B. Tech. Project Presentation:
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Development of Design Provisions of Eccentric Braced Frames

Presented by - Manjari

Guided by - Dr. Dugresh C. Rai

Objective

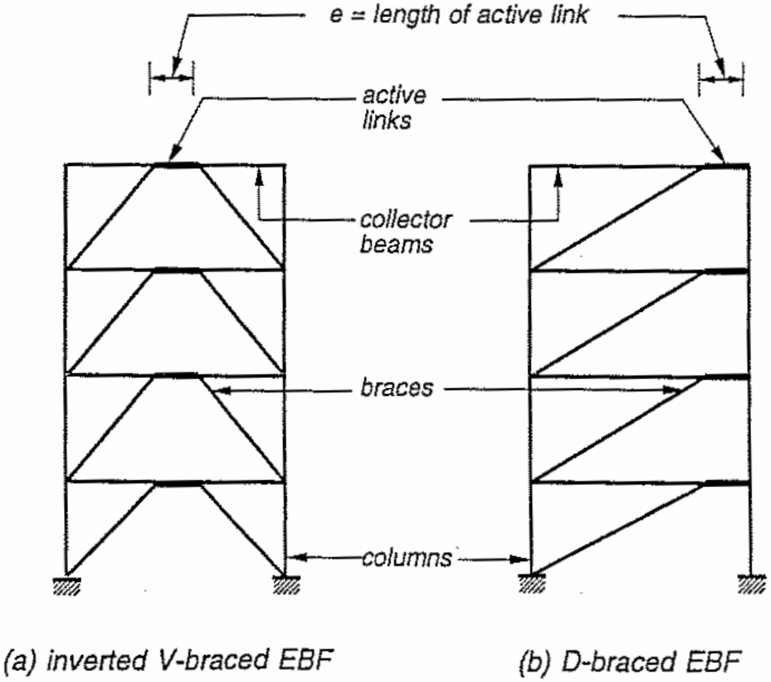
- To develop design provisions of eccentric braced frames as per Indian standards

Eccentric Braced Frames

- Braced frame in which at least one stable deformable link is formed in the beam.
- Incorporates both stiffness and ductility into a single bracing system
- Deliberate eccentricity is introduced

Structural Elements

- Link
- Collector Beam
- Brace
- Column
- Connections



Classification

- Eccentric Flexure Braced Frames
- Eccentric Shear Braced Frames

Design Philosophy

- The active link is primary seismic energy-dissipating element
- All other members are designed to resist the over strength design action generated by yielding of the active link plus design gravity loading.

Comparison of Codes

- Link:

Mode of failure of link	New Zealand Standard 3404	Uniform Building Code 1994	Seismic Provisions for Struc. Steel Building, AISC
Shear Yielding	e <=1.6 M_s/V_s	e<1.3 M_s/V_s (recommended upper limit) e< 1.6 M_s/V_s	e< 1.6 M_s/V_s
Balanced yielding	e= 2 M_s/V_s	e= 2 M_s/V_s	e= 2 M_s/V_s
Flexural Yielding	e > 3 M_s/V_s	e > 3 M_s/V_s	e > 3 M_s/V_s
Link Rotation Angle (radian)	0.09 for e < 1.6 M_s/V_s	0.06	0.08 for e < 1.6 M_s/V_s
	0.045 For e > 3 M_s/V_s		0.02 For e > 3 M_s/V_s

Link contd..

- The web of link should be single without doubler plate.
- Shear Section capacity is equal to nominal shear strength as per NZS 3404
- Shear section capacity is equal to 0.9 times nominal shear strength as per SPSSB.

Link contd..

- Link Rotation < 0.09

  for $e < 1.6\ M_s/V_s$

  < 0.045

  for $e > 3\ M_s/V_s$

  (NZS 3404)

- Link Rotation < 0.08

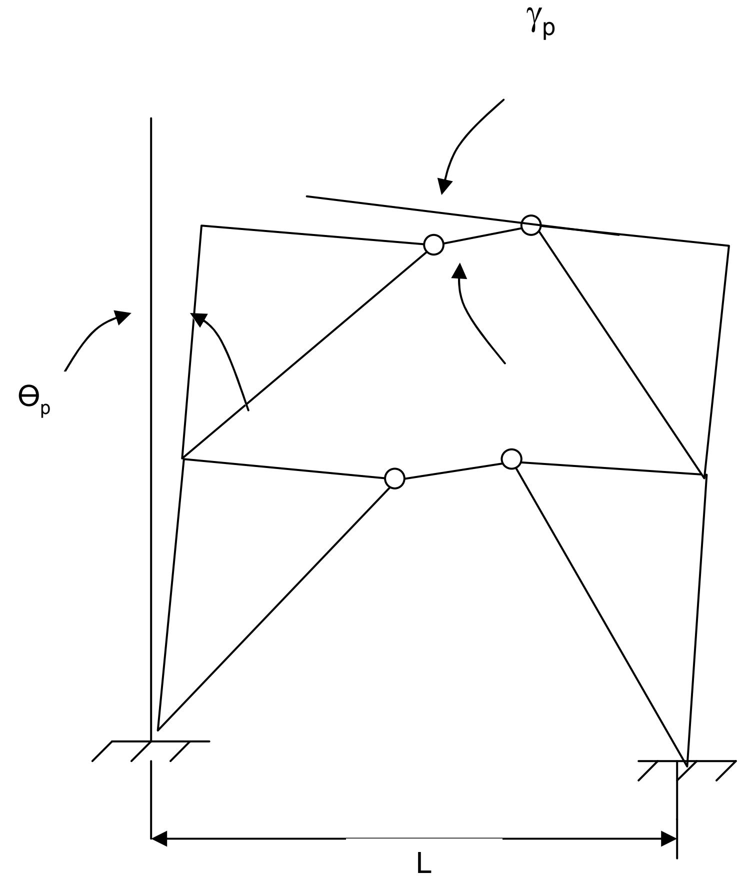
  for $e < 1.6\ M_s/V_s$

  < 0.02

  for $e > 3\ M_s/V_s$

  (SPSSB, 1997)

where $\gamma_p = (L/e) * \Theta_p$



Link Stiffener

- Full depth web stiffeners should be provided on both the sides of the link web at the diagonal brace ends of the Link.

Stiffener dimensions	New Zealand Standard 3404	Seismic Provisions for Struc. Steel Building, AISC
Thickness	$> 0.75\ t_w$	$>$Min $(0.75\ t_w$, 3/8 in)
Combined Thickness	$> b_f - 2\ t_{wb}$	$> b_f - 2\ t_{wb}$
Spacing	$< (38\ t_{wb} - d_b/5)$ for 0.09 radian $< (56\ t_{wb} - d_b/5)$ for 0.03 radian	$< (30\ t_{wb} - d_b/5)$for 0.08 radian $< (52\ t_{wb} - d_b/5)$ for 0.02 radian

Link to Column Connection

- When the link is adjacent to column, the welds should be designed for over strength shear capacity of member web as per NZS 3404.
- Rotation capability is enhanced by 20% of design Story Drift as per SPSSB, AISC (1997).

Lateral Support of Link

- Top and bottom flange of EBF active link members shall be laterally restrained at ends of active link.

- Design strength of end support should be 6% of the expected nominal strength of the link flange as per SPSSB.

- The design axial force shall be equal to 2.5 % of beam flange design capacity with a lateral displacement of 4mm as per NZS 3404.

- Study of codes suggests that guidelines have very slight variations at few places and are similar to a great extent.

Design Guidelines

Link:

- Compact section
- Specified minimum yield stress of steel used for Link shall not exceed 350 Mpa.
- Single thickness web

Design Guidelines Contd..

Nominal Section Capacities:

a) Required shear strength, Vu of the link shall not be greater than design shear strength of the link.

$Vn = Min\ (Vs,\ 2\ Mp/e)$

$Vs = fy\ Av/\sqrt{3}$

$Vd = Vn/\ mo$

Where

Vs = nominal shear strength of link

Vd = design shear strength of link

Design Guidelines Contd..

b) Nominal Moment capacity

If $n < 0.2$

$M_{ndy} = M_{dy}$

If $n > 0.2$

$M_{ndy} = 1.56\, M_{dy} (1-n)(n+0.6)$

Where

N = axial force applied on link

Nd = design axial force

Design Guidelines Contd..

- Length of link should not exceed-

  $[1.15 - 0.5\,\rho(A_w/A_g)]1.6\,M_s/V_s$ for $\rho(A_w/A_g) > 0.3$

  $1.6\,M_s/V_s$ for $\rho(A_w/A_g) > 0.3$

- Minimum length of the link shall not be less than the depth of the beam.

Design Guidelines Contd..

- Link Rotation Angle

  $\gamma_p < 0.09$ radians when $e < 1.6\ M_s/V_s$

  $\gamma_p < 0.045$ radians when $e > 3\ M_s/V_s$

- Interpolation shall be followed for γ_p when link length lies between $1.6\ M_s/V_s$ to M_s/V_s
- If link is connected to column flange and $e < 1.6\ M_s/V_s$, $\gamma_p < 0.09$ radians
- if link is connected to column web and $e < 1.6\ Ms/Vs$, $\gamma_p < 0.045$ radians

Design Guidelines Contd..

End Stiffeners

- Full depth end stiffeners shall be provided both sides on diagonal brace ends of link web.
- The combined width > $(b_f - 2t_w)$
- thickness > $0.75\ t_w$.

Design Guidelines Contd..

Intermediate Stiffeners:

a) $e < 1.6\ M_s/V_s$

- Spacing of intermediate stiffeners should not exceed $(30t_w - d/5)$ for link rotation angle of 0.09 radians and $(56t_w - d/5)$ for link rotation angle 0.03 radians.

- The combined width of these stiffeners shall not be less than $(bf\text{-}\ 2t_w)$ and thickness shall not be less than $0.75\ t_w$.

Design Guidelines Contd..

b) e> 2.6 Ms/Vs

In this case, Intermediate stiffeners shall be provided at a distance of 1.5 b_f from each end of link.

c)1.6 Ms/Vs < e < 2.6 Ms/Vs

Stiffeners provided shall meet the requirements of both a) and b).

d) e > 5 Ms/Vs

Intermediate stiffeners are not required in this case.

Design Guidelines Contd..

- Intermediate stiffeners shall be of full depth.
- If depth of link < 650 inches,

  stiffeners are required only on one side of web.

  if depth of link > 650 mm

  stiffeners shall be provided on both sides of link web.
- Thickness of one sided stiffeners > t_w
- width > { (bf/2) – $t_{w.}$ }

Design Guidelines Contd..

- Design strength of fillet weld which connects the link stiffener to web of link shall be able to withstand a force of $f_y\ A_{st}$.
- fillet weld which connects link stiffener to flanges of link shall be able to resist a force of fy $f_y\ A_{st}$ /4.

Design Guidelines

Link to Column Connection:

- Link to column connection should be designed for 20% greater than required inelastic rotation capability.

Design Guidelines

Lateral Support

- Top and bottom flange of EBF active link members shall be laterally restrained at ends of active link.
- Design strength of end support should be 6% of the expected nominal strength of the link flange.
- The design axial force shall be equal to 2.5 % of beam flange design capacity with a lateral displacement of 4mm.

Design Guidelines

Diagonal Brace and Beam Outside the Link

- Design axial and flexural strength should be 25 % more than the axial forces and moments generated by nominal shear strength of link to account for strain hardening.
- Beam outside the link shall be designed to withstand the forces generated by at least 1.1 times the nominal shear strength of link.

Design Guidelines

Column

- Design of the column shall take demand generated by coincident formation of yielding regions in link at appropriate number of levels.

- Design strength of column shall not be less than that required by 1.1 times of nominal strength of link to account for strain hardening.

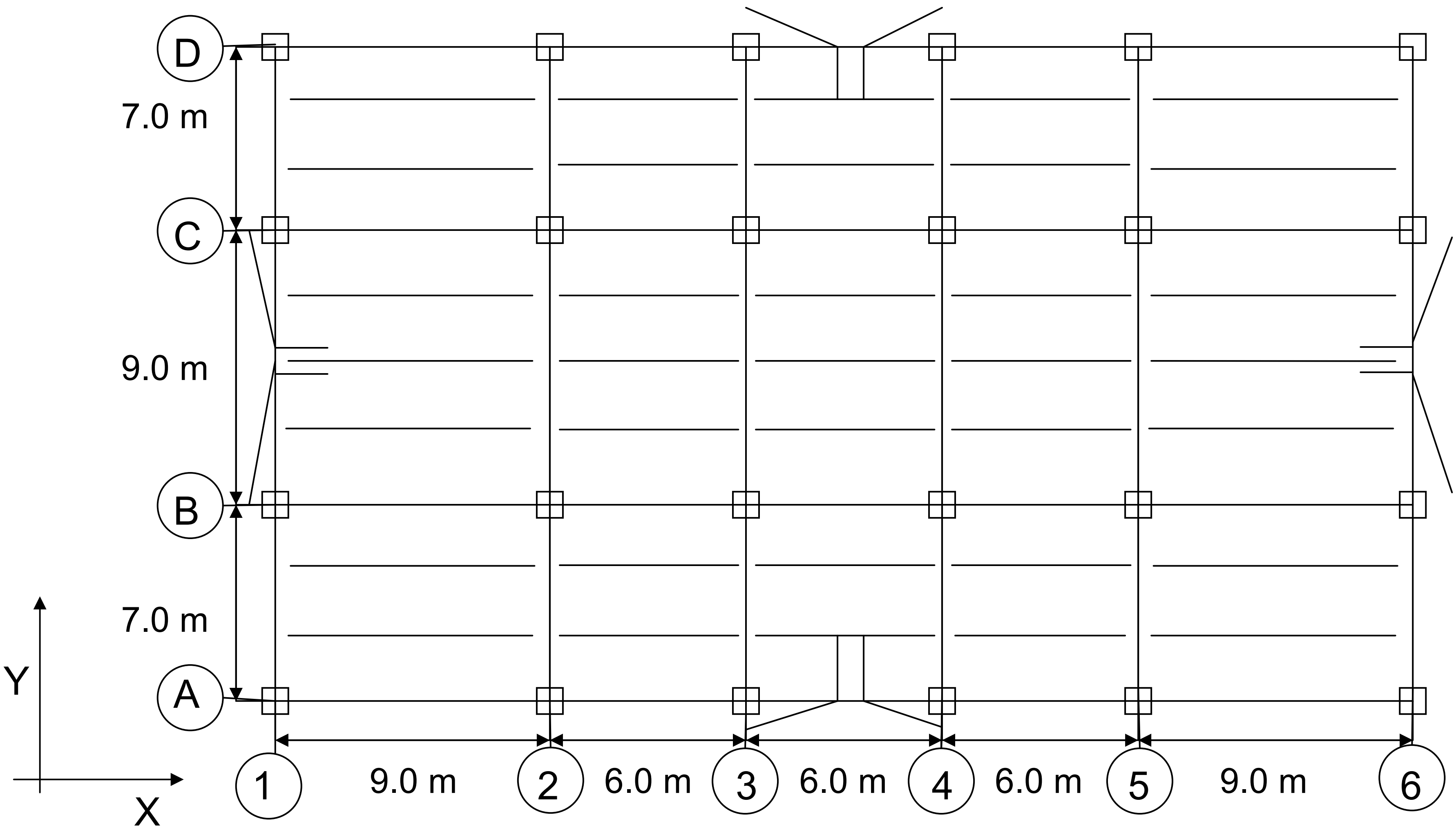
Design Example

Problem statement

Plan Dimension of a four storey building is given. The height of first storey of building is 4.3 m and rest of storeys are 3.5 m each. Building is located in seismic zone III on a site with medium soil. Design the building for seismic loads.

Design Example

Plan of Building



Design Example

Loads:		
Roof Loading:		
Roofing and insulation	0.3	kN/m^2
Metal deck	0.1	kN/m^2
Concrete fill	2.1	kN/m^2
Ceingling and mechanical	0.2	kN/m^2
Steel framing and fire proofing	0.4	kN/m^2
Total Dead Load	3.2	kN/m^2
Live Load	1.0	kN/m^2
Toal Load	4.2	kN/m^2

Design Example

Floor Loading:		
Metal deck	0.1	kN/m^2
Concrete fill	2.1	kN/m^2
Ceingling and mechanical	0.2	kN/m^2
Partition Load	1.0	kN/m^2
Steel framing inc.beams and columns	0.6	kN/m^2
Total Dead Load	4.0	kN/m^2
Liave Load	2.4	kN/m^2
Total Load	6.4	kN/m^2
Wall:		
Avergae weight	0.7	kN/m^2

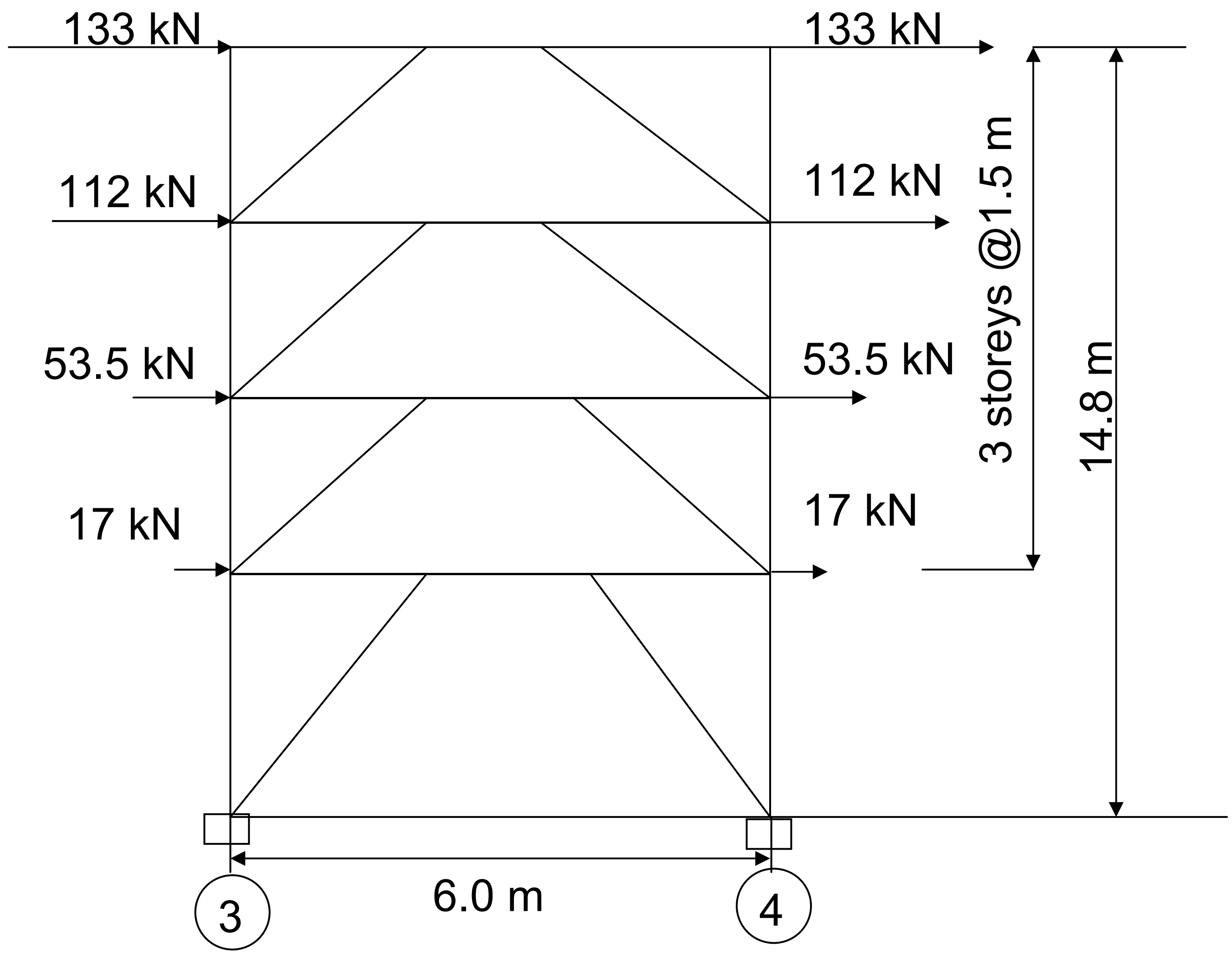
Design Steps

- Calculation of Seismic weight of building
  Total weight of building = 16335 kN

- Calculation of lateral load
  Lateral Load = 1225 kN

- Vertical and horizontal distribution of load

Design Steps



Design Steps

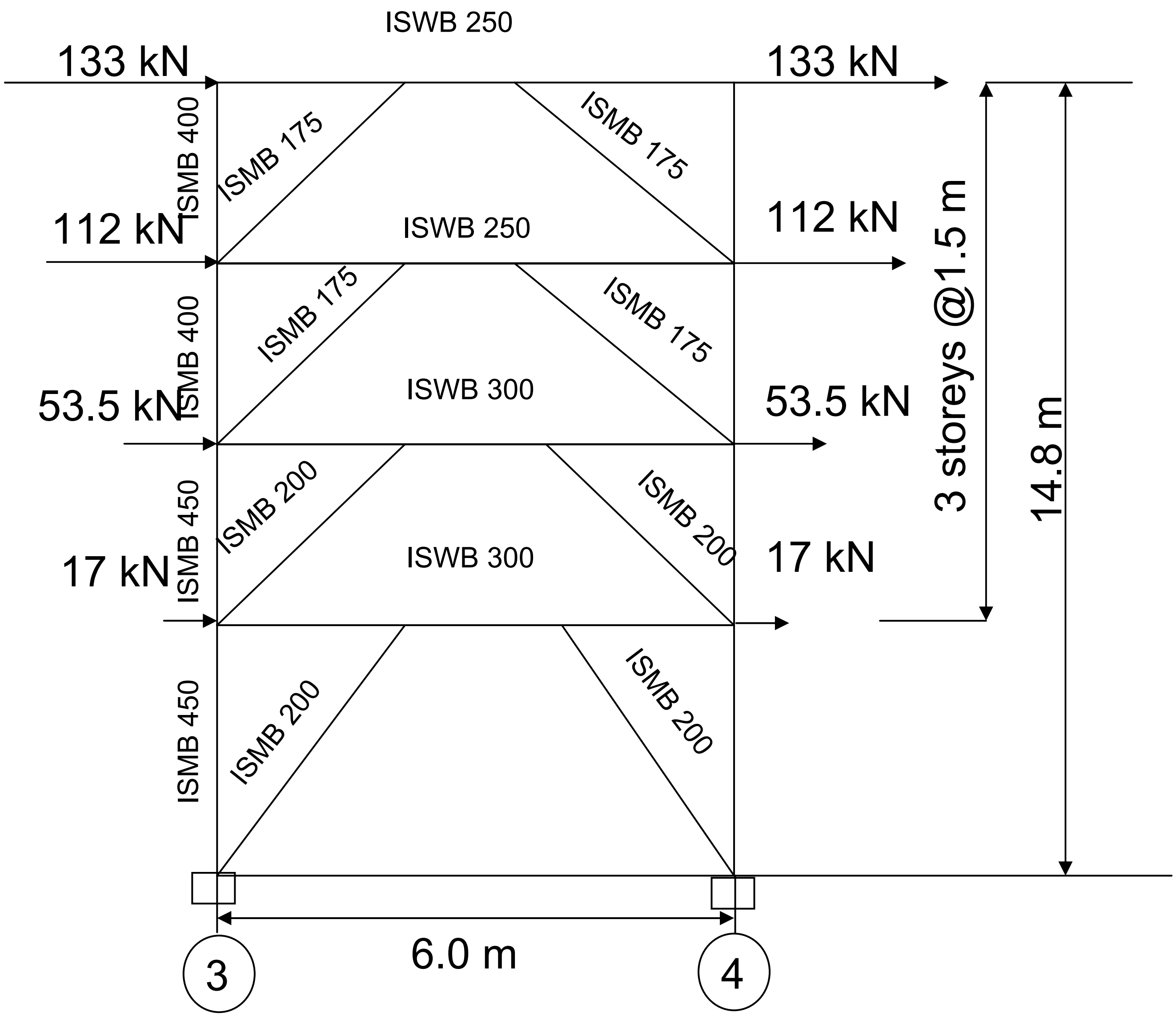
- Calculation of beam gravity load

- Calculation of column gravity load

Design Steps

- Determination of shear force in the link
  $V_u = F_x h/L$
- Link design as per required shear capacity
- Collector beam design check
- Design of Braces
- Design of Column

Design



ISWB 250
133 kN
133 kN
ISMB 400
ISMB 175
ISMB 175
112 kN
ISWB 250
112 kN
ISMB 400
ISMB 175
ISMB 175
53.5 kN
ISWB 300
53.5 kN
ISMB 450
ISMB 200
ISMB 200
17 kN
ISWB 300
17 kN
ISMB 450
ISMB 200
ISMB 200
3 storeys @1.5 m
14.8 m
6.0 m
3
4

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THANK YOU!