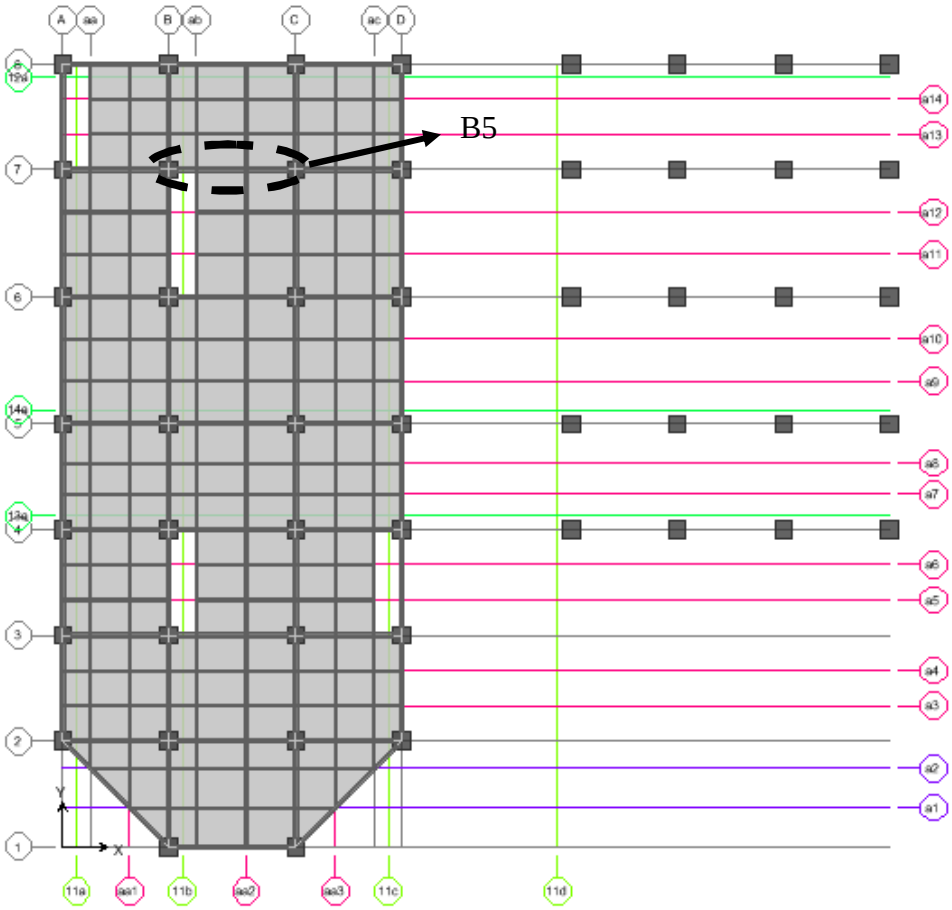
# LAMPIRAN I
# PERHITUNGAN KAPASITAS GESER DAN LENTUR BALOK BAJA

### L.1.1 Desain Balok

Jenis balok yang akan ditinjau dalam kasus ini adalah balok induk dengan profil IWF 400.200.8.13 mm, dan balok anak dengan profil IWF yang berukuran 200.100.8.11 mm.




**Gambar L2.1 Lokasi Balok yang Ditinjau (B5)**

Data Profil Balok: IWF 400.200.8.13- BJ.37

h = 400 mm $C_x$ = 42.3 mm $i_x$ = 168 mm

| | | |
|---|---|---|
| $b = 200$ mm | $C_r = 16$ mm | $i_y = 45.4$ mm |
| $t_w = 8$ mm | $A_g = 6600$ mm$^2$ | |
| $t_f = 13$ mm | $I_x = 2{,}37 \cdot 10^8$ mm$^4$ | |
| $f_y = 240$ mm | $f_u = 370$ mm | $E = 200000$ Mpa |

Output ETABS 9.7.2 untuk hasil gaya $V_u$ dan $M_u$ balok yang ditinjau adalah:

$V_u = -74013{,}600$ N

$M_u = -86899391{,}600$ Nmm

**Cek Balok Terhadap Geser**

$$\frac{h'}{t_w} = \frac{h - 2.(C_r + t_f)}{t_w} = \frac{400 - 2.(16 + 13)}{8} = 42{,}75$$

$$1{,}10\sqrt{\frac{K_n \times E}{f_y}} = 1{,}10\sqrt{\frac{5 \times 200000}{240}} = 71{,}0047$$

$$\frac{h'}{t_w} = 42{,}75 < 1{,}10\sqrt{\frac{K_n \times E}{f_y}} = 71{,}0047$$

$V_n = 0{,}6 \cdot f_y \cdot A_w$

$= 0{,}6 \cdot 240 \cdot (400 \cdot 8)$

$= 460800$ N

$\phi V_n = 0{,}9 \cdot 460800 = 414720$ N

$\phi V_n = 414720$ N $> V_u = 74013{,}600$ N $\longrightarrow$ OK!

$\therefore$ Balok kuat terhadap geser

**Cek Kelangsingan Penampang**

Cek Sayap:

$$\lambda_f = \frac{b}{2 \cdot t_s} = \frac{200}{2 \cdot 13} = 7{,}69$$

$$\lambda_{pf} = \frac{170}{\sqrt{f_y}} = \frac{170}{\sqrt{240}} = 11$$

$\lambda_f = 7{,}95 < \lambda_{pf} = 11 \rightarrow$ Sayap kompak

Cek Badan:

$$\lambda_w = \frac{h'}{t_w} = \frac{h - 2.(C_r + t_f)}{t_w} = \frac{400 - 2.(16 + 13)}{8} = 42{,}75$$

$\lambda_{pw} = \frac{1680}{\sqrt{f_y}} = \frac{1680}{\sqrt{240}} = 108{,}4$

$\lambda_w = 42.75 < \lambda_{pw} = 108{,}4 \rightarrow$ Badan kompak

$\therefore$ Maka penampang kompak $\rightarrow M_n = M_p = Z_x \,.\, f_y$

**Cek Balok Terhadap Lentur**

$M_n = M_p = Z_x \,.\, f_y$

$= A \,.\, (h/2 - C_x) \,.\, f_y$

$= 6600 \,.\, (400/2 - 42.3) \,.\, 240$

$= 249796800$ Nmm

$\phi M_n = 0{,}9 \,.\, 249796800 = 224817120$ Nmm

$\phi M_n = 224817120$ Nmm $> M_u = 86899391{,}600$ Nmm $\longrightarrow$ OK!

$\therefore$ Balok kuat terhadap lentur

**Cek lendutan**

$\Delta_{ETABS} = 3{,}579$ mm

$\Delta_{ijin} = \frac{L_{balok}}{240} = \frac{6000}{240} = 25$ mm

$\Delta = 3{,}579$ mm $< \Delta_{ijin} = 25$ mm $\longrightarrow$ OK!

$\therefore$ Balok kaku

# LAMPIRAN II
# VERIFIKASI *SOFTWARE*

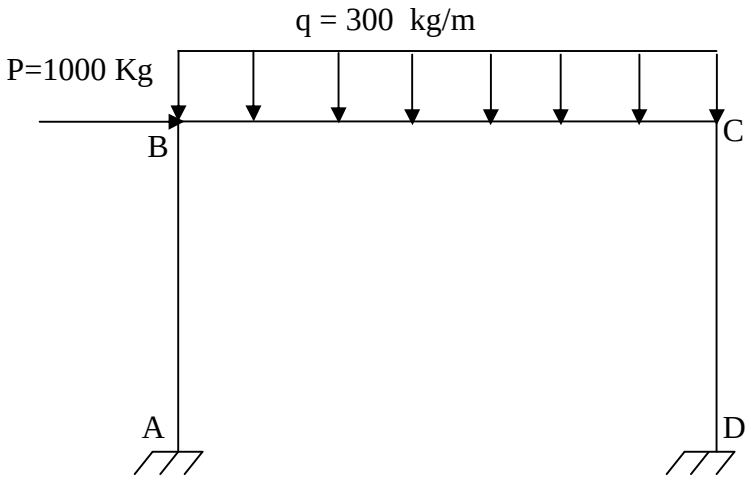
## L2.1 Verifikasi *Software*

Untuk memvalidasi hasil perangkat lunak (*software*) maka pada Lampiran II ini disertakan hasil perhitungan secara manual dengan menggunakan dasar teori Analisis Struktur Metode Matrik berdasarkan teori Holzer [Holzer, 1985] dibandingkan dengan hasil ETABS dengan tinjauan studi kasus portal statis tak tentu.

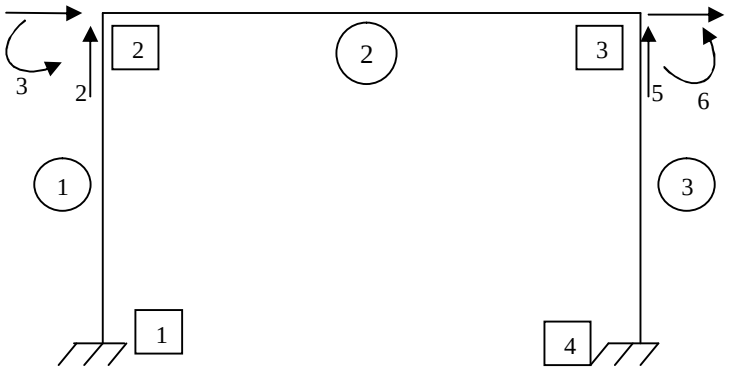
Diketahui struktur statis tak tentu dengan tinggi 4 meter dan lebar 4 meter. Adapun data struktur seperti yang tercantum dibawah ini.

| | | | |
|---|---|---|---|
| B | = 0,2 m | I | = 0,000260417 $m^4$ |
| H | = 0,25 m | A | = 0,05 $m^2$ |
| E | = $10^9$ $kg/m^2$ | | |

Dengan beban seperti yang terdapat pada Gambar L2.1




**Gambar L2.1 Portal Perletakan Jepit-jepit**




**Gambar L2.2 DOF Struktur**

$$Mcode = \begin{pmatrix} 0 & 1 & 4 \\ 0 & 2 & 5 \\ 0 & 3 & 6 \\ 1 & 4 & 0 \\ 2 & 5 & 0 \\ 3 & 6 & 0 \end{pmatrix}$$

1. Menghitung matriks kekakuan struktur tiap elemen

a. Elemen 1 (Batang AB)

$$\alpha_1 = \frac{EI_{ab}}{L_{ab}^{\ 3}} = 4069{,}010417$$

$$\beta_1 = \frac{AL_{ab}^{\ 2}}{I_{ab}} = 454{,}43787$$

$$c_{11} = \frac{0}{L_{ab}} = 0$$

$$c_{12} = \frac{-L_{ab}}{L_{ab}} = -1$$

$g_{11} = \alpha_1(\beta_1.c_{11}^{\ 2} + 12.c_{12}^{\ 2})$ = 48828,125

$g_{12} = \alpha_{11}.c_{11}.c_{12}(\beta_1 - 12)$ = 0

$g_{13} = \alpha_1(\beta_1.c_{12}^{\ 2} + 12c_{11}^{\ 2})$ =12500000

$g_{14} = -\alpha_1.6.L_{ab}.c_{12}$ = -97656,25

$g_{15} = \alpha_1.6.L_{ab}.c_{11}$ = 0

$g_{16} = \alpha_1.4L_{ab}^{\ 2}$ = 260416,6667

$g_{17} = \alpha_1.2L_{ab}^{\ 2}$ = 130208,333

**Matrik kekakuan**

$$K^{(1)} = \begin{pmatrix} g_{11} & g_{12} & g_{14} & -g_{11} & -g_{12} & g_{14} \\ g_{12} & g_{13} & g_{15} & -g_{12} & -g_{13} & g_{15} \\ g_{14} & g_{15} & g_{16} & -g_{14} & -g_{15} & g_{17} \\ -g_{11} & -g_{12} & -g_{14} & g_{11} & g_{12} & -g_{14} \\ -g_{12} & -g_{13} & -g_{15} & g_{12} & g_{13} & -g_{15} \\ g_{14} & g_{15} & g_{17} & g_{14} & -g_{15} & g_{16} \end{pmatrix}$$

$$K^{(1)} = \begin{pmatrix} 48828{,}125 & 0 & -97656{,}25 & -48828{,}125 & 0 & -97656{,}25 \\ 0 & 12500000 & 0 & 0 & -12500000 & 0 \\ -97656{,}25 & 0 & 260416{,}6667 & 97656{,}25 & 0 & 130208{,}3333 \\ -48828{,}125 & 0 & 97656{,}25 & 48828{,}125 & 0 & 97656{,}25 \\ 0 & -12500000 & 0 & 0 & 12500000 & 0 \\ -97656{,}25 & 0 & 130208{,}3333 & 97656{,}25 & 0 & 260416{,}667 \end{pmatrix}$$

$$\underline{M}\ K^{1} = \begin{pmatrix} 48828{,}125 & 0 & 97656{,}25 & 0 & 0 & 0 \\ 0 & 12500000 & 0 & 0 & 0 & 0 \\ 97656{,}25 & 0 & 260416{,}7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

b. Elemen 2 (Batang BC)

$$\alpha_2 = \frac{EI_{bc}}{L_{bc}^{\ 3}} = 4069{,}010417$$

$$\beta_2 = \frac{AL_{bc}^{\ 2}}{I_{bc}} = 3072$$

$$c_{21} = \frac{L_{bc}}{L_{bc}} = 1$$

$$c_{22} = \frac{0}{L_{bc}} = 0$$

$g_{21} = \alpha_2(\beta_2 . c_{21}^{\ 2} + 12 . c_{22}^{\ 2})$ = 12500000

$g_{22} = \alpha_2 . c_{21} . c_{22}(\beta_2 - 12)$ = 0

$g_{23} = \alpha_2(\beta_2 . c_{22}^{\ 2} + 12 c_{21}^{\ 2})$ = 48828,125

$g_{24} = -\alpha_2 . 6 . L_{bc} . c_{22}$ = 0

$g_{25} = \alpha_2.6.L_{bc}.c_{21}$ = 97656,25

$g_{26} = \alpha_2.4L_{bc}^{\ 2}$ = 260416,6667

$g_{27} = \alpha_2.2L_{bc}^{\ 2}$ = 130208,333

**Matrik kekakuan**

$$K^{(2)} = \begin{pmatrix} g_{21} & g_{22} & g_{24} & -g_{21} & -g_{22} & g_{24} \\ g_{22} & g_{23} & g_{25} & -g_{22} & -g_{23} & g_{25} \\ g_{24} & g_{25} & g_{26} & -g_{24} & -g_{25} & g_{27} \\ -g_{21} & -g_{22} & -g_{24} & g_{21} & g_{22} & -g_{24} \\ -g_{22} & -g_{23} & -g_{25} & g_{22} & g_{23} & -g_{25} \\ g_{24} & g_{25} & g_{27} & g_{24} & -g_{25} & g_{26} \end{pmatrix}$$

$$K^{(2)} = \begin{pmatrix} 12500000 & 0 & 0 & -12500000 & 0 & 0 \\ 0 & 48828,125 & 97656,25 & 0 & 48828,125 & 97656,25 \\ 0 & 97656,25 & 260416,6667 & 0 & -97656,25 & 130208,3333 \\ -12500000 & 0 & 0 & 12500000 & 0 & 0 \\ 0 & -48828,125 & -97656,25 & 0 & 48828,125 & 97656,25 \\ 0 & 97656,25 & 130208,3333 & 0 & 97656,25 & 260416,667 \end{pmatrix}$$

$$\underline{M}.\ K^1 = \begin{pmatrix} 12500000 & 0 & 0 & -12500000 & 0 & 0 \\ 0 & 48828,125 & 97656,25 & 0 & 48828,125 & 97656,25 \\ 0 & 97656,25 & 260416,6667 & 0 & -97656,25 & 130208,3333 \\ -12500000 & 0 & 0 & 12500000 & 0 & 0 \\ 0 & -48828,125 & -97656,25 & 0 & 48828,125 & 97656,25 \\ 0 & 97656,25 & 130208,3333 & 0 & 97656,25 & 260416,667 \end{pmatrix}$$

c. Elemen 3 (Batang CD)

$\alpha_3 = \dfrac{EI_{cd}}{L_{cd}^{\ 3}}$ = 4069,010417

$\beta_3 = \dfrac{AL_{cd}^{\ 2}}{I_{cd}}$ = 454,43787

$c_{31} = \dfrac{0}{L_{cd}} = 0$

$c_{32} = \dfrac{-L_{cd}}{L_{cd}} = -1$

$g_{31} = \alpha_3(\beta_3.c_{31}^{\ 2} + 12.c_{32}^{\ 2})$ = 48828,125

$g_{32} = \alpha_3.c_{31}.c_{32}(\beta_3 - 12) \quad = 0$

$g_{33} = \alpha_3(\beta_3.c_{32}^{\ 2} + 12c_{31}^{\ 2}) \quad = 12500000$

$g_{34} = -\alpha_3.6.L_{cd}.c_{32} \quad = -97656{,}25$

$g_{35} = \alpha_3.6.L_{cd}.c_{31} \quad = 0$

$g_{36} = \alpha_3.4L_{cd}^{\ 2} \quad = 260416{,}6667$

$g_{37} = \alpha_3.2L_{cd}^{\ 2} \quad = 130208{,}333$

**Matriks Kekakuan**

$$K^{(3)} = \begin{pmatrix} g_{31} & g_{32} & g_{34} & -g_{31} & -g_{32} & g_{34} \\ g_{32} & g_{33} & g_{35} & -g_{32} & -g_{33} & g_{35} \\ g_{34} & g_{35} & g_{36} & -g_{34} & -g_{35} & g_{37} \\ -g_{31} & -g_{32} & -g_{34} & g_{31} & g_{32} & -g_{34} \\ -g_{32} & -g_{33} & -g_{35} & g_{32} & g_{33} & -g_{35} \\ g_{34} & g_{35} & g_{37} & g_{34} & -g_{35} & g_{36} \end{pmatrix}$$

$$K^{(3)} = \begin{pmatrix} 48828{,}125 & 0 & -97656{,}25 & -48828{,}125 & 0 & -97656{,}25 \\ 0 & 12500000 & 0 & 0 & -12500000 & 0 \\ -97656{,}25 & 0 & 260416{,}6667 & 97656{,}25 & 0 & 130208{,}3333 \\ -48828{,}125 & 0 & 97656{,}25 & 48828{,}125 & 0 & 97656{,}25 \\ 0 & -12500000 & 0 & 0 & 12500000 & 0 \\ -97656{,}25 & 0 & 130208{,}3333 & 97656{,}25 & 0 & 260416{,}667 \end{pmatrix}$$

$$\underline{M}\ K^3 = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 48828{,}125 & 0 & 97656{,}25 \\ 0 & 0 & 0 & 0 & 12500000 & 0 \\ 0 & 0 & 0 & 97656{,}25 & 0 & 260416{,}7 \end{pmatrix}$$

$$\boldsymbol{K = K^1 + K^2 + K^3}$$

$$K = \begin{pmatrix} 1,25488e7 & 0 & 9,76563e4 & -1,25e7 & 0 & 0 \\ 0 & 1,25488e7 & 9,76563e4 & 0 & -4,88218e4 & 9,76563e4 \\ 9,76563e4 & 9,76563e4 & 5,20833e5 & 0 & 9,76563e4 & 1,30208e5 \\ -1,25e7 & 0 & 0 & 1,25488e7 & 0 & 9,76563e4 \\ 0 & -4,88281e4 & -9,76563e4 & 0 & 1,25488e7 & -9,76563e4 \\ 0 & 9,76563e4 & 1,30208e5 & 9,76563e4 & -9,76563e4 & 5,20833e5 \end{pmatrix}$$

2. Menghitung matriks beban

$$\bar{Q} = \begin{pmatrix} 1000 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$\hat{F}^{(1)} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$\hat{F}^{(2)} = \begin{pmatrix} 0 \\ \frac{1}{2} q_1 . L_{bc} \\ \frac{1}{12} q_1 . L_{bc}{}^2 \\ 0 \\ \frac{1}{12} q_1 . L_{bc} \\ -\frac{1}{12} q_1 . L_{bc}{}^2 \end{pmatrix} = \begin{pmatrix} 0 \\ 600 \\ 400 \\ 0 \\ 600 \\ -400 \end{pmatrix}$$

$$\hat{F}^{(3)} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$\hat{Q} = \sum_{i=1}^{n} \hat{F}^{(i)}$$

$$\hat{Q} = \begin{pmatrix} 0 \\ 600 \\ 400 \\ 0 \\ 600 \\ -400 \end{pmatrix} \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix}$$

$$Q = \bar{Q} - \hat{Q}$$

$$Q = \begin{pmatrix} 1000 \\ -600 \\ -400 \\ 0 \\ -600 \\ 400 \end{pmatrix}$$

3. Menghitung matriks peralihan titik nodal $q$

$$K.q = Q$$

$$q = K^{-1}Q$$

$$q = \begin{pmatrix} 0.014681903 \\ -1.37525E-05 \\ -0.003238957 \\ 0.01463395 \\ -8.22475E-05 \\ -0.001178969 \end{pmatrix}$$

4. Mencari gaya reaksi

$$\bar{F} = K^{(i)}D + \hat{F}$$

$$\bar{F}^1 = K^{(1)}D + \hat{F}$$

$$\begin{pmatrix} 0 & 0 & 0 & -48828{,}125 & 0 & -97656{,}25 \\ 0 & 0 & 0 & 0 & -12500000 & 0 \\ 0 & 0 & 0 & 97656{,}25 & 0 & 130208{,}333 \\ 0 & 0 & 0 & 48828{,}125 & 0 & 97656{,}25 \\ 0 & 0 & 0 & 0 & 12500000 & 0 \\ 0 & 0 & 0 & 97656{,}25 & 0 & 260416{,}6667 \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0{,}014681903 \\ -1{,}37525E^{-05} \\ -0{,}003238957 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 1 \\ 0 & 2 \\ 0 & 3 \end{pmatrix}$$

$$= \begin{pmatrix} -400{,}5854 \\ 171{,}9064 \\ 1012{,}04 \\ 400{,}5854 \\ -171{,}9064 \\ 590{,}3001 \end{pmatrix} \begin{matrix} H_A \\ V_A \\ M_A \\ H_B \\ V_B \\ M_B \end{matrix}$$

$$\bar{F}^2 = K^{(2)}D + \bar{F}$$

$$\begin{pmatrix} 12500000 & 0 & 0 & -1250000 & 0 & 0 \\ 0 & 48828{,}125 & 97656{,}25 & 0 & -48828{,}125 & 97656{,}25 \\ 0 & 97656{,}25 & 260416{,}6667 & 0 & -97656{,}25 & 130208{,}333 \\ -12500000 & 0 & 0 & 12500000 & 0 & 0 \\ 0 & -48828{,}125 & -97656{,}25 & 0 & 48828{,}125 & -97656{,}25 \\ 0 & 97656{,}25 & 130208{,}333 & 0 & -97656{,}25 & 260416{,}6667 \end{pmatrix}$$

$$\begin{pmatrix} 0.014681903 \\ -1.37525\text{E}-05 \\ -0.003238957 \\ 0.01463395 \\ -8.22475\text{E}-05 \\ -0.001178969 \end{pmatrix} + \begin{pmatrix} 1000 & 1 \\ -600 & 2 \\ -400 & 3 \\ 0 & 4 \\ -600 & 5 \\ 400 & 6 \end{pmatrix} = \begin{pmatrix} 599{,}4146341 \\ -428{,}0936455 \\ -990{,}3011121 \\ -599{,}4146341 \\ 428{,}0936455 \\ 722{,}0734698 \end{pmatrix} \begin{matrix} H_B \\ V_B \\ M_B \\ H_C \\ V_C \\ M_C \end{matrix}$$

$$\bar{F}^3 = K^{(3)}D + \hat{F}$$

$$\begin{pmatrix} 48828{,}125 & 0 & 97656{,}25 & 0 & 0 & 0 \\ 0 & 12500000 & 0 & 0 & 0 & 0 \\ 97656{,}25 & 0 & 260416{,}6667 & 0 & 0 & 0 \\ -48828{,}125 & 0 & -97656{,}25 & 0 & 0 & 0 \\ 0 & -12500000 & 0 & 0 & 0 & 0 \\ 97656{,}25 & 0 & 130208{,}333 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0{,}014681903 \\ -1{,}37525E^{-05} \\ -0{,}003238957 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 1 \\ 0 & 2 \\ 0 & 3 \end{pmatrix}$$

$$= \begin{pmatrix} 599{,}4146 \\ -1028{,}094 \\ 1122{,}073 \\ -599{,}4146 \\ 1028{,}094 \\ 1275{,}585 \end{pmatrix} \begin{matrix} H_C \\ V_C \\ M_C \\ H_D \\ V_D \\ M_D \end{matrix}$$

**Dengan menggunakan metode *slope deflection***

Pada lampiran ini juga disertakan perhitungan menggunakan metode *slope deflection* [Hibbeler, 2011]. . Secara umum dapat disimpulkan bahwa hasil analisis dengan software valid.

$$M^\circ_{AB} = 0$$

$$M^\circ_{BA} = 0$$

$$M^\circ_{BC} = -\frac{1}{12}qL^2 = -\frac{1}{12}300.4^2 = -400\,\text{kg}$$

$$M^\circ_{CB} = \frac{1}{12}qL^2 = \frac{1}{12}300.4^2 = 400\,\text{kg}$$

$$M^\circ_{CD} = 0$$

$$M^\circ_{DC} = 0$$

$$M_{AB} = M^\circ_{AB} + \frac{2EI}{L}(2\theta_A + \theta_B - 3\frac{\Delta}{L})$$

$$M_{AB} = 0 + \frac{2EI}{4}(2\theta_A + \theta_B - 3\frac{\Delta}{4})$$

$$M_{AB} = \frac{2\theta_B}{4}EI - \frac{6\Delta}{16}EI$$

$$M_{BA} = M^{\circ}_{BA} + \frac{2EI}{L}(2\theta_B + \theta_A - 3\frac{\Delta}{L})$$

$$M_{BA} = 0 + \frac{2EI}{4}(2\theta_B + \theta_A - 3\frac{\Delta}{4})$$

$$M_{BA} = \theta_B EI - \frac{6\Delta}{16} EI$$

$$M_{BC} = M^{\circ}_{BC} + \frac{2EI}{L}(2\theta_B + \theta_C)$$

$$M_{BC} = -400 + \frac{2EI}{4}(2\theta_B + \theta_C)$$

$$M_{BC} = -400 + \theta_B EI + \frac{2}{4}\theta_C EI$$

$$M_{CB} = M^{\circ}_{CB} + \frac{2EI}{L}(2\theta_C + \theta_B)$$

$$M_{CB} = 400 + \frac{2EI}{4}(2\theta_C + \theta_B)$$

$$M_{CB} = 400 + \frac{2}{4}\theta_B EI + \theta_C EI$$

$$M_{CD} = M^{\circ}_{CD} + \frac{2EI}{L}(2\theta_C + \theta_D - 3\frac{\Delta}{L})$$

$$M_{CD} = 0 + \frac{2EI}{4}(2\theta_C + \theta_D - 3\frac{\Delta}{4})$$

$$M_{CD} = \theta_C EI - \frac{6\Delta}{16} EI$$

$$M_{DC} = M^{\circ}_{DC} + \frac{2EI}{L}(2\theta_D + \theta_C - 3\frac{\Delta}{L})$$

$$M_{DC} = 0 + \frac{2EI}{4}(2\theta_D + \theta_C - 3\frac{\Delta}{4})$$

$$M_{DC} = \frac{2\theta_C}{4} EI - \frac{6\Delta}{16} EI$$

**Meninjau Titik B**

$M_{BA} + M_{BC} = 0$

$$\theta_B EI - \frac{6\Delta}{16} EI - 400 + \theta_B EI + \frac{2}{4}\theta_C EI = 0$$

$$2\theta_B EI + \frac{2}{4}\theta_C EI - \frac{6\Delta}{16} EI = 400 \text{ ……..(1)}$$

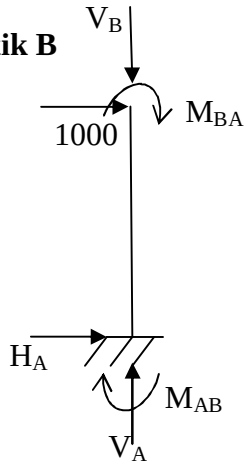
**Meninjau Titik C**

$M_{CB} + M_{CD} = 0$

$$400 + \frac{2}{4}\theta_B EI + \theta_C EI + \theta_C EI - \frac{6\Delta}{16} EI$$

$$\frac{2}{4}\theta_B EI + 2\theta_C EI - \frac{6\Delta}{16} EI = -400 \text{ …….. (2)}$$

**Titik B**




$M_B = 0$

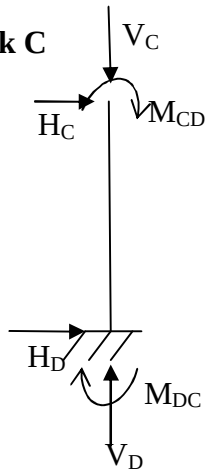
$$-4H_A + M_{AB} + M_{BA} = 0$$

$$-4H_A + \frac{2\theta_B}{4} EI - \frac{6\Delta}{16} EI + \theta_B EI - \frac{6\Delta}{16} EI = 0$$

$$\frac{3\theta_B}{2} EI - \frac{3\Delta}{4} EI = 4H_A$$

$$H_A = \frac{3\theta_B}{8} EI - \frac{3\Delta}{16} EI$$

**Titik C**




$\sum M_C = 0$

$$4H_D + M_{CD} + M_{DC} = 0$$

$$4H_D + \theta_C EI - \frac{6\Delta}{16} EI + \frac{2\theta_C}{4} EI - \frac{6\Delta}{16} EI = 0$$

$$\frac{3\theta_C}{2} EI - \frac{3\Delta}{4} EI = -4H_D$$

$$H_D = -\frac{3\theta_C}{8} EI + \frac{3\Delta}{16} EI$$

$$\sum H = 0$$

$$H_A - H_D + 1000 = 0$$

$$\frac{3\theta_B}{8} EI - \frac{3\Delta}{16} EI + \frac{3\theta_C}{8} EI - \frac{3\Delta}{16} EI + 1000 = 0$$

$$\frac{3\theta_B}{8} EI + \frac{3\theta_C}{8} EI - \frac{3\Delta}{8} EI = -1000 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Dengan mensubstitusikan ke 3 persamaan diatas didapatkan:

$$\theta_B = \frac{17600}{21}$$

$$\theta_C = \frac{6400}{21}$$

$$\Delta = \frac{80000}{21}$$

Dengan didapatkan $\theta_B$, $\theta_C$,$\Delta$ maka dapat dihitung pula persamaan $M_{AB}$, $M_{BA}$, $M_{BC}$, $M_{CB}$, $M_{CD}$, $M_{DC}$.

$$M_{AB} = -\frac{21200}{21} \text{kgm}$$

$$M_{BA} = -\frac{12400}{21} \text{kgm}$$

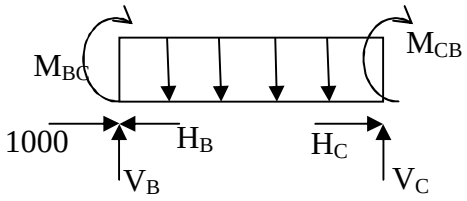
$$M_{BC} = \frac{12400}{21} \text{ kgm}$$

$$M_{CB} = \frac{23600}{21} \text{ kgm}$$

$$M_{CD} = -\frac{23600}{21} \text{ kgm}$$

$$M_{DC} = -\frac{26800}{21} \text{ kgm}$$

**Tinjau Elemen 2**




$\sum Mc = 0$

$M_{BC} + M_{CB} + qL(0,5L) + 4V_B = 0$

$\frac{23600}{21} + \frac{12400}{21} - 300.4(2) = -4V_B$

$V_B = 171,43 \text{ kg}$

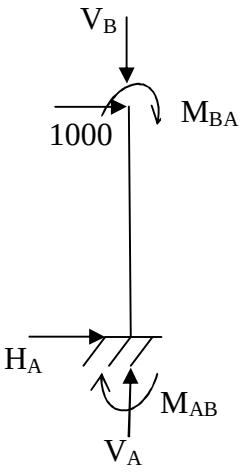
$\sum Mc = 0$

$M_{BC} + M_{CB} + qL(0,5L) - 4V_C = 0$

$\frac{23600}{21} + \frac{12400}{21} + 300.4(2) = 4V_C$

$V_C = 1028,57 \text{ kg}$

**Tinjau elemen 1**




$\sum M_B = 0$

$M_{AB} + M_{BA} - H_A.4 = 0$

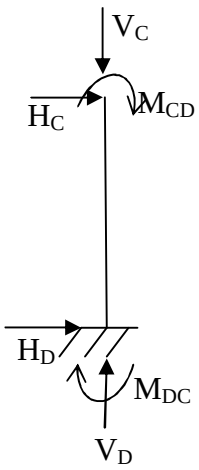
$-\frac{21200}{21} - \frac{12400}{21} = 4H_A$

$H_A = -400 \text{ kg}$

$\sum V = 0$

$V_A = V_B = 171,43 \text{ kg}$

**Tinjau elemen 3**




$\sum M_C = 0$

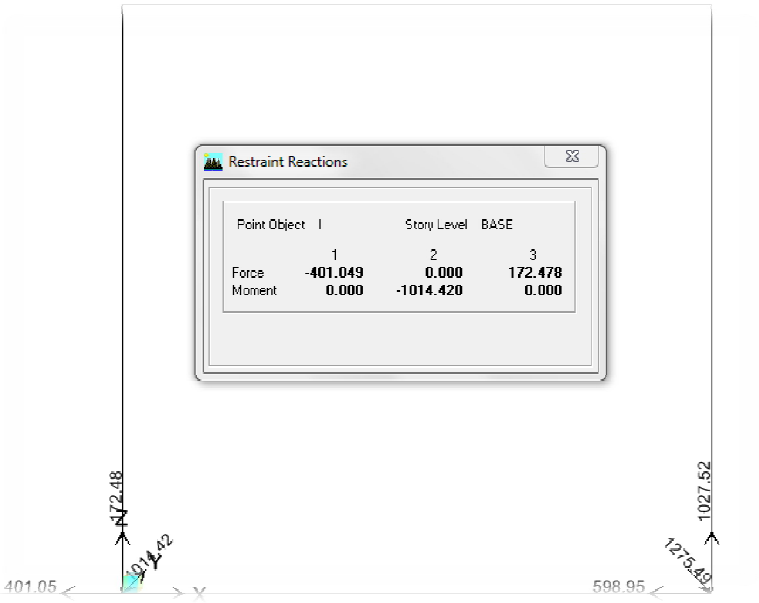
$M_{CD} + M_{CD} - H_D.4 = 0$

$-\frac{23600}{21} - \frac{26800}{21} = 4H_d$

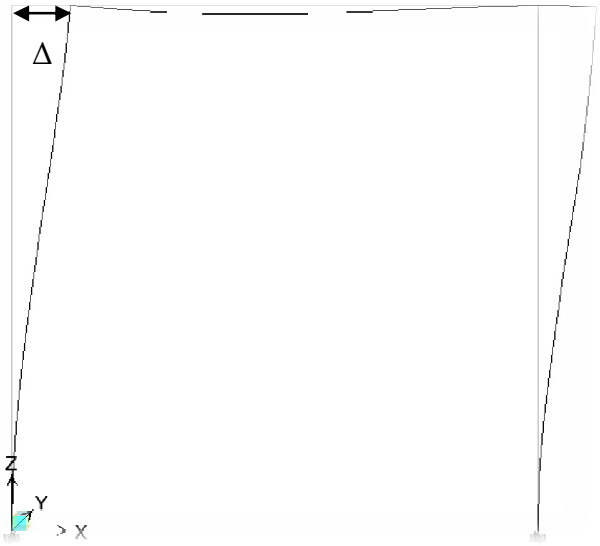
$H_D = -600 \text{ kg}$

$\sum V = 0$

$V_D = V_C = 1028,57 \text{ kg}$




**Gambar L2.3 Reaksi Perletakkan *ETABS***




**Gambar L2.4 Garis Elastisitas *ETABS***

**Tabel L2.1 Hasil Verifikasi**

| Titik | Reaksi Perletakan | | | | | |
|---|---|---|---|---|---|---|
| | Manual | | | ETABS 9.7.2 | | |
| | Aksial (Kg) | Lintang (Kg) | Momen (Kg.m) | Aksial (Kg) | Lintang (Kg) | Momen (Kg.m) |
| **A** | -400 | 171,43 | 1012,040 | -401,05 | 172,48 | 1014,420 |
| **D** | -600 | 1028,57 | 1275,585 | 598,95 | 1027,52 | 1275,493 |

**Tabel L2.2 Perbedaan Nilai Verifikasi**

| Titik | Perbedaan Nilai Reaksi Perletakan | | |
|---|---|---|---|
| | Aksial (Kg) | Lintang (Kg) | Momen (Kg.m) |
| **A** | 1,05 | 1,05 | 2,38 |
| **D** | 1,05 | 1,05 | 0,092 |