/800$$

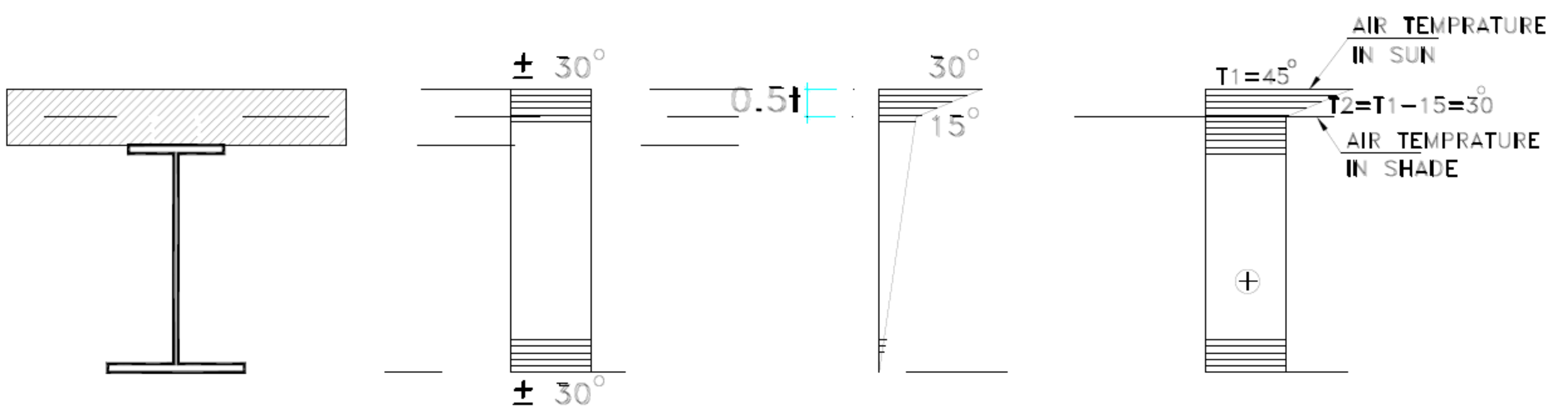
Creep and Shrinkage

- Concrete is subject to creep under sustained (dead) loading.
- The creep effect is **neglected** with un-shored composite beam (**Case-I**).
- In bridges, the creep effect may be approximated by multiplying the modular ratio, n by 3 in calculated the effect of dead loads. This is for shored composite beam (**Case-II**).
- Creep reduces concrete stresses, so when computing the maximum concrete stress, neglect creep.



Temperature Effect

- Variation in temperature to be considered: ± 30°C.
- The temperature variation is generally taken as uniform.
- Variable temperature distribution should consider the variation in conductivity between concrete and steel.



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3. Composite Continuous Beam Design:

- Simple composite beams are not used for long spans due to:

  1- The stress in concrete exceeds the allowable one causing failure.

  2- The composite action doesn't work because the difference in inertia between steel beam and concrete strip.

- Composite construction of continuous beams makes it possible to further reduce the depth and deflection.

3. Composite Continuous Beam Design:

- For the "negative" moment, the concrete will crack and thus does not enhance the performance.

- Tensile cracks in the negative-moment zone can be treated by different ways:

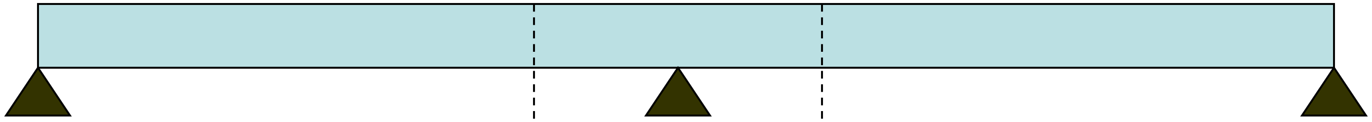
  1- If the tensile stresses in concrete is less than the allowable, the composite action can be assumed, the construction method-1 (Case-1, un-shored) is preferred to reduced stresses in concrete.

  2- If the tensile stresses in concrete is exceeding the allowable, the steel section in the negative-moment zone may be strengthened to substitute the loss of the concrete.

  3- Additional steel reinforcement may be arranged at the negative-moment zone in the longitudinal direction as a supplementary part of the steel section.

3. Composite Continuous Beam Design:

Analysis should consider the variation in inertia

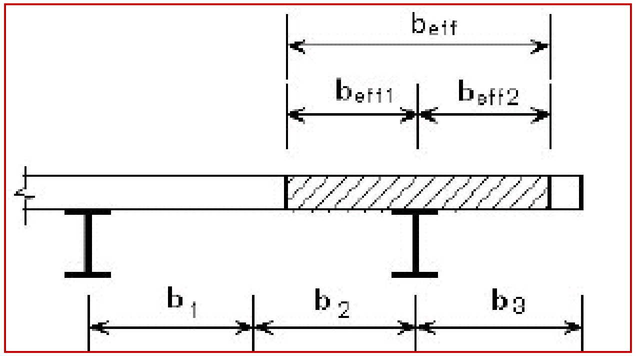


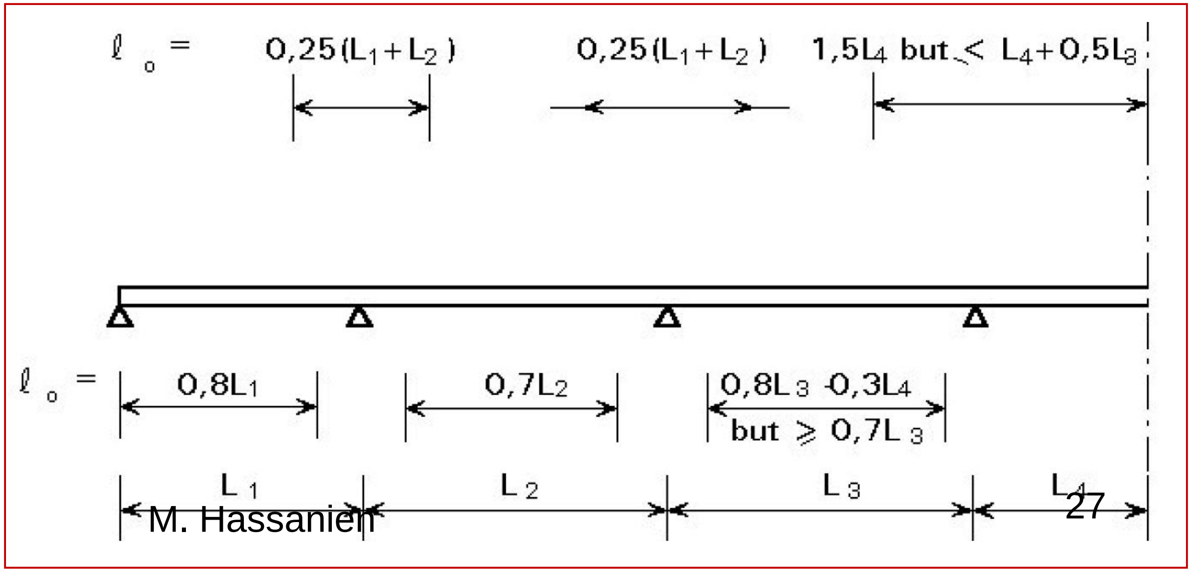
Case-2				Case-1
DL_1+DL_2+LL	I_S I_V	I_S I_V	I_S I_V	DL_1 DL_2+LL
DL_1+DL_2+LL	I_S I_V	I_S I_S	I_S I_V	DL_1 DL_2+LL
DL_1+DL_2+LL	I_{S1} I_V	I_{S2} I_{S2}	I_{S1} I_V	DL_1 DL_2+LL

3. Composite Continuous Beam Design:

Effective Width of Concrete Slab ($b_E = b_{EL} + b_{ER}$)

- b_{EL} or b_{ER} = the smallest of:
  - $l_o/8$
  - Half the center-to-center spacing.
  - 6 t (t = slab thickness).
  - Distance to slab edge.





3. Composite Continuous Beam Design:

- At negative moment regions, the lower flange of the steel beam shall be checked against the **lateral torsional buckling**. The point of contraflexture is treated as a brace point for lateral torsional buckling.

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Summary of Today's Topics

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