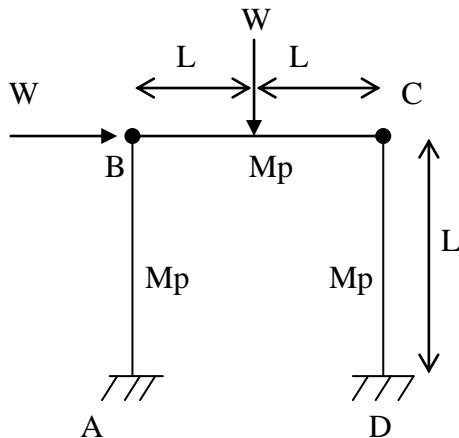


## METODE KERJA VIRTUIL (*Virtual Work Method*)

### Pada Portal

Contoh : Portal



Jumlah mekanisme

Bebas :  $N = N - r$      $n = 4 - 2 = 2$

$N = 4$  (jumlah yang mungkin sendi plastis)

Jumlah reaksi = 5     $r = 2$  (tk redundan)

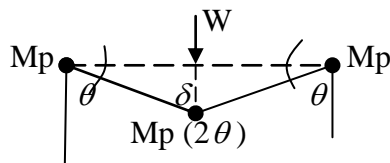
Jumlah  $\Sigma = 3$  (M, V, H)    (S-3)

(kalau kita potong batang BC →

Seperti kantilever) dan di D perlu

Satu momen,  $r = 3 - 1 = 2$

Mekanisme balok :



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

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

$$= 4 Mp \cdot \theta$$

$$W_c = \frac{4Mp}{L}$$

Mekanisme goyangan :

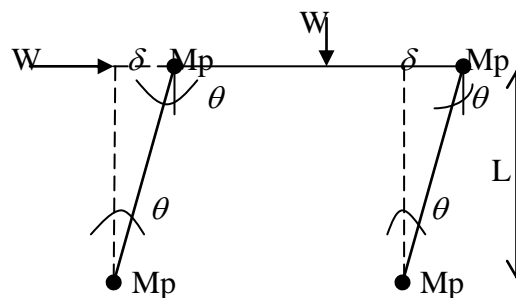
$\delta$  sama, maka

$\theta$  pada kaki kolom sama

Tidak ada pergerakan

Vertikal → usaha dari

Beban vertikal = 0



$$\delta = \theta \cdot L$$

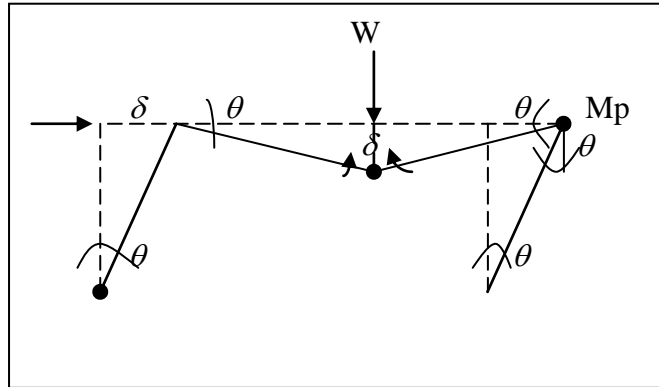
$$UL = W_1 \delta = W \cdot \theta \cdot L$$

$$UD = Mp \cdot \theta + Mp \cdot \theta + Mp \theta$$

$$= 3 Mp \cdot \theta$$

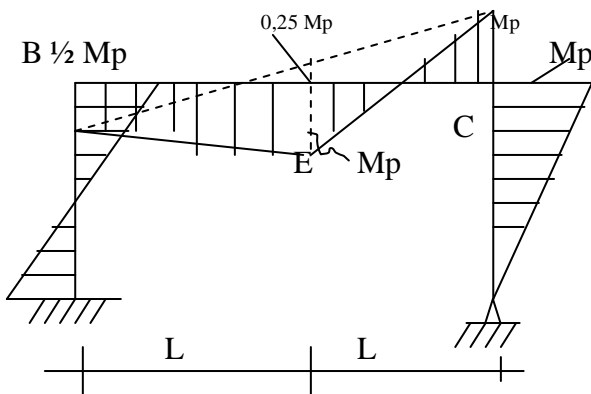
$$W_c = \frac{3M_p}{L}$$

Mekanisme  
Gabungan



$$\begin{aligned} UD &= M_p \theta + M_p \cdot 2\theta + M_p \theta + M_p \cdot \theta \\ &= 5 M_p \theta \end{aligned}$$

Diagram momen lentur plastis



$$W_c = \frac{5M_p}{L} = 2 \frac{1}{2} M_p / L$$

( $W_c$  terkecil) = nilai terkecil momen plastis

$$\text{Atau: } \frac{W_c \cdot L}{2 \frac{1}{2}} = M_p$$

Cat: D = Sendi  $\rightarrow M_D = 0$

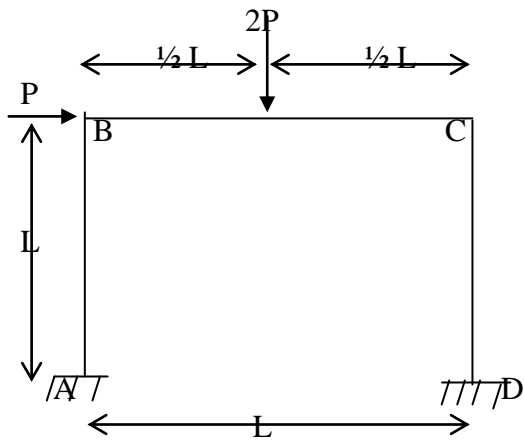
A = Jepit  $\rightarrow M_A = M_p, M_C = M_p, M_E = M_p$

Jika BE  $\rightarrow$  Balok perletakan sederhana, di E

$$\begin{aligned} M &= \frac{W \cdot 2L}{4} = \frac{W \cdot L}{2} \\ &= \frac{1}{2} \cdot 2,5 \frac{W_c \cdot L}{2,5} = 1,25 M_p \end{aligned}$$

Karena linear maka pengurangan momen dari  $M_p$  di titik C  $\rightarrow 1,5 M_p$ , jadi di titik B =  $0,5 M_p$

Contoh:



$N = 5$  (jumlah kemungkinan sendi plastis)

$r = 3$  (tingkat redundan portal ini)

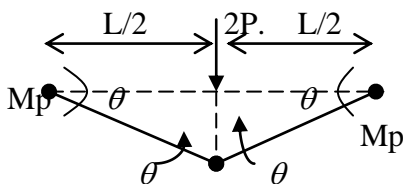
$N = 5 - 3 = 2$

(Jumlah mekanisme terpisah yang mungkin bebas)

→ mekanisme balok

→ mekanisme panel/ portal

Mekanisme balok

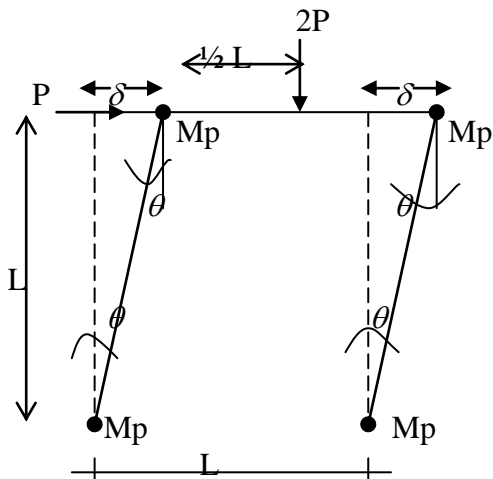


Usaha luar =  $2P \cdot \frac{1}{2} L \cdot \theta$

Usaha dalam =  $4M_p \cdot \theta$

Jadi  $P_c = \frac{4M_p}{L}$

Mekanisme panel



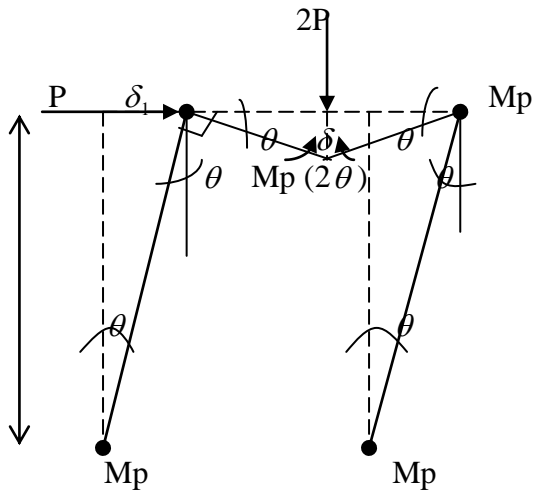
UL =  $P \cdot \delta = P \cdot L \cdot \theta$

UD =  $(M_p \cdot \theta) 4 = 4M_p \cdot \theta$

UD = UL

Jadi  $P_c = \frac{4M_p}{L}$

Mekanisme gabungan



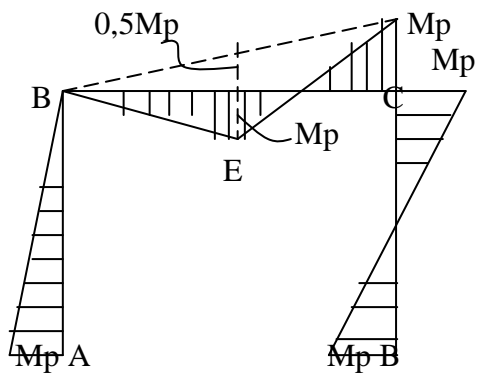
$$UL = P \cdot L \theta + 2P \cdot \frac{L}{2} \cdot \theta = 2P \cdot L \cdot \theta$$

$$UD = Mp \cdot \theta + Mp(2\theta) + Mp \cdot \theta + Mp \cdot \theta + Mp \cdot \theta = 6 Mp \cdot \theta$$

$$UL = UD$$

$$P_c = \frac{6Mp}{2L} = \frac{3Mp}{L} \text{ (terkecil)}$$

Diagram momen (moment diagram)



Total ordinat momen di balok BC

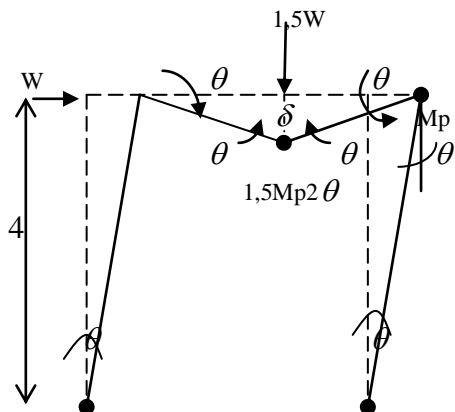
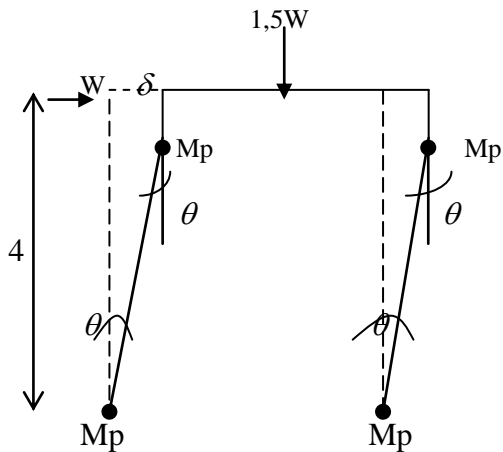
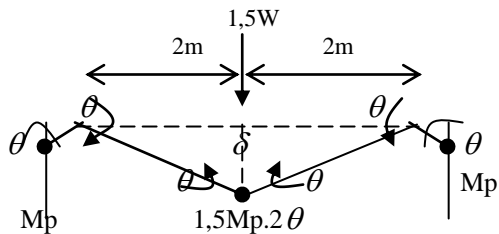
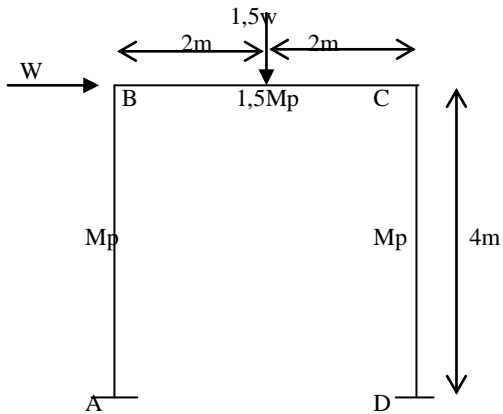
$$\frac{2P \cdot L}{4} = \frac{1}{2} PL = \frac{1}{2} \cdot \frac{3MP}{L} \cdot L = \frac{3}{2} Mp$$

Momen max di E = Mp

Kelebihan momen 0,5 Mp

Jadi momen pada setiap penampang tidak lebih Besar dari Mp

Contoh



$$N = 5, \quad r = 3$$

$$N = 5 - 3 \text{ (mekanisme bebas)}$$

$$\text{Usaha Luar} = 1,5W \cdot 2\theta = 3W\theta$$

$$\text{Usaha dalam} = Mp\theta + 1,5Mp \cdot 2\theta + Mp\theta$$

$$= 5Mp\theta$$

$$W_c = \frac{5}{3} Mp = 1,67 Mp$$

$$\text{Usaha Luar} = W \cdot 4\theta = 4W \cdot \theta$$

$$\text{Usaha dalam} = Mp\theta + Mp\theta + Mp\theta + Mp\theta$$

$$= 4Mp\theta$$

$$W_c = \frac{4Mp}{4} = Mp \text{ (terkecil)}$$

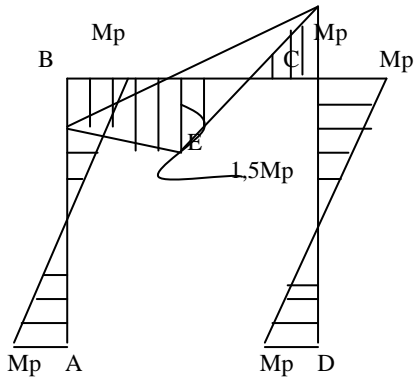
$$UL = W4\theta + 1,5W \cdot \theta \cdot 2 = 7W\theta$$

$$UD = Mp\theta + 1,5Mp2\theta + Mp\theta + Mp\theta$$

$$+ Mp\theta$$

$$= 7Mp\theta$$

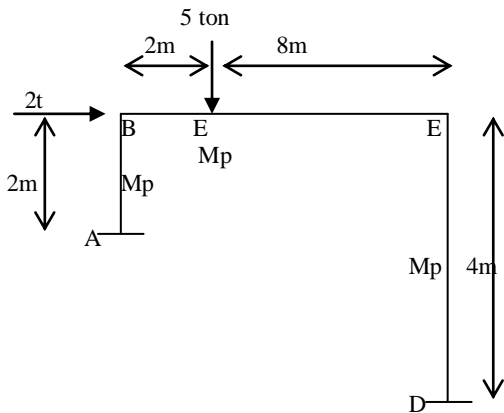
$$W_c = \frac{7Mp}{7} = Mp \text{ (terkecil)}$$



Bentang BC  $\rightarrow M = \frac{1}{4} \cdot 1,5W \cdot 4 = 1,5W$   
 $= 1,5 Mp$

Terjadi 5 sendi plastis  $\rightarrow$  kasus kelebihan keruntuhan

Contoh: tentukan nilai momen plastis penuh dari portal ini

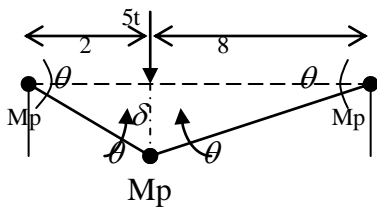


$$N = 5$$

$$r = 3$$

$$n = 5 - 3 = 2 \rightarrow \text{m. Balok}$$

$$\rightarrow \text{m. Panel}$$



$$\delta = \theta \cdot 2 = \theta_1 \cdot 4 \rightarrow \theta_1 = \frac{1}{2} \theta$$

$$UL = 5 \cdot \theta \cdot 2 = 10\theta$$

$$UD = Mp\theta + Mp(\theta + \theta_1) + Mp\theta_1$$

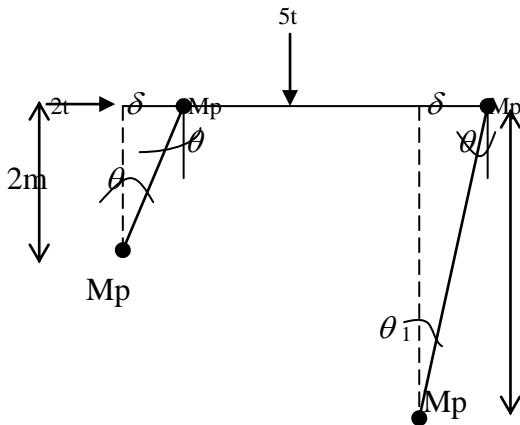
$$= Mp\theta + 1\frac{1}{2} Mp\theta + \frac{1}{2} Mp\theta$$

$$= 3 Mp\theta$$

$$UL = UD \rightarrow 10\theta = 3Mp\theta$$

$$\rightarrow Mp = 10/3 = 3.33 \text{ t.m}$$

Mekanisme Balok



$$\delta = \theta \cdot 2 = \theta_1 \cdot 4 \rightarrow \theta_1 = \frac{\theta}{2}$$

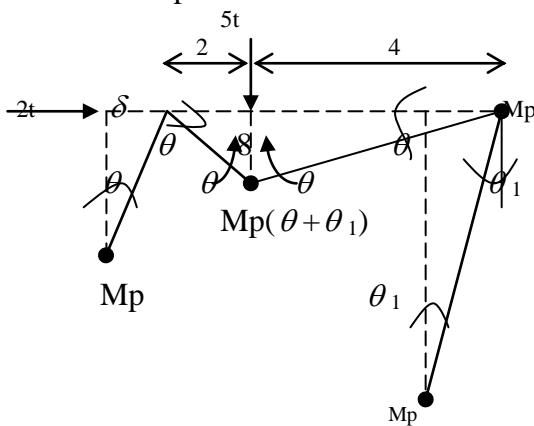
$$UL = 2 \cdot 2 \theta = 4\theta$$

$$UD = Mp\theta + Mp\theta + Mp\theta_1 + Mp\theta_1$$

$$= 3 Mp\theta$$

$$UL = UD \rightarrow Mp = \frac{4}{3} = 1,33 \text{ t.m}$$

Mekasnisme panel



$$UL = 2 \cdot \theta \cdot 2 + 5 \cdot \theta \cdot 2 = 14\theta$$

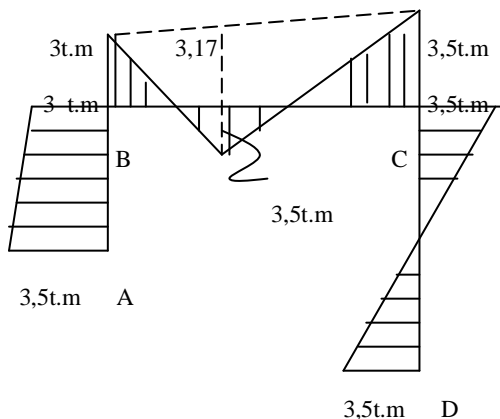
$$UD = Mp\theta + Mp(\theta + \theta_1) + Mp\theta_1 + Mp\theta_1$$

$$+ Mp\theta_1$$

$$= 4 Mp\theta$$

$$UL = UD \rightarrow \frac{14}{4} = 3,5 \text{ t.m}$$

Mekanisme gabungan

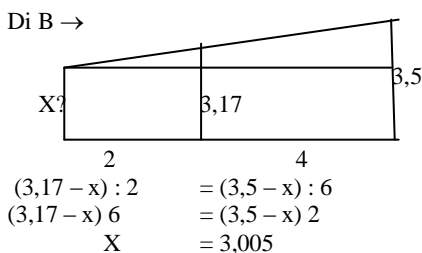


Momen plastis penampang untuk portal (yang max)  $M_p = 3,5 \text{ t.m}$

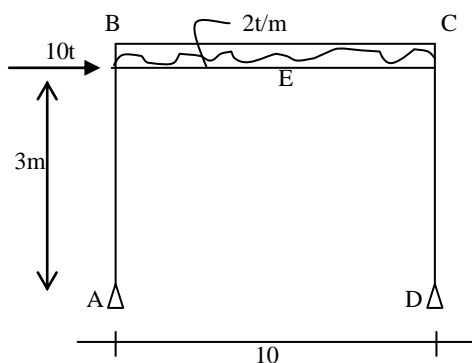
Balok BC  $\rightarrow M = \frac{5.2.4}{6} = 6,67 \text{ t.m}$

Sisa =  $6,67 - 3,5 = 3,17$

Diagram momen plastis



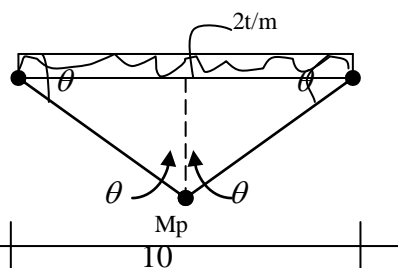
Contoh : tentukan momen plastis portal berikut



$N = 3$   
 $R = 1$   
 $n = 3 - 1 = 2$

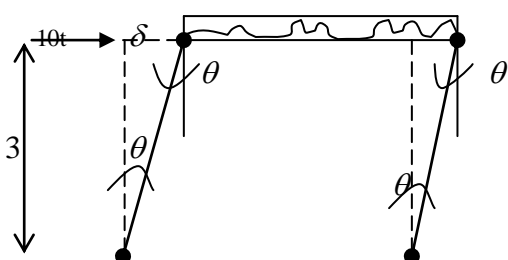
- mekanisme bebas  $\rightarrow$  balok  $\rightarrow$  panel
- mekanisme gabungan

Mekanisme balok



$UL = 2 \times \frac{1}{2} \cdot 10 \cdot 5 \theta = 50 \theta$   
 $UD = 4 M_p \theta$   
 $M_p = 12,5 \text{ t.m}$

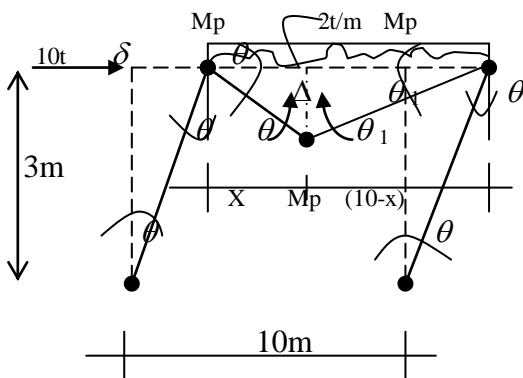
Mekanisme panel



$UL = 10 \cdot 3 \cdot \theta = 30 \theta$   
 $UD = 2 M_p \cdot \theta$   
 $M_p = 15 \text{ t.m}$



Mekanisme kombinasi



$$\begin{aligned} \delta &= \theta \cdot 3 \text{ m} \\ \Delta &= \theta \cdot x = \theta_1 \cdot (10-x) \\ \theta_1 &= \frac{x}{(10-x)} \theta \\ \text{UL} &= 10 \cdot 3 \theta + 2 \cdot \frac{1}{2} \cdot 10 \cdot \theta \cdot X \\ &= 30 \theta + 10x \\ \text{UD} &= M_p (\theta + \theta_1) + M_p \theta_1 + M_p \theta \\ &= 2 M_p \theta + 2 M_p \frac{x}{(10-x)} \theta \end{aligned}$$

$$\text{UL} = \text{UD} \rightarrow 30 \theta + 10x \cdot \theta = 2 M_p \cdot \theta + 2 M_p \left( \frac{x}{10-x} \right) \theta$$

$$30 \theta + 10x \cdot \theta = 2 M_p \left( 1 + \frac{x}{10-x} \right) \theta$$

$$\frac{30+10x}{2} = M_p \left( 1 + \frac{x}{10-x} \right)$$

$$= M_p \left( \frac{10-x+x}{10-x} \right) = M_p \left( \frac{10}{10-x} \right)$$

$$M_p = \frac{1}{2} \left( \frac{10-x}{10} \right) \cdot 10(3+x) = \frac{(3+x)(10-x)}{2}$$

$$\frac{dM_p}{dx} = 0 \rightarrow M_p \text{ max}$$

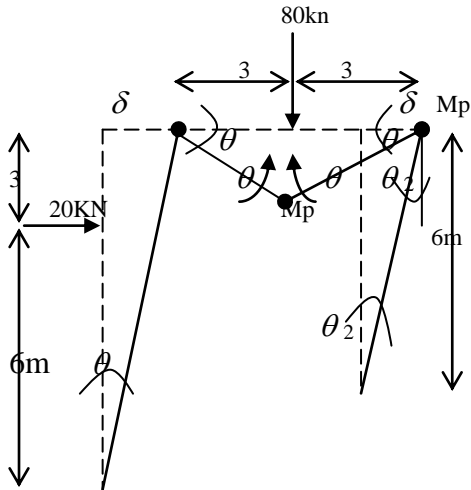
$$\frac{dM_p}{dx} = \frac{1}{2} [(3+x)(-1) + 1 \cdot (10-x)] = 0$$

$$-3 - x + 10 - x = 0 \rightarrow x = 3,5 \text{ m}$$

$$\text{Jadi } M_p = \frac{1}{2} (3 + 3,5) (10 - 3,5) = 21,2 \text{ t.m (terbesar)}$$



Mekanisme gabungan  
Pergoyangan dan balok CE



$$\begin{aligned} \text{Usaha luar} &= 80 \cdot 3 \cdot \theta + 20 \cdot 6 \cdot \theta \\ &= 360 \cdot \theta \end{aligned}$$

$$\begin{aligned} \text{Usaha dalam} &= Mp \cdot 2\theta + Mp \cdot \theta + Mp \cdot \theta_2 \\ &= 4 \frac{1}{2} Mp \theta \end{aligned}$$

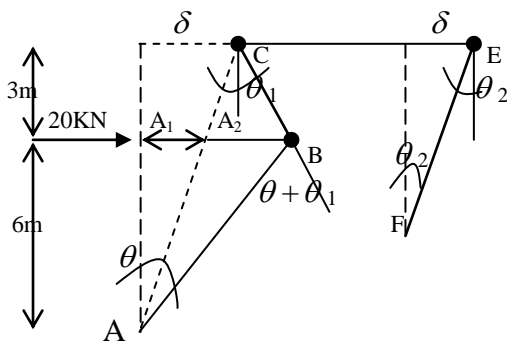
$$\delta = 9 \theta = 6 \theta_2$$

$$\theta_2 = 1 \frac{1}{2} \theta$$

$$UL = UD \rightarrow MP = 80 \text{ KN.m}$$

(Terbesar)

Pergoyangan dan balok AC



$$\Delta_2 = 3\theta_1 = 6\theta \rightarrow \theta_1 = 2\theta$$

$$\delta = 9\theta = 6\theta_2 \rightarrow \theta_2 = 1 \frac{1}{2} \theta$$

$$\text{Usaha luar} = 20 \cdot 6 \cdot \theta + 20 \cdot 6 \cdot \theta = 240 \theta$$

$$\begin{aligned} \text{Usaha dalam} &= Mp(\theta + \theta_1) + Mp \theta_1 + Mp \theta_2 \\ &= Mp3\theta + Mp2\theta + Mp1 \frac{1}{2} \theta \\ &= 6 \frac{1}{2} Mp \theta \end{aligned}$$

$$UL = UD \rightarrow MP = 36,9 \text{ KN.m}$$