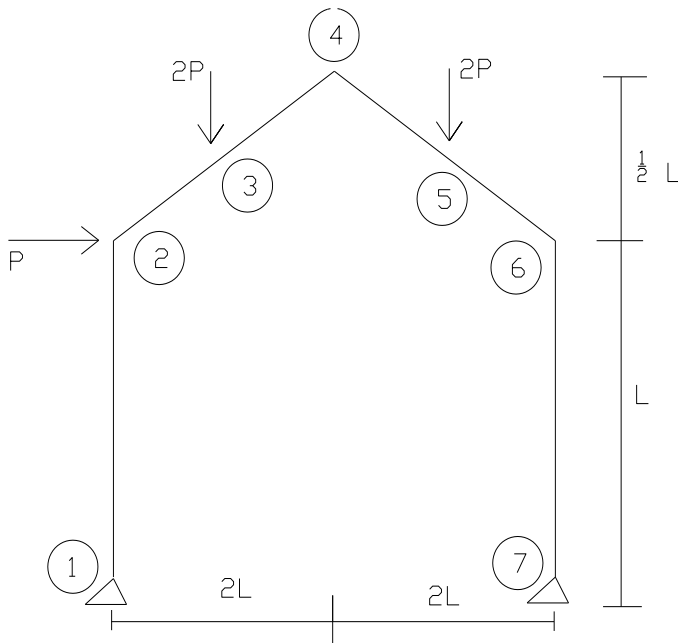


## METODE KERJA VIRTUIL (*Virtual Work Method*)

### GABLE FRAME (Rangka atap dengan balok miring)

Penyelesaiannya dengan cara “pusat rotasi” (Instantaneous center). Dimana dicari hubungan rotasi defleksi dari geometri gerakan mekanismenya.

Contoh :



$$\begin{aligned} N &= 5 \\ R &= 2 \\ n &= 5 - 2 = 3 \end{aligned}$$

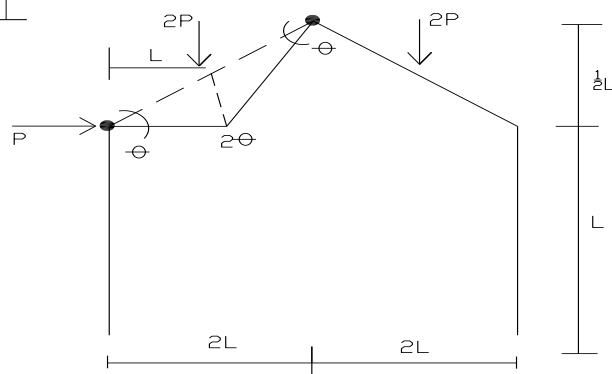
Ada 3 mekanisme bebas → balok, panel, gable, ditambah mekanisme gabungan

- Balok + panel
- Balok + gable
- Panel + gable

#### a) Mekanisme Balok

$$2P \cdot L\theta = Mp(\theta + 2\theta + \theta)$$

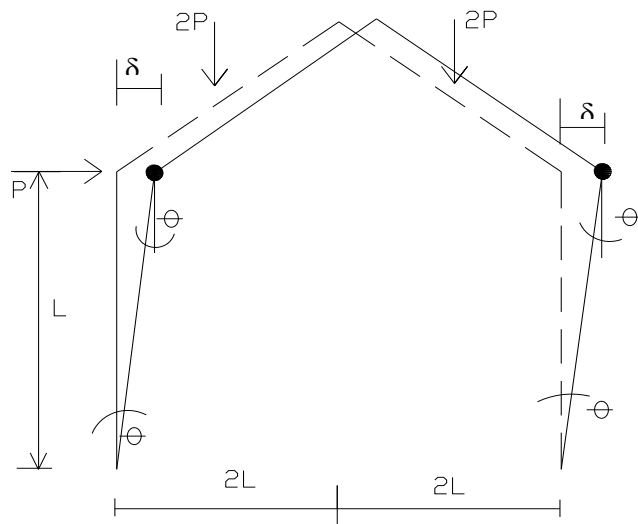
$$Pu = \frac{4}{2} \cdot \frac{Mp}{L}$$



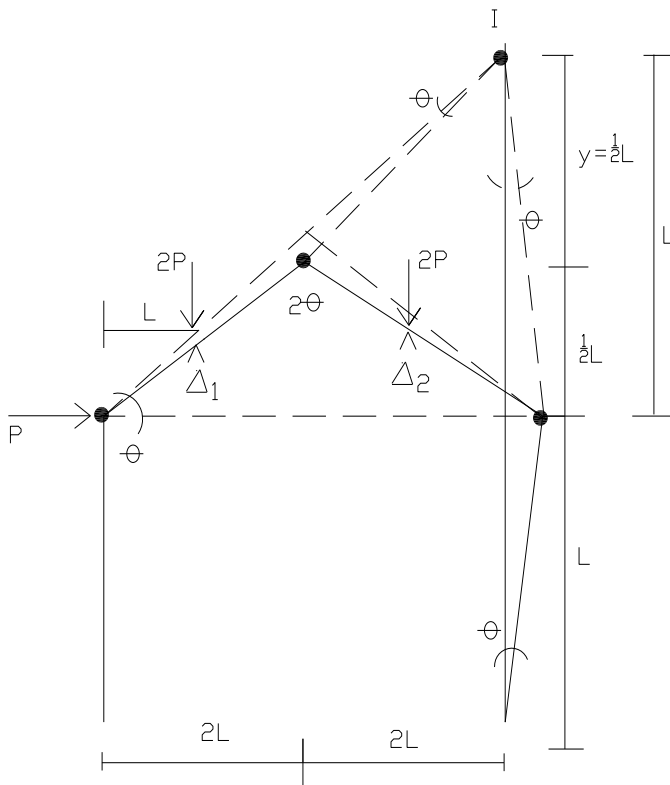
#### b) Mekanisme Panel/Pergoyangan

$$P \cdot L\theta = Mp(\theta + \theta)$$

$$Pu = \frac{2Mp}{L}$$



c) Mekanisme Gable



$$\frac{y}{2L} = \frac{y + \frac{L}{2}}{4L}$$

$$4Ly = 2Ly + L^2$$

$$2Ly = L^2$$

$$2y = L$$

$$y = \frac{1}{2}L$$

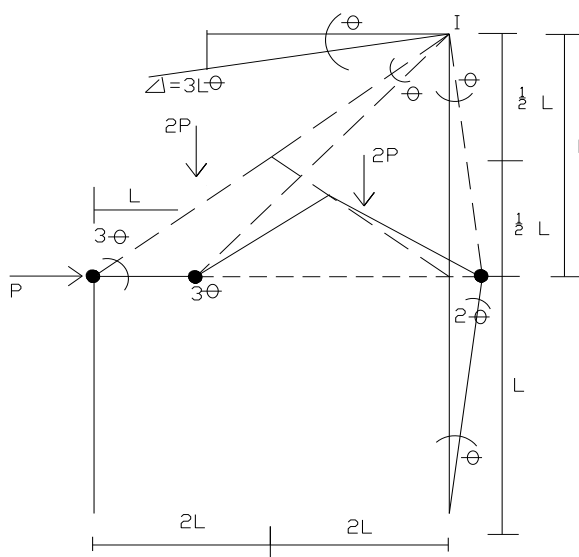
$$\Delta_1 = r \cdot L \cdot \theta$$

$$\Delta_2 = L \cdot \theta$$

$$2P \cdot L \cdot \theta \times 2 = Mp(\theta + 2\theta + \theta)$$

$$Pu = \frac{5}{4} \cdot \frac{Mp}{L}$$

d) Mekanisme Gabungan Balok dan Panel



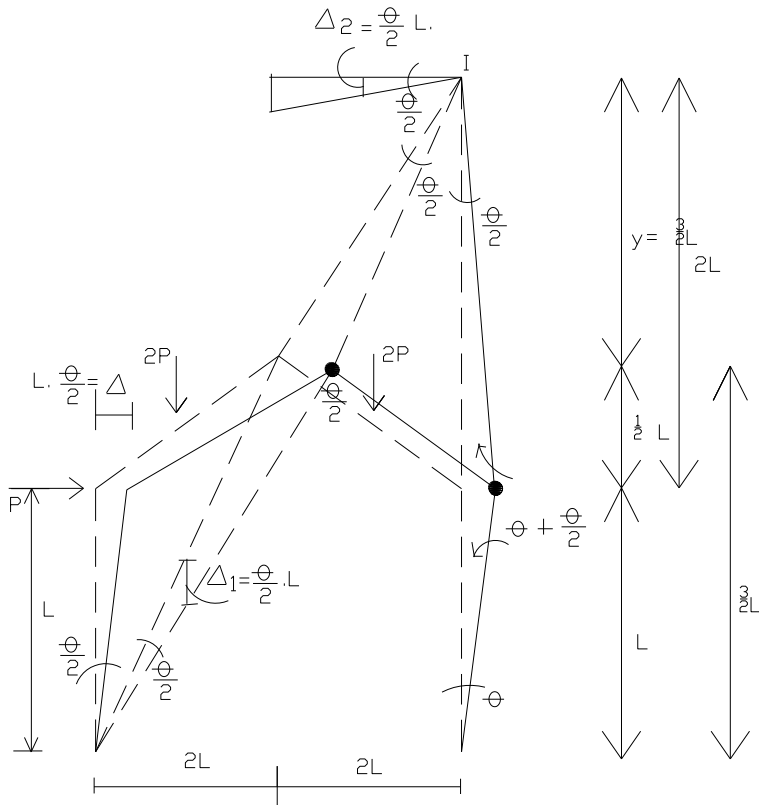
$$2P \cdot 3\theta L + 2P \cdot \theta L$$

$$= Mp \cdot 3\theta + Mp \cdot 3\theta + Mp \cdot 2\theta$$

$$8P \cdot \theta \cdot L = 8Mp \cdot \theta$$

$$Pu = \frac{Mp}{L}$$

e) Mekanisme Gabungan Panel dan Gable



$$\frac{y}{2L} = \frac{y + L + \frac{L}{2}}{4L}$$

$$4Ly = 2Ly + 3L^2$$

$$2Ly = 3L^2$$

$$y = \frac{3}{2}L$$

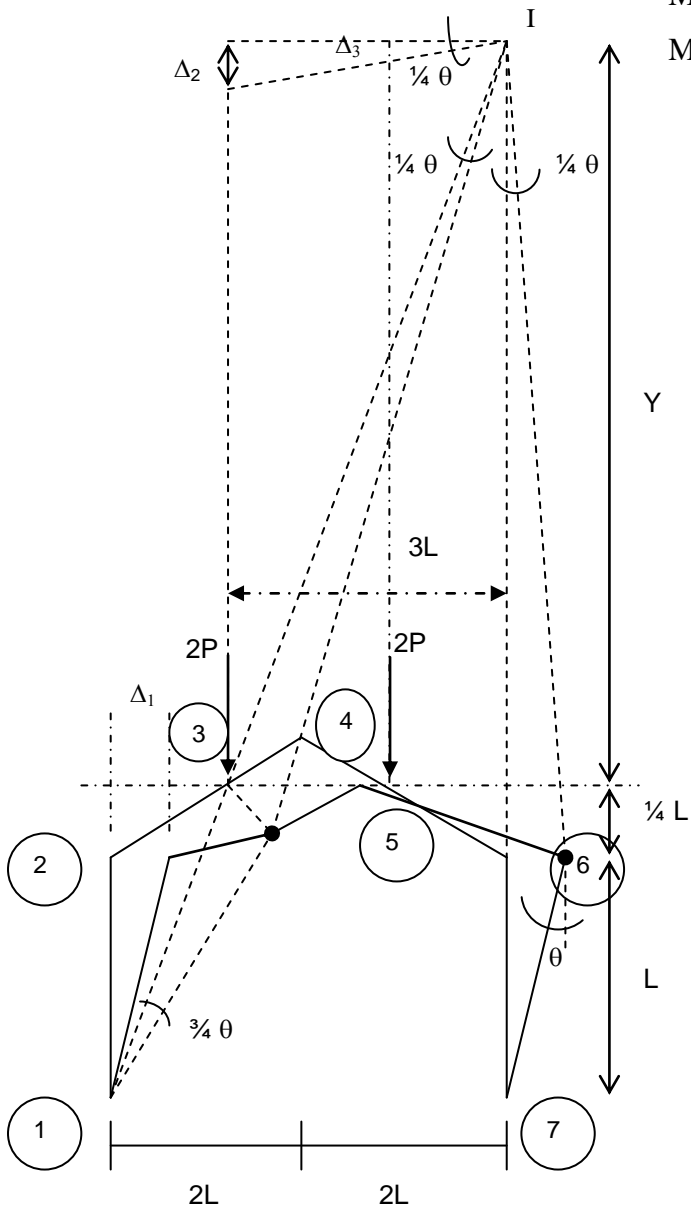
$$P \cdot L \frac{\theta}{2} + 2P \cdot \frac{\theta}{2} L + 2P \cdot \frac{\theta}{2} L$$

$$= Mp \cdot \frac{\theta}{2} 2 + Mp \left( \theta + \frac{\theta}{2} \right)$$

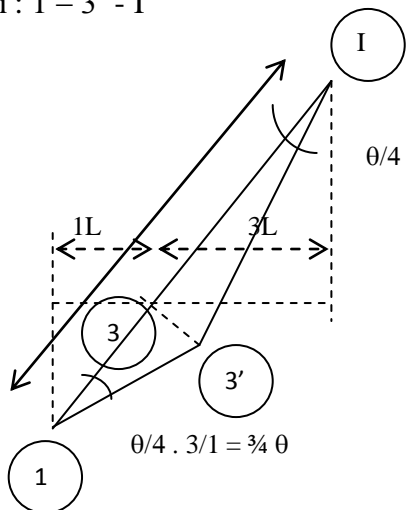
$$2 \frac{1}{2} P \cdot L \cdot \theta = 2 \frac{1}{2} Mp \cdot \theta$$

$$Pu = \frac{Mp}{L}$$

f) Mekanisme Panel dan Balok 2-4



Dari : 1 - 3' - I



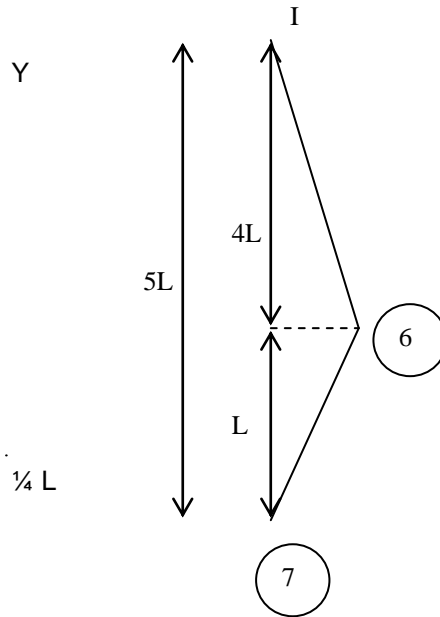
Mencari kedudukan I dari

Mekanisme Panel dan Balok 2-4

Mencari kedudukan I dari geometri :

$$\frac{3L}{4L} = \frac{Y}{Y + \frac{5}{4}L} \rightarrow Y = \frac{15}{4}L$$

Dari : 7 - I - 6



Jumlah Rotasi θ di (6)

$$\theta + 1/4 \theta = 5/4 \theta$$

Jumlah Rotasi  $\theta$  di 3' :  $\frac{3}{4}\theta + \frac{\theta}{4} = \theta$

Displacement :

$$\Delta_1 = L \cdot \frac{3}{4}\theta = \frac{3}{4}L\theta$$

$$\Delta_2 = 3L \cdot \frac{\theta}{4} = \frac{3}{4}L\theta$$

$$\Delta_3 = L \cdot \frac{\theta}{4} = \frac{1}{4}L\theta$$

$$\frac{\Delta_2}{1 - 3 \cdot \frac{\theta}{4}} = \frac{3L}{1 - 3}$$

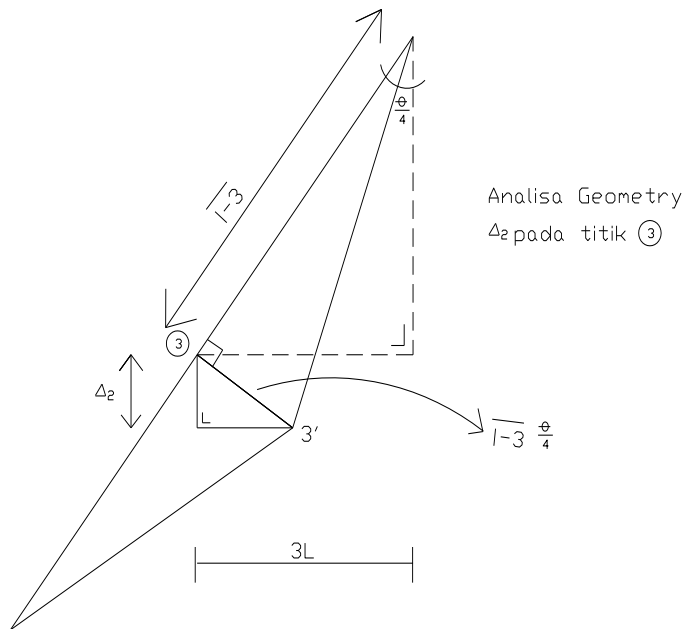
$$\Delta_2 = 3L \cdot \frac{\theta}{4} = \frac{3}{4}L \cdot \theta$$

Ultimate Load

$$P(\Delta_1) + 2P(\Delta_2) + 2P(\Delta_3) = Mp \cdot \frac{5}{4}\theta + Mp \cdot \theta$$

$$P \cdot \frac{3}{4}L\theta + 2P \cdot \frac{3}{4}L\theta + 2P \cdot \frac{1}{4}L\theta = \frac{9}{4}Mp$$

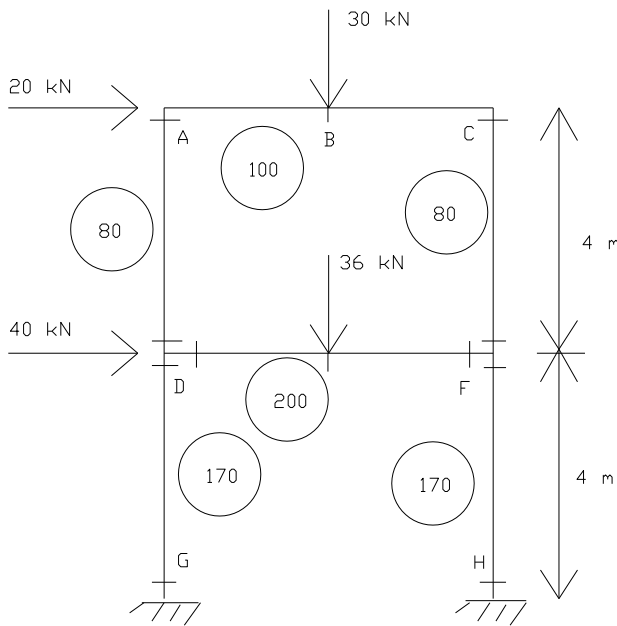
$$Pu = \frac{9}{11}Mp \quad \text{Terkecil}$$



**Contoh : Portal Bertingkat**

Tentukan "Collapse Load" dalam  $\lambda$

momen plastis dalam KN.m



$$N = 12$$

$$r = 6$$

$$m = N - r = 12 - 6 = 6$$

Mekanisme-mekanisme bebas

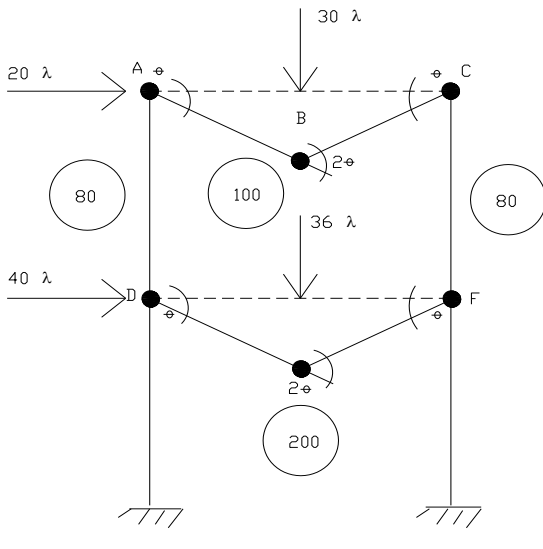
2 joint rotations (D & F)

2 member mekanisme (1 & 2)

2 frame mechanism (3 & 4)

**- Mekanisme Balok**

Karena :  $M_p \text{ kolom} < M_p \text{ balok} \rightarrow$  maka sendi di kolom



Mech.1 (balok AC)

$$30\lambda \cdot 4\phi = 80(\phi) + 100(2\phi) + 80(\phi)$$

$$120\lambda \cdot \phi = 360\phi$$

$$\lambda = 3,0$$

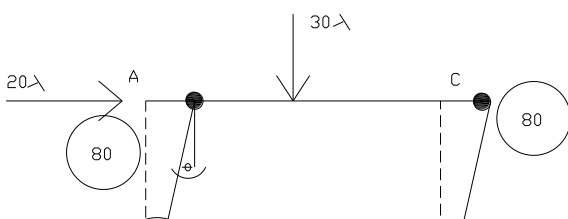
Mech.2 (balok DF)

$$36\lambda \cdot 4\phi = 200(\phi + 2\phi + \phi)$$

$$144\lambda \cdot \phi = 800\phi$$

$$\lambda = 5,556$$

**- Mekanisme Portal**

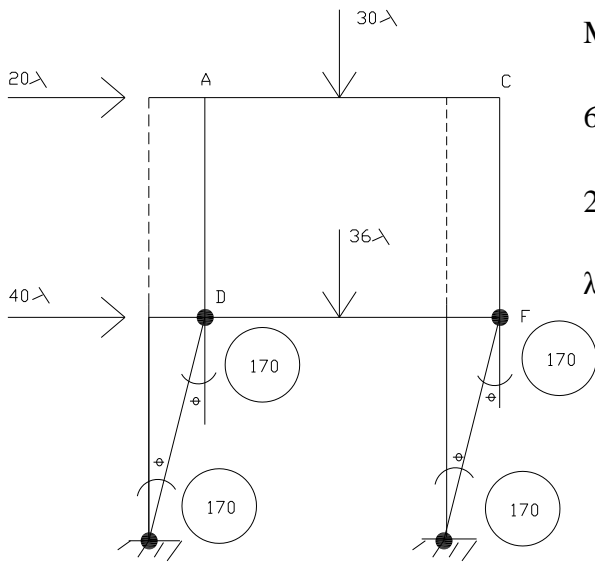


Mech.3

$$20\lambda \cdot 4\phi = 80(\phi + \phi + \phi + \phi)$$

$$80\lambda \cdot \phi = 320\phi$$

$$\lambda = 4,000$$

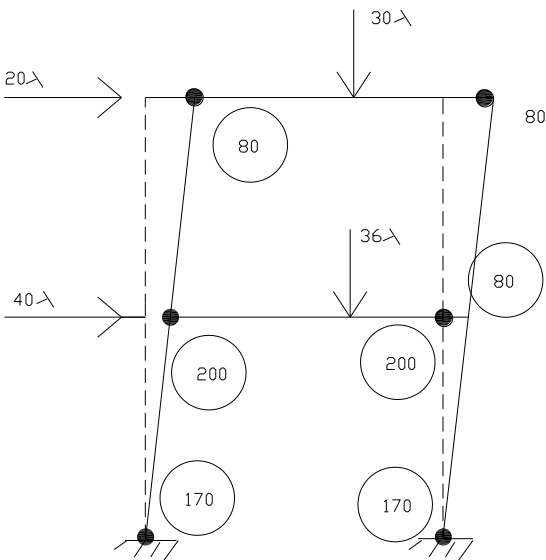


Mech.4

$$60\lambda \cdot 4\phi = 170(\phi + \phi + \phi + \phi)$$

$$240\lambda \cdot \phi = 680\phi$$

$$\lambda = 2,833$$

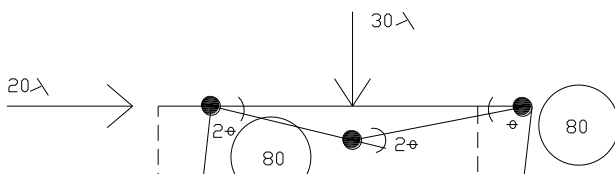


Mech.5 (mech. 3 + mech. 4)

$$80\lambda \cdot \phi + 240\lambda \cdot \phi = 320\phi + 680\phi - 80(\phi + \phi) - 170(\phi + \phi) + 200(\phi + \phi)$$

$$320\lambda \cdot \phi = 900\phi$$

$$\lambda = 2,812$$



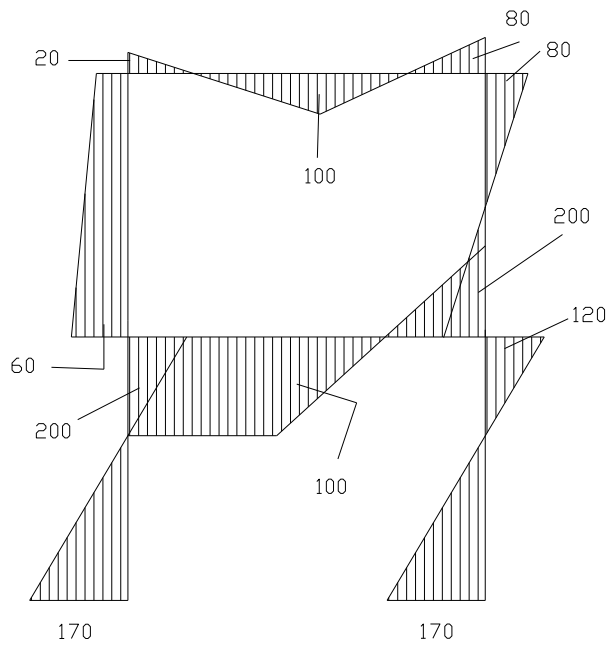
Mech.6 (mech.(5)+(1))

$$320\lambda \cdot \emptyset + 120\lambda \cdot \emptyset = 900\emptyset + 360\emptyset - 80(2\emptyset)$$

$$440\lambda \cdot \emptyset = 1100\emptyset$$

$$\lambda = 2,500$$

**Terkecil**

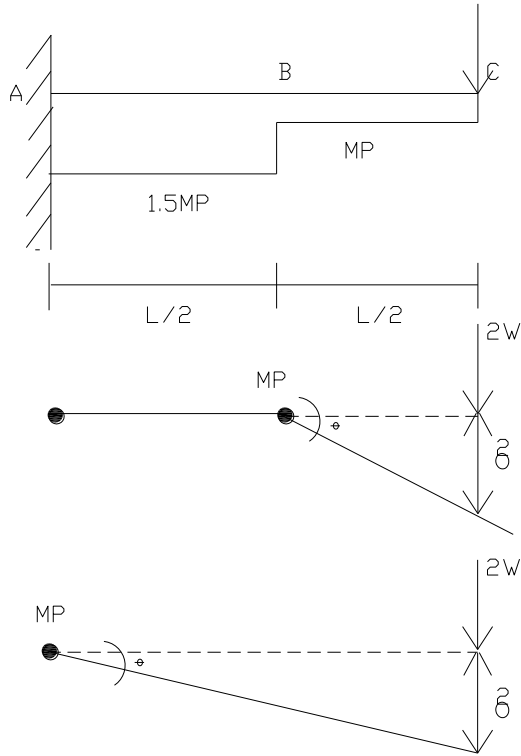


Bidang Momen



**Contoh : Non Uniform Cross-Section**

1)



Case I

$$UL = 2W \cdot \frac{L}{2} \cdot \theta$$

$$UD = Mp \cdot \theta$$

$$UL = UD \rightarrow Wc = \frac{Mp}{L}$$

Case II

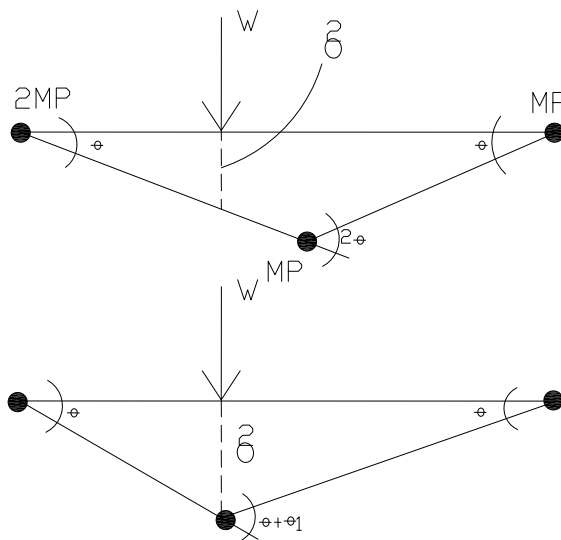
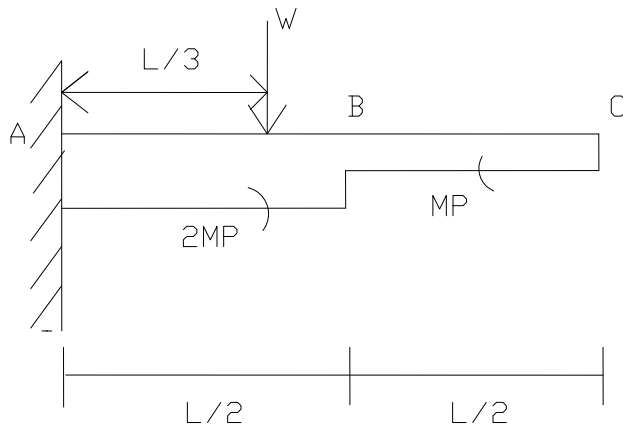
$$UL = 2W \cdot L \cdot \theta$$

$$UD = 1,5Mp \cdot \theta$$

$$UL = UD \rightarrow Wc = 0,75 \frac{Mp}{L} \text{ (terkecil)}$$

Jadi  $Wc$  balok ABC  $\rightarrow 0,75 \text{ Mp/L}$

2)



Case I

$$UL = W \cdot \frac{L}{3} \cdot \theta$$

$$UD = 2Mp \cdot \theta + Mp(\theta + \theta) + Mp \cdot \theta = 5Mp \cdot \theta$$

$$UL = UD \rightarrow Wc = 15 \frac{Mp}{L}$$

$$\delta = \frac{L}{3} \theta = \frac{2}{3} L \theta_1 \rightarrow \theta_1 = \frac{1}{2} \theta$$

Case II

$$UL = W \cdot \frac{L}{3} \cdot \theta$$

$$UD = 2Mp \cdot \theta + 2Mp(\theta + \theta_1) + Mp \cdot \theta_1 = 2Mp \cdot \theta + 2Mp \cdot 1\frac{1}{2} \theta + \frac{1}{2} Mp \cdot \theta$$

$$= 5\frac{1}{2} Mp \cdot \theta$$

$$UL = UD \rightarrow Wc = 16\frac{1}{2} \frac{Mp}{L}$$