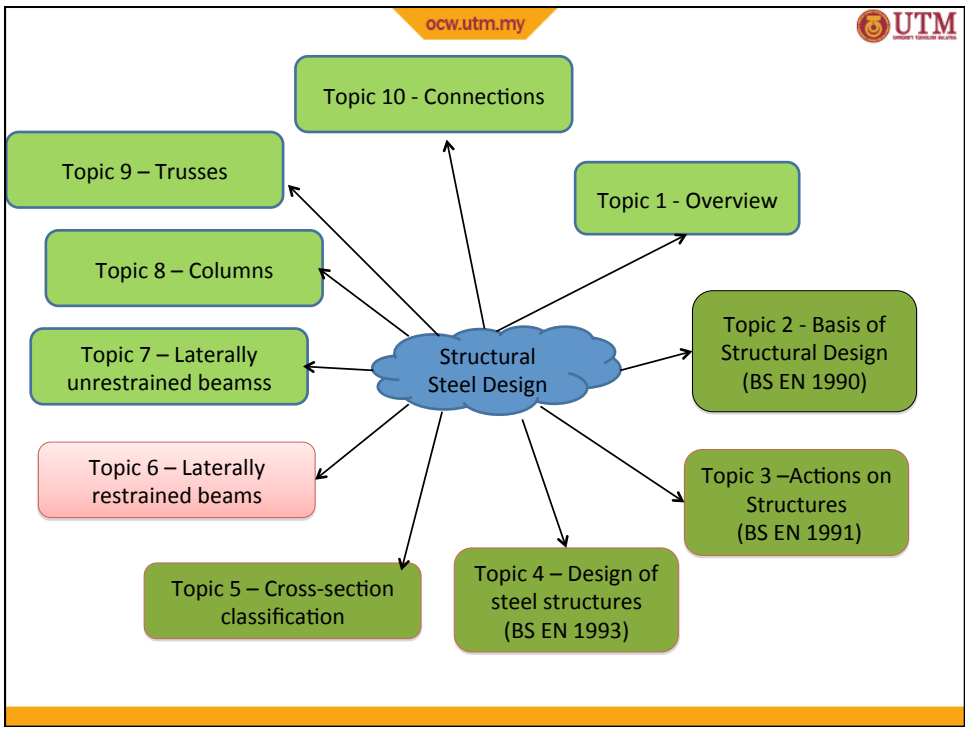
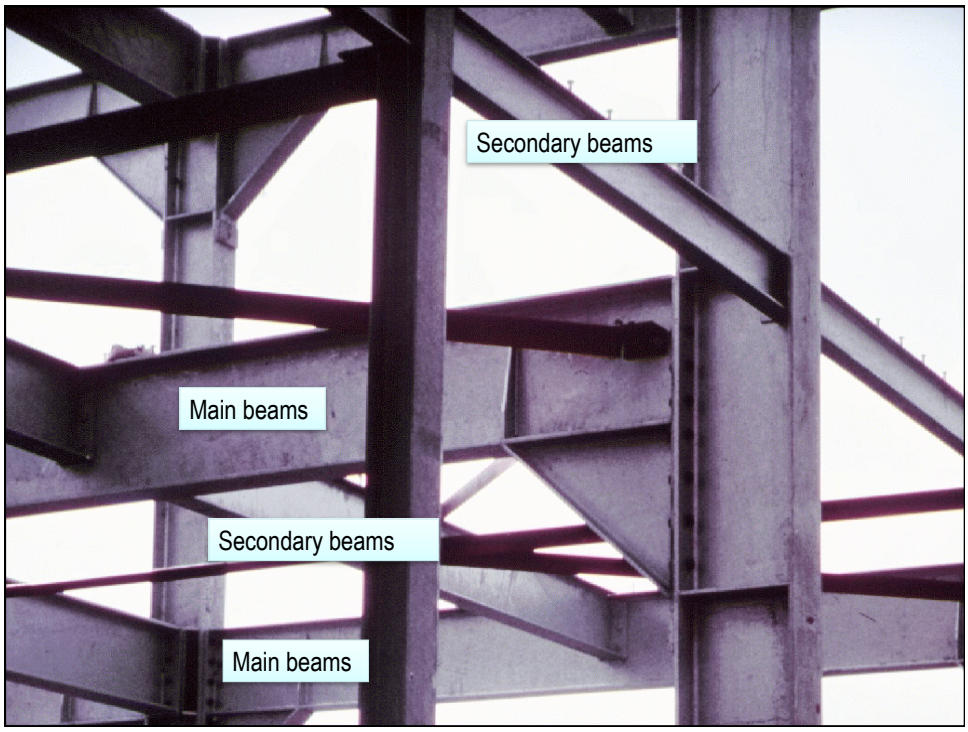
UTM OPENCOURSEWARE

Structural Steel and Timber Design SAB3233

Topic 6
Laterally restrained beams

Prof Dr Shahrin Mohammad





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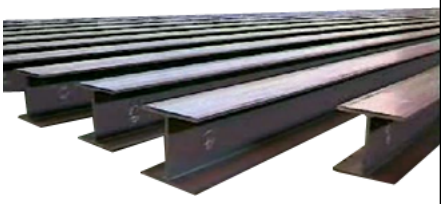
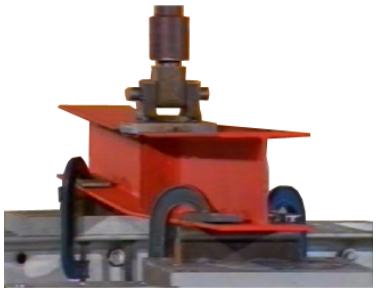
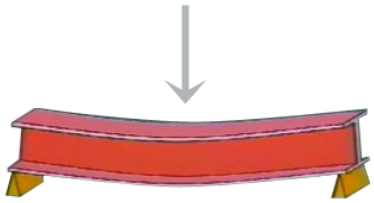
UTM

Beam is a member predominantly subject to bending. A beam is a structural member which is subject to transverse loads, and accordingly must be designed to withstand shear and moment. Generally, it will be bent about its major axis



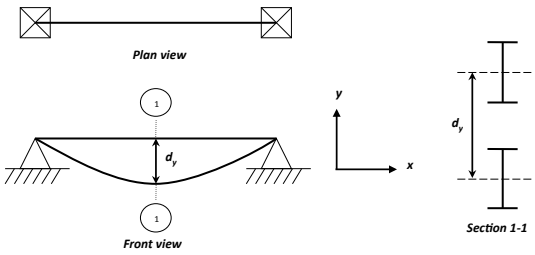




Types of restraining condition of beam

1. Restrained Beam

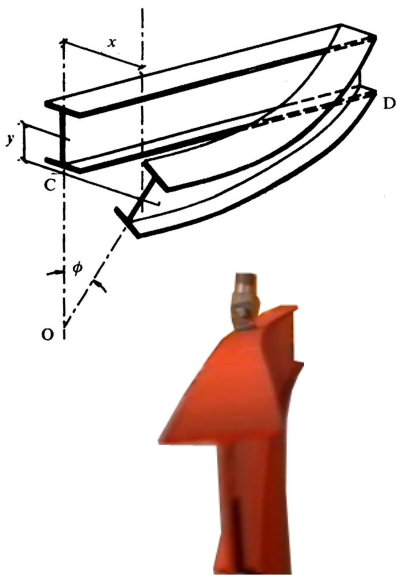
   A beam where the compression flange is restrained against lateral deflection and rotation. Only vertical deflection exists.



Types of restraining condition of beam

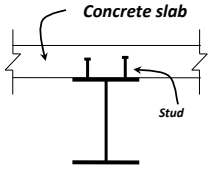
2. Unrestrained Beam

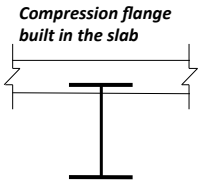
- The compression flange is not restrained from deflect laterally and rotate about the plan of the section, which is called lateral torsional buckling
- Three components of displacement i.e. vertical, horizontal and torsional displacement

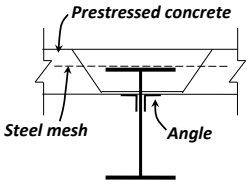


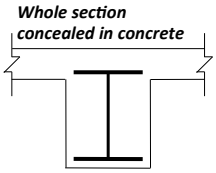
Restrained Beam

A full lateral restraint may be provided by concrete floor which sufficiently connected to the beam, or by sufficient bracing members added.









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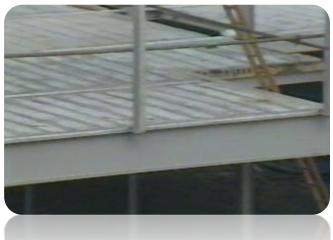

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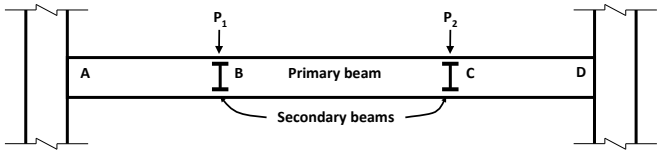
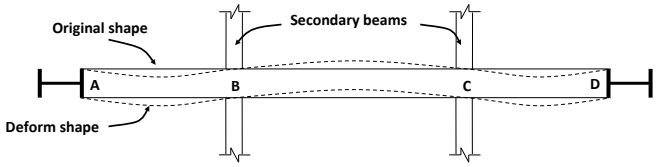
Restrained Beam

- Lateral restraint may be of along the span or at some points along the span.



Front view of the primary beam



Plan view

Points A, B, C and D are restrained from deform laterally by the secondary beams and the connection at column

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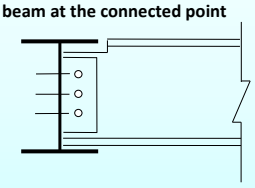
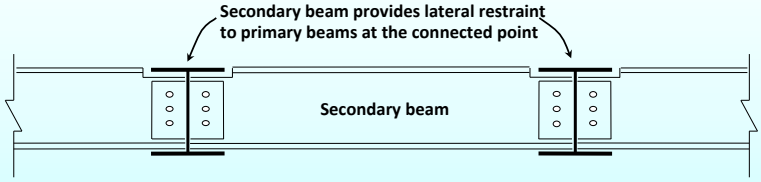
LATERAL RESTRAINT

Secondary beam provides lateral restraint to the primary beam at the connected point



Lateral restraint exist at the beam end which fixed in the concrete



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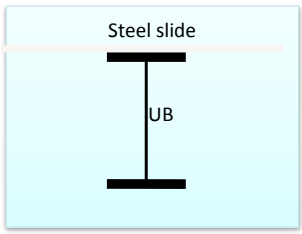
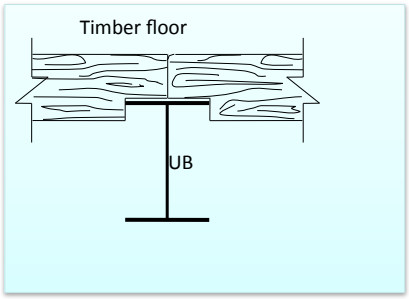
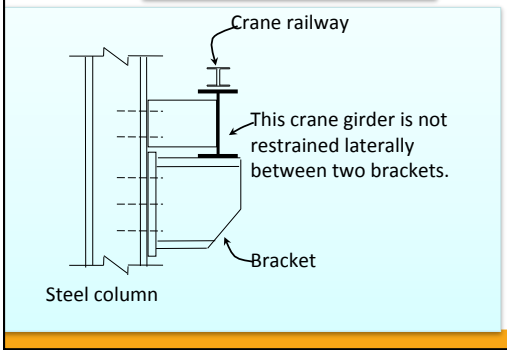
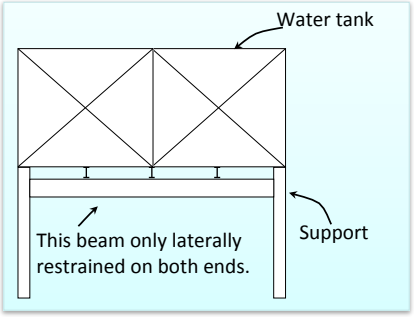
Unrestrained Beam

Examples :









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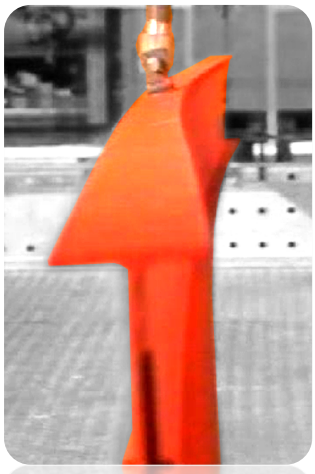

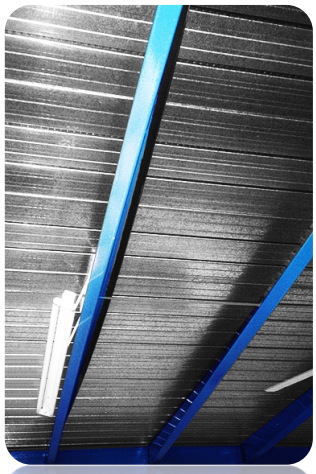

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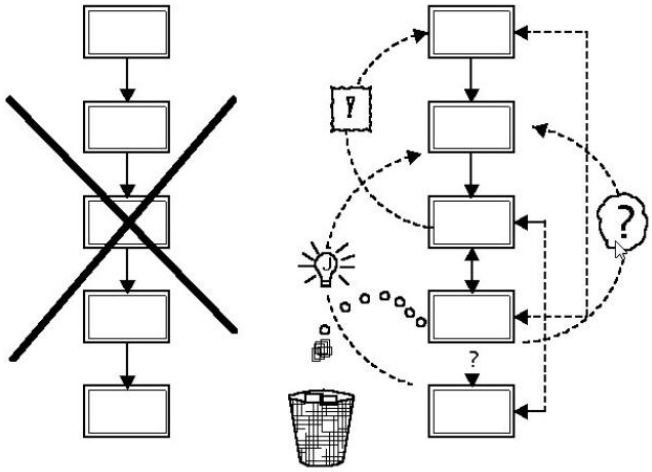
DESIGN CHECK :

- Generally, the section of beam is selected based on the moment capacity
- Once a trial section has been selected, design check is carried out to ensure that all the other strength components are satisfied
- The basic concept of design check is to ensure :

  Design resistance {R} > Design effects {E}

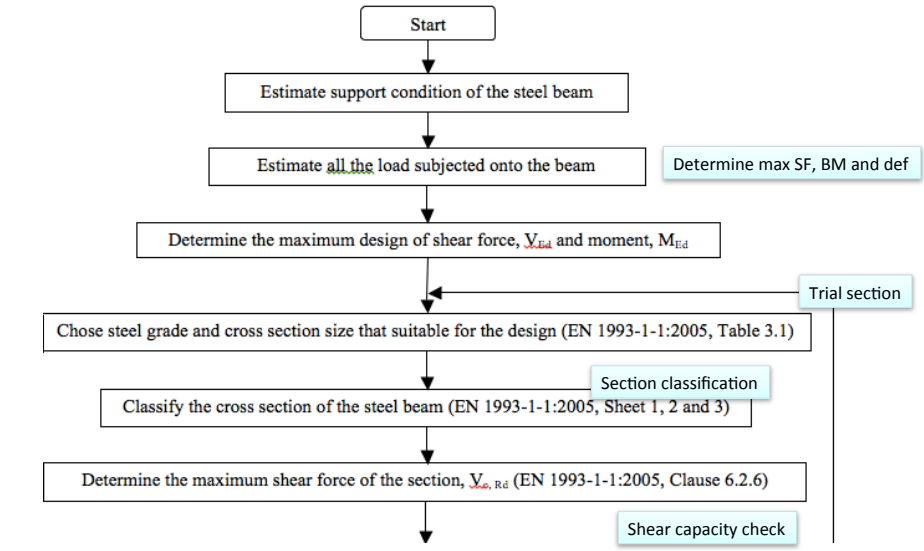


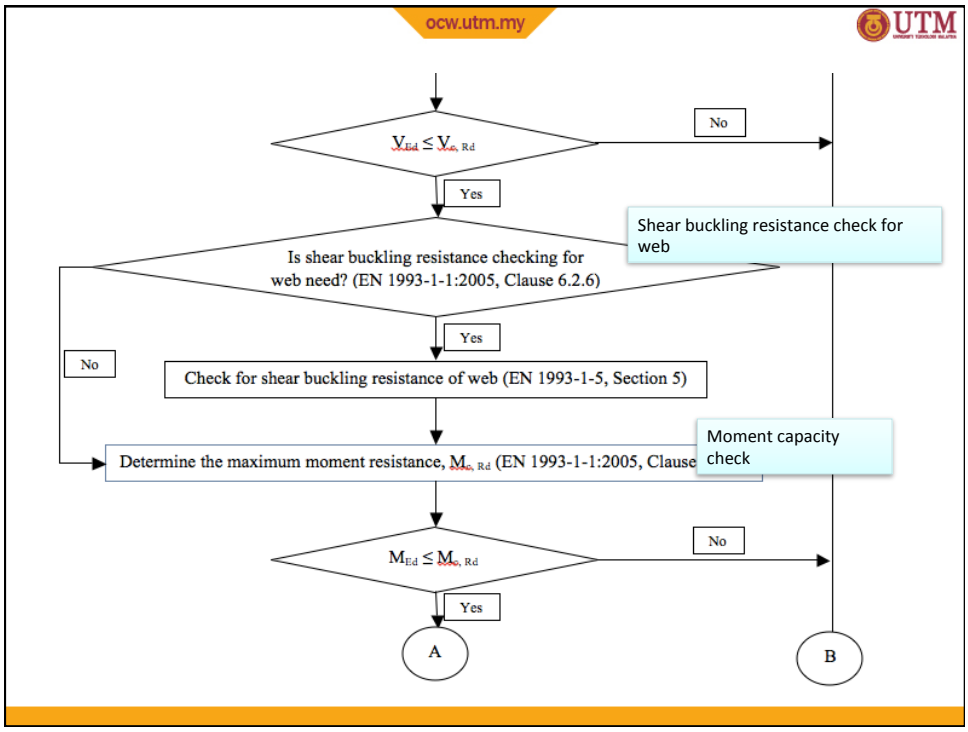
DESIGN PROCESS

DESIGN CHECK :

- Restrained beam
  - Flow chart
  - Classification of cross section (cl.5.5)
  - Shear cl.6.2.6
  - Shear buckling resistance check for web
  - Bending moment cl.6.2.5
  - Combined bending and shear resistance checking
  - Deflection Check
  - Example (Page ??)

Design Procedure :

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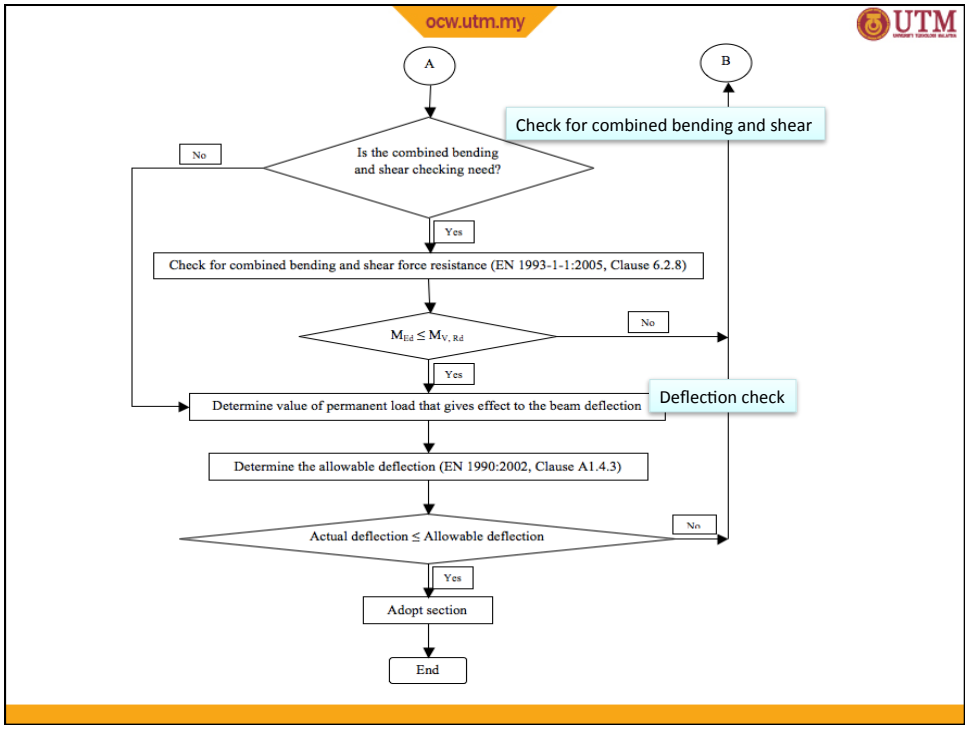
UTM
$V_{Ed} \leq V_{c, Rd}$
No
Yes
Shear buckling resistance check for web
Is shear buckling resistance checking for web need? (EN 1993-1-1:2005, Clause 6.2.6)
Yes
No
Check for shear buckling resistance of web (EN 1993-1-5, Section 5)
Moment capacity check
Determine the maximum moment resistance, $M_{c, Rd}$ (EN 1993-1-1:2005, Clause
$M_{Ed} \leq M_{c, Rd}$
No
Yes
A
B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UTM
A
B
Check for combined bending and shear
Is the combined bending and shear checking need?
No
Yes
Check for combined bending and shear force resistance (EN 1993-1-1:2005, Clause 6.2.8)
$M_{Ed} \leq M_{V, Rd}$
No
Yes
Deflection check
Determine value of permanent load that gives effect to the beam deflection
Determine the allowable deflection (EN 1990:2002, Clause A1.4.3)
Actual deflection ≤ Allowable deflection
No
Yes
Adopt section
End

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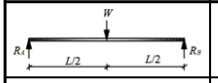
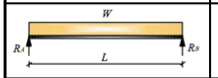
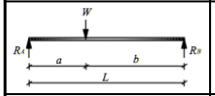
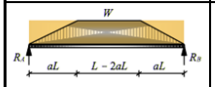
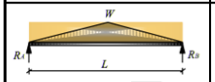
Determination of Maximum Beam Moment and Shear

Support reactions, maximum moment and deflection

Loading arrangement	Support reactions	Maximum bending moment	Maximum deflection
	$R_A = R_B = \frac{W}{2}$	$\frac{WL}{4}$	$\frac{WL^3}{48EI}$
	$R_A = R_B = \frac{W}{2}$	$\frac{WL}{8}$	$\frac{5WL^3}{384EI}$
	$R_A = \frac{Wb}{L}$ $R_B = \frac{Wa}{L}$	$\frac{Wab}{L}$	$\frac{Wab(L+b)}{27EIL}\sqrt{3a(L+b)}$ when $a > b$
	$R_A = R_B = \frac{W}{2}$	$WL\left[\frac{3-4a^2}{24(1-a)}\right]$	$\frac{WL^3}{1920EI}\frac{(4a^2-5)^2}{1-a}$
	$R_A = R_B = \frac{W}{2}$	$\frac{WL}{6}$	$\frac{WL^3}{60EI}$

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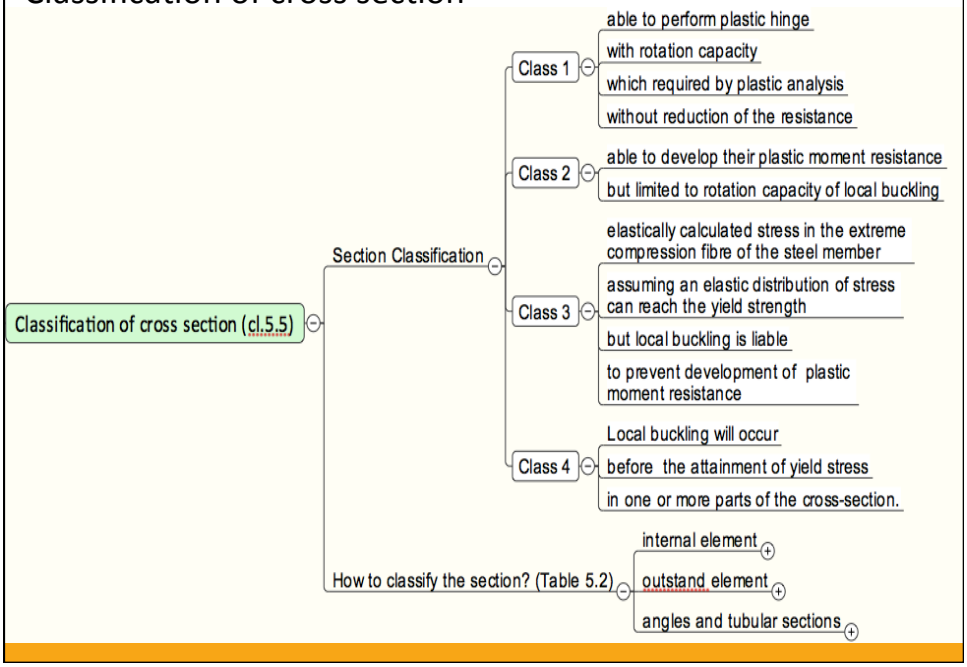
Classification of cross section



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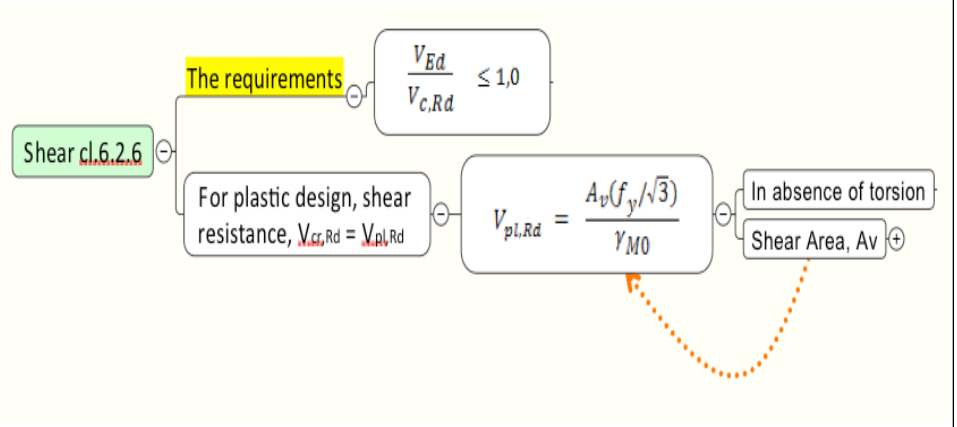
Shear check (cl.6.2.6)



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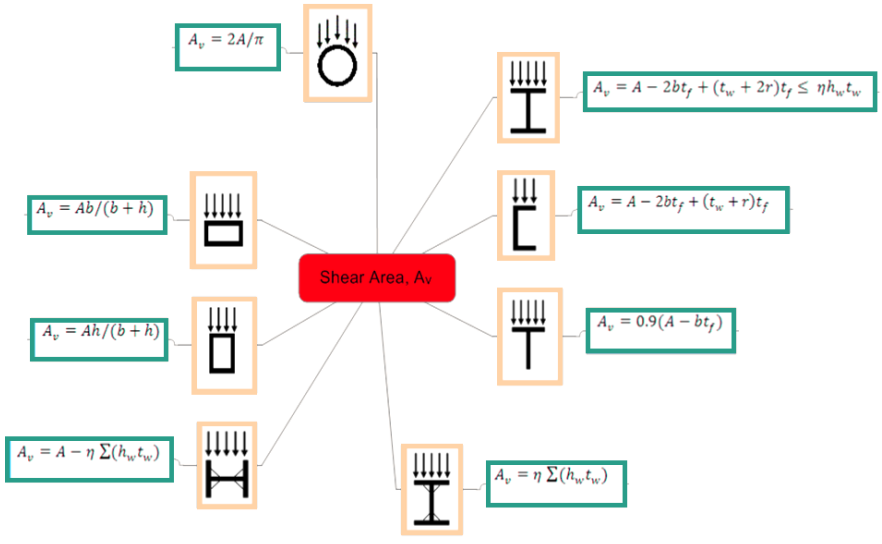
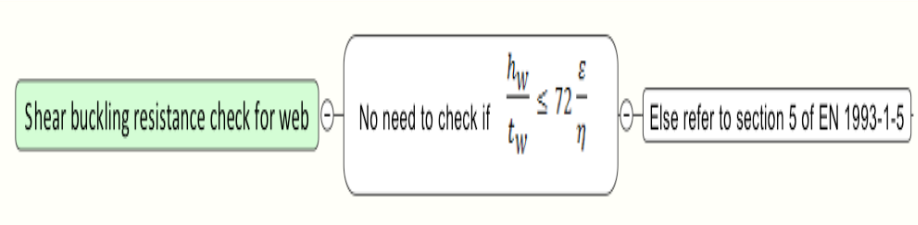
Shear check (contd)



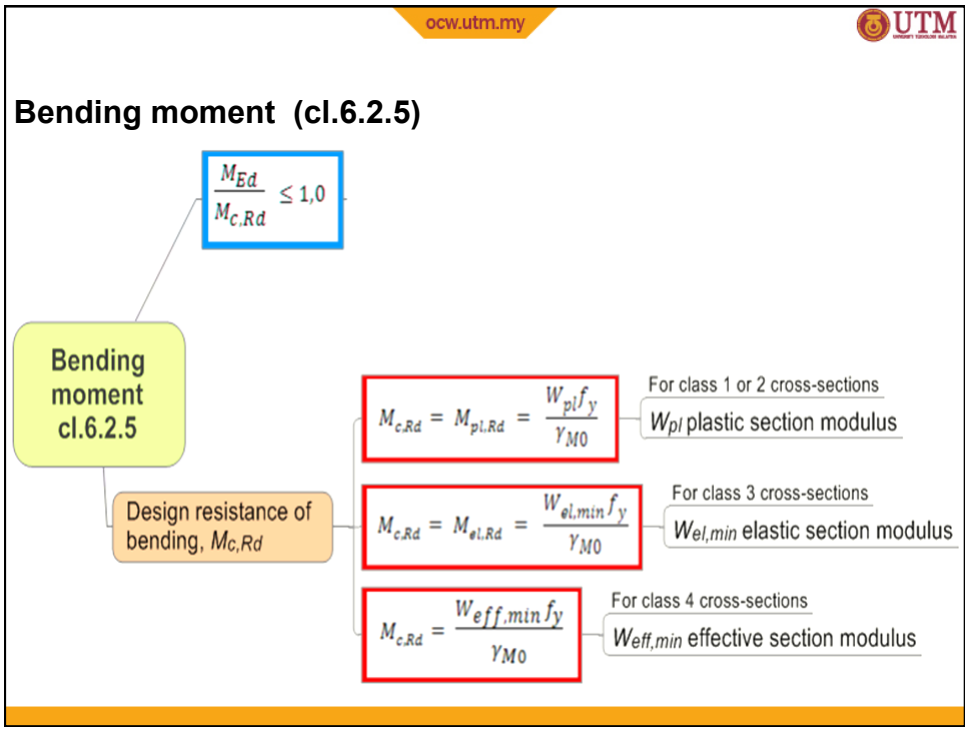
Shear buckling resistance check for web



Bending moment (cl.6.2.5)

- In a simple single span, failure occurs when design value of thebending moment M_{Ed} exceeds design moment resistance of the cross section $M_{c.Rd}$.
- Magnitude depends on section shape, material strength and section classification.
- Where shear force on cross-section is small its effect on the resistance moment may be neglected.

EC3 sets this limit as a shear force of 50% of the plastic shear resistance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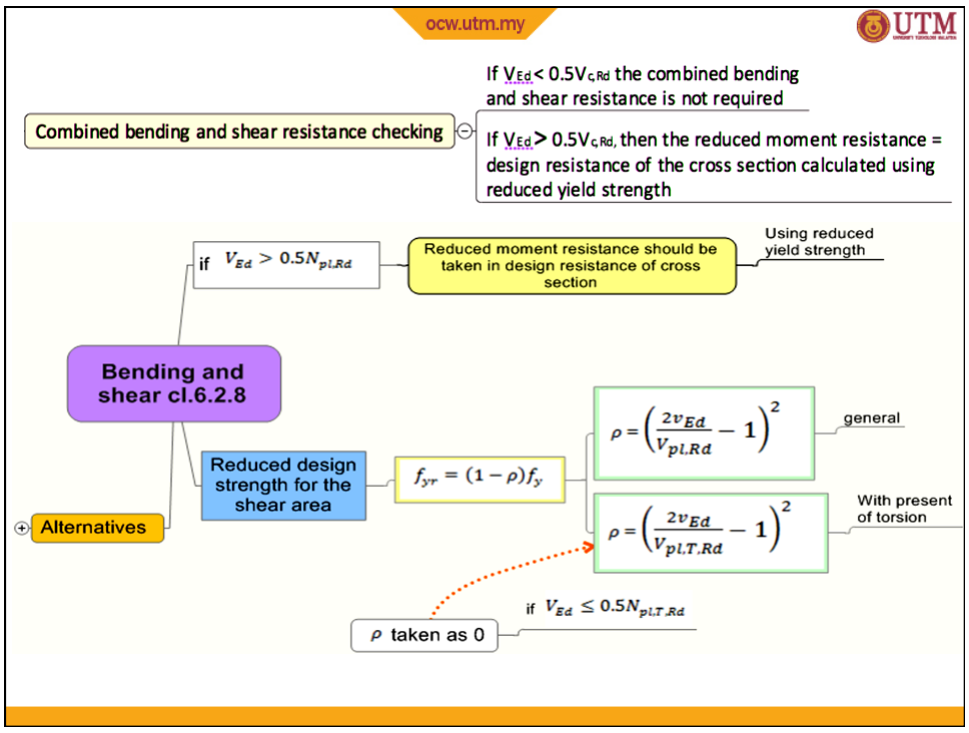
UTM
Bending moment (cl.6.2.5)
$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$
Bending moment cl.6.2.5
Design resistance of bending, $M_{c,Rd}$
$M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$
For class 1 or 2 cross-sections
W_{pl} plastic section modulus
$M_{c,Rd} = M_{el,Rd} = \frac{W_{el,min} f_y}{\gamma_{M0}}$
For class 3 cross-sections
$W_{el,min}$ elastic section modulus
$M_{c,Rd} = \frac{W_{eff,min} f_y}{\gamma_{M0}}$
For class 4 cross-sections
$W_{eff,min}$ effective section modulus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UTM
Combined bending and shear resistance checking
If $V_{Ed} < 0.5V_{c,Rd}$ the combined bending and shear resistance is not required
If $V_{Ed} > 0.5V_{c,Rd}$, then the reduced moment resistance = design resistance of the cross section calculated using reduced yield strength
Bending and shear cl.6.2.8
if $V_{Ed} > 0.5N_{pl,Rd}$
Reduced moment resistance should be taken in design resistance of cross section
Using reduced yield strength
Reduced design strength for the shear area
$f_{yr} = (1 - \rho) f_y$
$\rho = \left(\frac{2v_{Ed}}{V_{pl,Rd}} - 1\right)^2$
general
$\rho = \left(\frac{2v_{Ed}}{V_{pl,T,Rd}} - 1\right)^2$
With present of torsion
Alternatives
ρ taken as 0
if $V_{Ed} \leq 0.5N_{pl,T,Rd}$

Combined Bending and Shear (cl.6.2.8) contd

- Alternative for I section (equal flanges) and bending about major axis, the reduced design plastic resistance moment allowing for the shear force is as follow:

Alternatives

$$M_{y,c,Rd} = \frac{\left[W_{pl,y} - \frac{\rho A_w^2}{4t_w}\right] f_y}{\gamma_{M0}}$$

But $M_{y,V,Rd} \leq M_{y,c,Rd}$

$A_w = h_w t_w$

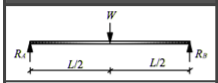
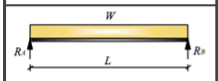
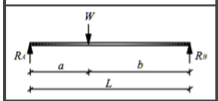
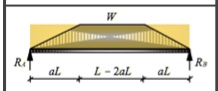
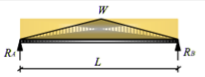
Deflection check

Deflection Check
- deflection limits
- deflection

The vertical deflection limits

Condition	Limits	
	d_{max}	d_2
Roofs generally	L/200	L/250
Roofs frequently carrying personnel	L/250	L/300
Floors generally	L/250	L/300
Floors and roofs supporting plaster	L/250	L/350
Floors supporting columns	L/400	L/500

Support reactions, maximum moment and deflection

Loading arrangement	Support reactions	Maximum bending moment	Maximum deflection
	$R_A = R_B = \frac{W}{2}$	$\frac{WL}{4}$	$\frac{WL^3}{48EI}$
	$R_A = R_B = \frac{W}{2}$	$\frac{WL}{8}$	$\frac{5WL^3}{384EI}$
	$R_A = \frac{Wb}{L}$ $R_B = \frac{Wa}{L}$	$\frac{Wab}{L}$	$\frac{Wab(L+b)}{27EIL}\sqrt{3a(L+b)}$ when $a > b$
	$R_A = R_B = \frac{W}{2}$	$WL\left[\frac{3-4a^2}{24(1-a)^1}\right]$	$\frac{WL^3}{1920EI}\frac{(4a^2-5)^2}{1-a}$
	$R_A = R_B = \frac{W}{2}$	$\frac{WL}{6}$	$\frac{WL^3}{60EI}$

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Example 1 – restrained beam design

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Thank You