LAMPIRAN I

PERENCANAAN SAMBUNGAN BALOK-KOLOM

Kolom IWF 350.250.8.12

Balok IWF 300.200.8.12

Berdasarkan tabel profil di ketahui :

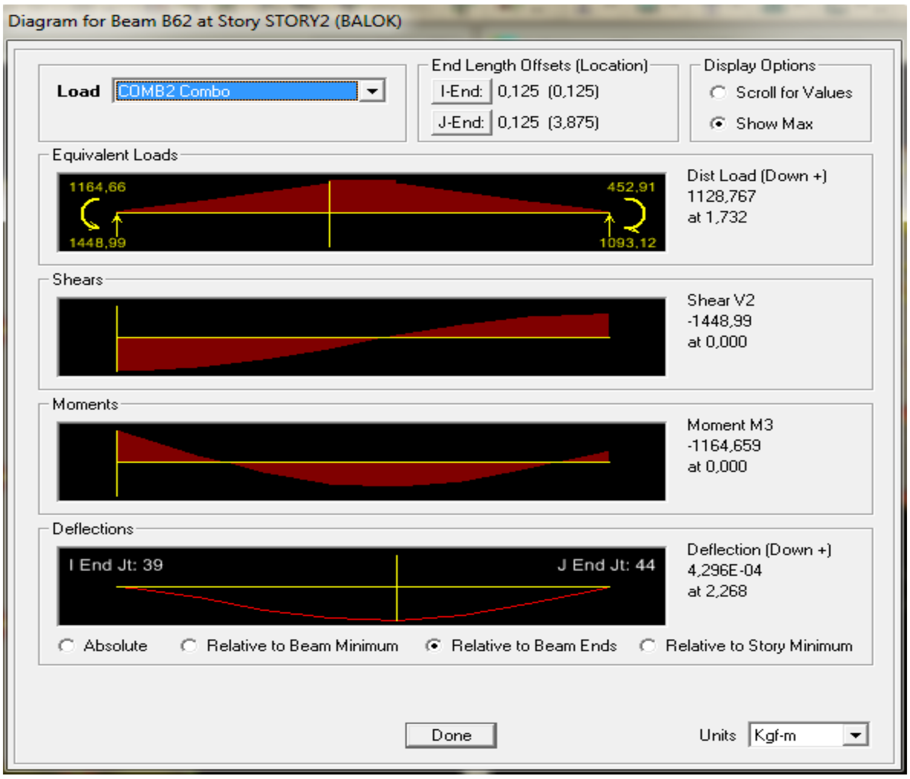
BJ 37

f_u = 370 MPa	A_g = 72,38 cm² = 7238 mm²
f_y = 240 MPa	C_r = 18 mm
b = 200 mm	I_x = 11300 cm^4 = 11300 10^4 mm^4
d = 294 mm	I_y = 1600 cm^4 = 1600 10^4 mm^4
t_w = 8 mm	C_x = 2,83 cm = 28,3 mm
t_f = 12 mm	r_x = 12,5 cm = 125 mm
S_x = 771 cm^3 = 771 10^3 mm^3	r_y = 4,71 cm = 47,1 mm
S_y = 160 cm^3 = 160 10^3 mm^3	

M_u dan V_u didapatkan dari Etabs pada story 2 :

Combo 2 : M_u = -1164,659 kgm

V_u = -1448,99 kgm



Gambar L1.1 *Output* M_u dan V_u

a. Menghitung Tahanan Nominal Baut

i. Geser

Berdasarkan persamaan 2.33, maka Tahanan Geser Baut dapat dihitung sebagai berikut :

1 bidang geser :

$\Phi R_n = 0{,}75\ (0{,}4\ .\ fu^b)\ A_b$

$= 0{,}75\ (0{,}4\ .\ 825)\ 380{,}133$

$= 94082{,}84599$ N = 94,083 KN

2 bidang geser :

$\Phi R_n = 2\ (94082{,}84599)$

$= 188165{,}692$ N = 188,166 KN

ii. Tumpu

Berdasarkan persamaan 2.35, maka Tahanan Tumpu Nominal dapat dihitung sebagai berikut :

Web balok :

$\Phi R_n = 0{,}75\ (2{,}4\ fu^p)\ d_b\ .\ t_p$

$= 0,75\ (2.4 \ .\ 370).\ 22\ .\ 7$

$= 102564$ N = 102,564 KN

Flens balok

$\Phi R_n \quad = 0,75\ (2,4\ fu^p)\ d_b\ .\ t_p$

$= 0,75\ (2,4)\ (370)\ (22)\ (11)$

$= 161172$ N = 161,172 KN

iii. Tarik

Berdasarkan persamaan 2.34, maka Tahanan Tarik Baut dapat dihitung sebagai berikut :

$\Phi R_n \quad = 0,75\ (0,75\ fu^b)\ A_b$

$= 0,75\ (0,75\ .\ 825)\ 380,133$

$= 176405,4703$ N = 176,4054703 KN

b. Perhitungan Siku Penyambung Atas dan Bawah

$$d = \frac{M}{2T} = \frac{116465,9}{2 \times 176,4054703} = 330 \text{ mm} = 450 \text{ mm}$$

Jarak baut terhadap *flens* atas balok = ½ (450 – 350) = 50 mm

Menggunakan Profil Siku 100.200.14 sehingga :

$a = 50 - t_{siku} - r_{siku} = 50 - 14 - 15 = 21$ mm

dengan d = 450 mm, maka gaya yang bekerja pada profil siku adalah :

$$T = \frac{M}{d} = \frac{116465,9}{450} = 258,81 = 259K$$

Gaya ini menimbulkan momen pada profil siku sebesar :

$M = 0,5\ .\ T\ .\ a$

$= 0,5\ (\ 259000\ )\ (\ 21\ )$

$= 2719500$ Nmm

Kapasitas nominal penampang persegi adalah :

$$\Phi Mn = 0,9 \left(\frac{b.d^2}{4} \right) fy$$

$$\text{Sehingga } b = \frac{4 \times 2719500}{0,9 \times 240 \times 14^2} = 256,944 = 260\text{mm}$$

c. Perhitungan Sambungan pada *Flens* Balok

Gaya geser pada *flens* balok = $\frac{144899}{300}$ = 482,99 = 483 KN

Baut penyambung adalah baut dengan satu bidang geser :

$$N = \frac{483}{94{,}083} = 5{,}13 = 6 \text{ baut}$$

d. Perhitungan Sambungan *Web* Balok Siku 100.200.14

Tahanan dua bidang geser (188,166 KN) lebih besar dari tahanan tumpu (102,564 KN)

Maka tahanan baut di tentukan oleh tahanan tumpu :

$$N = \frac{116{,}4659}{102{,}564} = 1{,}13 = 2 \text{ baut}$$

e. Sambungan *Web* Balok dengan *Flens* Kolom

Baut yang menghubungkan balok dengan flens kolom adalah sambungan dengan satu bidang geser (Φ R_n = 94,083 KN), sehingga :

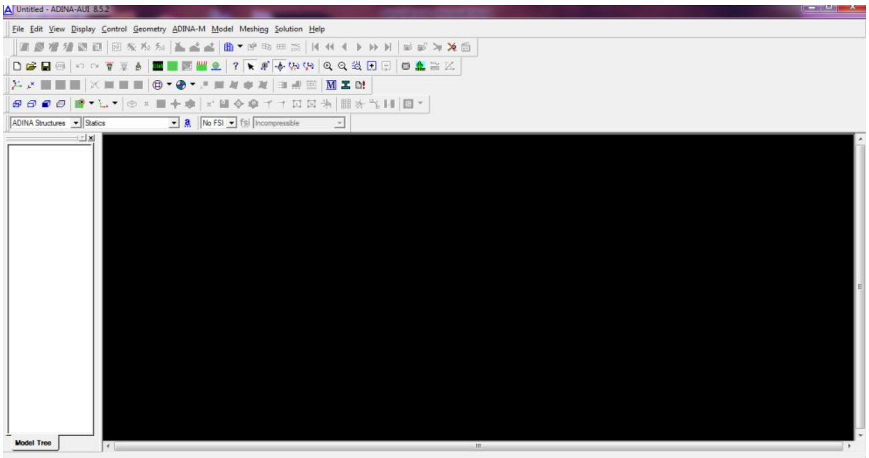
$$N = \frac{116{,}4659}{94{,}083} = 1{,}237 = 2 \text{ baut}$$

LAMPIRAN II

ANALISIS LENDUTAN PADA BALOK

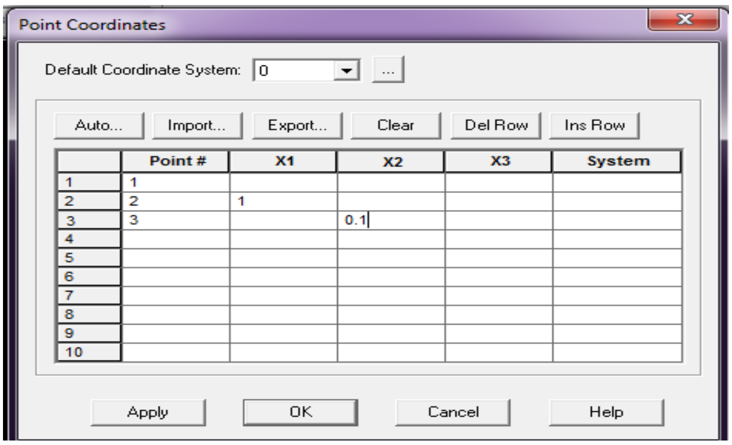
Program yang dipakai untuk pemodelan dan analisis adalah *ADINA 8.6* Berikut ini langkah-langkah dalam pemodelan struktur.

Aktifkan program *ADINA 8.6*. Pilih *File*, *New Model* untuk membuat desain dari awal. Kemudian akan muncul tampilan sebagai berikut.

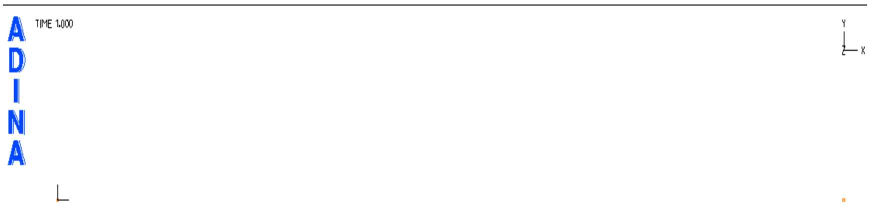


Gambar L2.1 Tampilan *New Model ADINA* [ADINA, 2009]

Meng*Input point* seperti pada tampilan berikut ini. Klik *Geometry*, pilih *Point*, klik *apply* setelah itu klik *OK* dan akan muncul 3 titik seperti terlihat pada gambar sebagai berikut :



Gambar L2.2 Tampilan *Input Point ADINA* [ADINA, 2009]

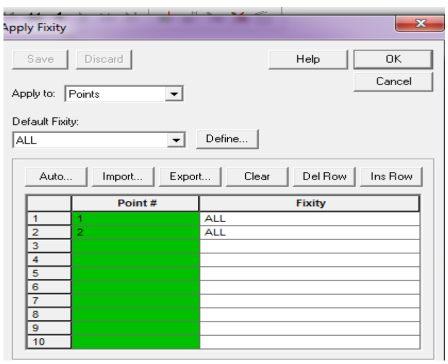


Gambar L2.3 Tampilan *Input* Titik *ADINA* [ADINA, 2009]

Langkah selanjutnya membuat garis. Klik *Geometry*, klik *lines*, kilk *add* masukan garis nomor 1 kemudian isi *point* 1 dengan angka 1 dan *point* 2 dengan angka 2 dan klik *OK* akan muncul garis seperti pada gambar sebagai berikut :

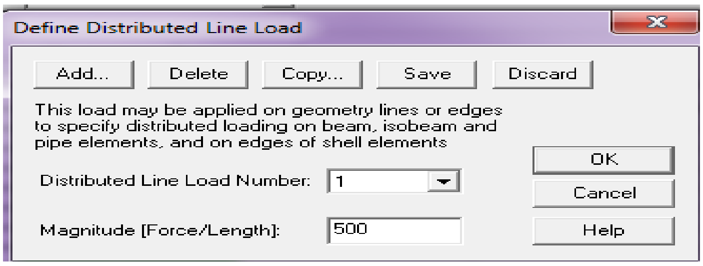
Gambar L2.4 Tampilan *Input Garis* [ADINA, 2009]

Kemudian pasang tumpuan pada ujung titiknya. Klik *Apply Fixity*, masukkan angka 1 di baris pertama dari kolom Point # dan angka 2 pada baris pertama dari kolom point # dan klik OK. Seperti pada gambar di bawah ini.

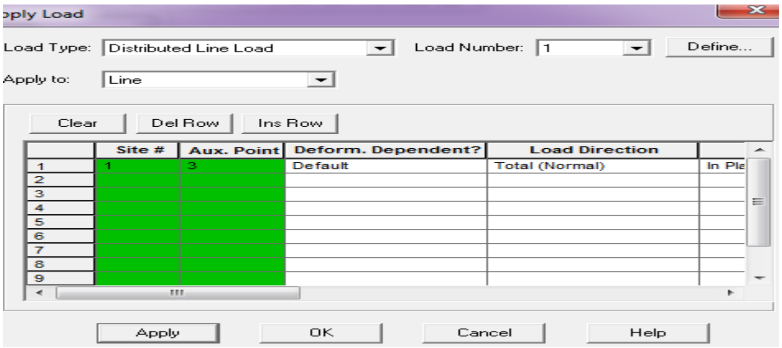


Gambar L2.5 Tampilan *Input* Tumpuan [ADINA, 2009]

Langkah selanjutnya memasukan beban. Klik *Apply Load* , ubah *Load Type* menjadi *Distributed Line Load*, klik *define*, klik *add*, masukan *Magnitude*sebesar 500 N dan klik OK. Pada baris pertama dari tabel di kotak dialog Terapkan beban, mengatur *Line* # untuk 1 dan *Aux. Point* ke 3.



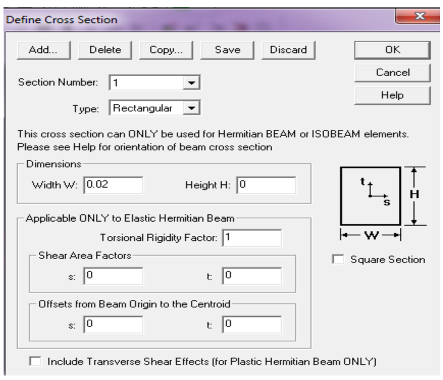
Gambar L2.6 Tampilan *Input* Beban [ADINA, 2009]



Gambar L2.7 Tampilan *Input Point* Pembebanan [ADINA, 2009]

Mendefinisikan Penampang

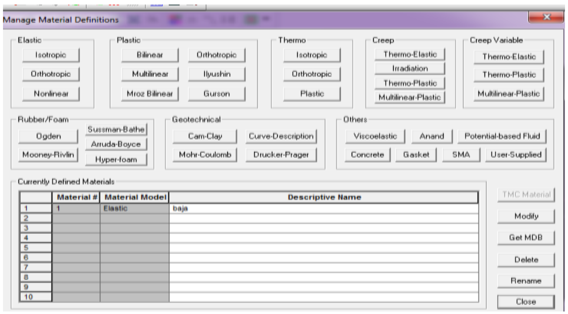
Klik *Cross Sections*. kemudian menambahkan nomor bagian 1, mengatur Lebar untuk 0,02, klik *Square Section button* dan klik *OK*.



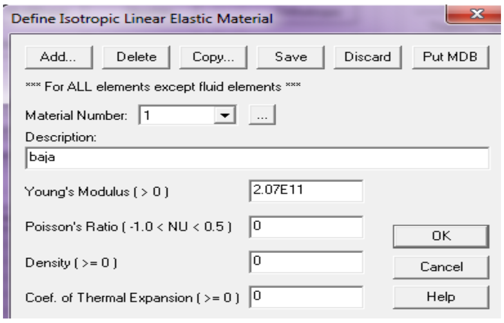
Gambar L2.8 Tampilan Penampang [ADINA, 2009]

Mendefinisikan Material

Klik *Manage Materials*, klik *Isotropik elastis*. Dalam Tentukan Bahan isotropik kotak dialog Linear elastis, menambahkan materi 1, mengatur Modulus elastisitas untuk 2.07E11 dan klik OK.



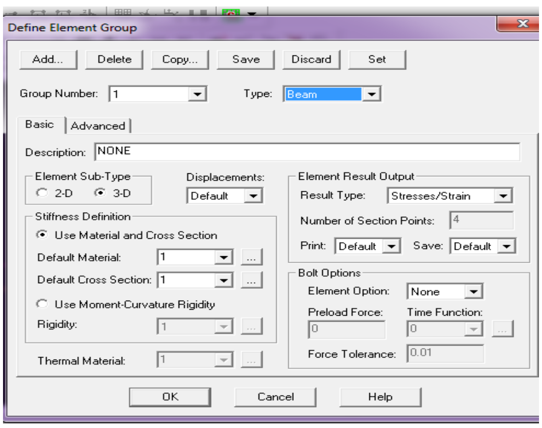
Gambar L2.9 Tampilan *Input Material* [ADINA, 2008]



Gambar L2.10 Tampilan *Input Young Modulus* [ADINA, 2009]

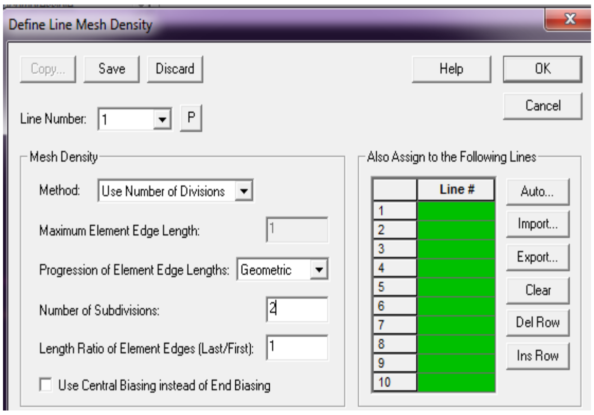
Mendefinisikan Elemen Hingga

Element group: klik *Define Element* , klik *Groups* Tentukan Elemen, menambahkan grup 1, mengatur Ketik untuk *Beam* dan klik OK.



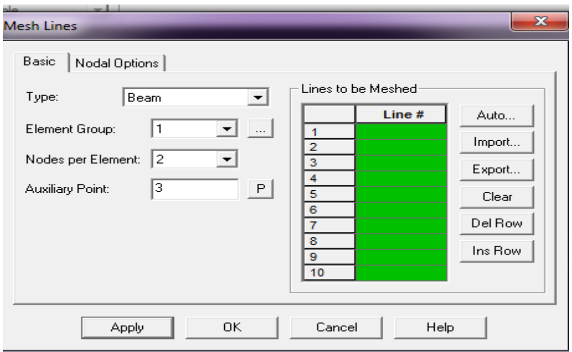
Gambar L2.11 Tampilan *Input Element Group* [ADINA, 2009]

Specifying the mesh refinement: klik *Subdivide Lines* , pastikan bahwa “*Method”* menjadi *“Use Number of Divisions*”, atur *Number of Subdivisions* 2 dan klik

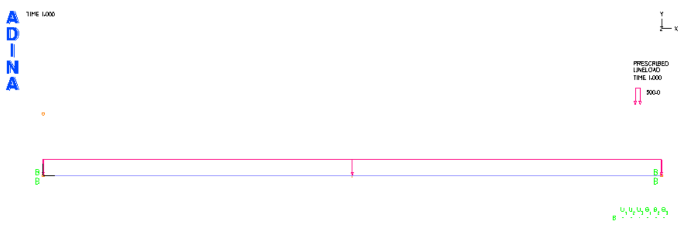


Gambar L2.12 Tampilan *Input Mesh Density* [ADINA, 2009]

Adding elements: klik *Mesh Lines* , mengatur *Auxiliary Point* 3, masukan angka 1 Tabel Kolom pertama of the Line # dan klik OK



Gambar L2.13 Tampilan *Input Mesh Lines* [ADINA, 2009]



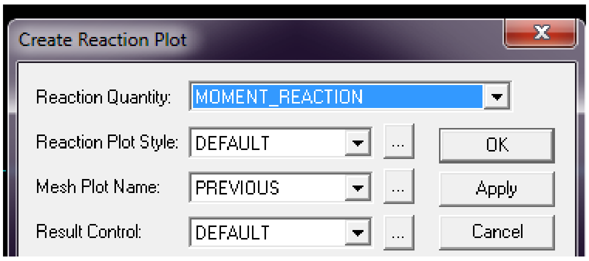
Gambar L2.14 Tampilan Pemodelan [ADINA, 2009]

Save ADINA-IN pada file baru , pilih *File→Save As*, simpan dengan nama Soal dan klik *Save*. klik Data *File/Solution*, klik *run file*

Buka file baru untuk melihat hasil momen dan reaksinya kemudian buka post processing,

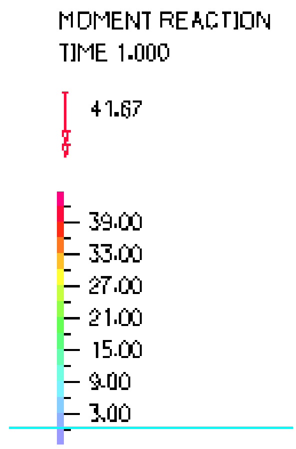
Untuk melihat hasil reaksi dan momen yang dihasilkan dari beban 500N/m adalah sebagai berikut

Klik display → reaction plot → create. Kemudian akan muncul tampilan seperti di bawah ini:



Gambar L2.15 Tampilan *Input Momen Reaction* [ADINA, 2009]

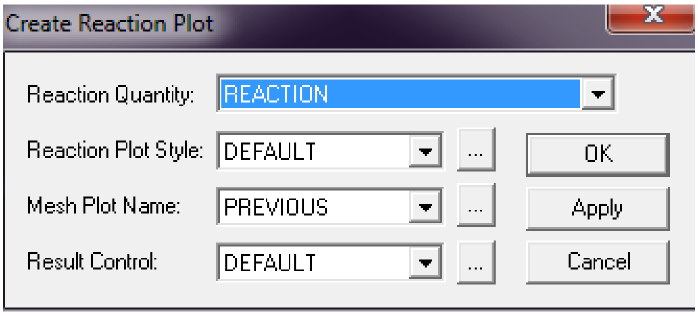
Kemudian pilih *moment reaction* dan klik ok. Kemudian akan muncul hasil dari moment tersebut yaitu 41,67 N/m



Gambar L2.16 Tampilan *Input Hasil Momen* [ADINA, 2009]

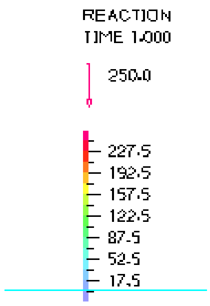
Klik display → reaction plot → create

Kemudian akan muncul tampilan seperti di bawah ini:

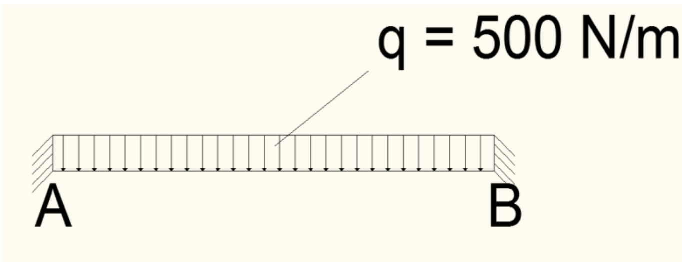


Gambar L2.17 Tampilan *Input Reaction* [ADINA, 2009]

Kemudian pilih *moment reaction* dan klik ok. Kemudian akan muncul hasil dari reaksi tersebut yaitu 250 N



Gambar L2.18 Tampilan Hasil *Reaction* [ADINA, 2009]



Gambar L2.19 Tampilan Balok dengan Beban Merata

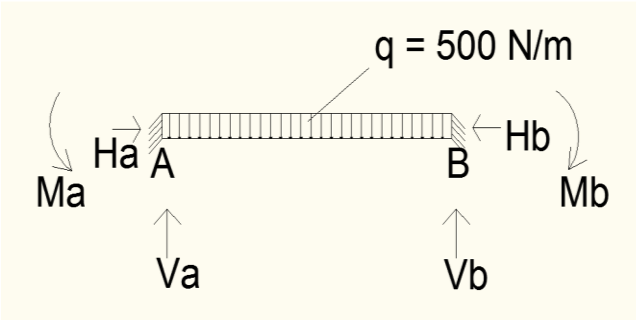
Q = 500 N/m

L = 1 meter

b= 0,02 m

h= 0,02 m

Menggunakan Metode Slope Deflection



Gambar L2.20 Tampilan Reaksi pada Balok

$$M^o ab = -\frac{1}{12} q\, L_{ab}^2$$

$$= -\frac{1}{12} 500\ 1^2$$

$$= -\ 41{,}667 \text{ N/m}$$

$$M^o ba = \frac{1}{12} q\, L_{ab}^2$$

$$= \frac{1}{12} 500\ 1^2$$

$$= 41{,}667 \text{ N/m}$$

Mencari Va, Vb :

Σ Vb = 0

Va - ½ q l_{ab}= 0

$$Va = \left(\frac{500\ .1}{2}\right) = 250\ N$$

Σ Va = 0

Vb + ½ q l_{ba}= 0

$$Vb = \left(\frac{500\ .1}{2}\right) = -250\ N$$

Lendutan :

$$\left(EI,\ w_x\right) = -\frac{1}{24} qx^4 + \frac{1}{12} qL\, x^3 - \frac{1}{24} qL^2 x^2$$

$$\left(EI,\ w_{\left(\frac{1}{2}\right)L}\right) = -\frac{1}{24}q\left(\frac{1}{2}L\right)^4 + \frac{1}{12}\text{qL}\left(\frac{1}{2}L\right)^3 - \frac{1}{24}\text{qL}^2\left(\frac{1}{2}L\right)^2$$

$$\left(EI,\ w_{\left(\frac{1}{2}\right)L}\right) = -\frac{1}{24}q\left(\frac{1}{16}L^4\right) + \frac{1}{12}\text{qL}\left(\frac{1}{8}L^3\right) - \frac{1}{24}\text{qL}^2\left(\frac{1}{4}L^2\right)$$

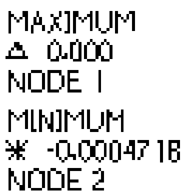
$$\left(EI,\ w_{\left(\frac{1}{2}\right)L}\right) = -\frac{1}{348}qL^4 + \frac{1}{96}\text{qL}^4 - \frac{1}{96}\text{qL}^4$$

Maka rumus lendutannya adalah

$$\delta = -\frac{q\,L^4}{384\,EI}$$

Berdasarkan rumus lendutan di atas dapat dihitung nilai lendutan sebagai berikut

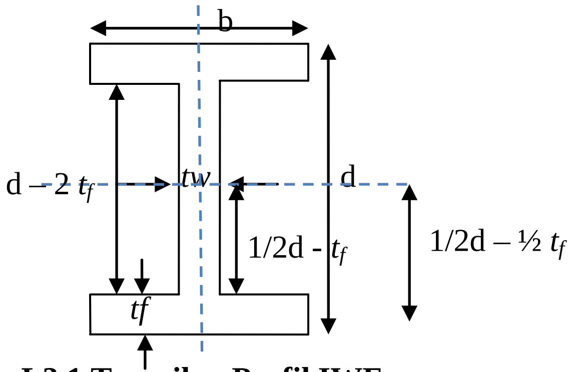
$$\delta = -\frac{q\,L^4}{384\,EI} = \frac{500\ 1^4}{384\ .\ 2{,}07E^{11}\ \frac{1}{12}\ 0{,}02\ .\ 0{,}02^3} = -0{,}00047176$$



Gambar L2.21 Tampilan Hasil Lendutan pada Balok

Dari hasil di atas bahwa kasus 1 tentang defleksi pada suatu balok dalam program ADINA 8.6 menghasilkan nilai momen 41,67 N/m dan nilai reaksi 250 N, sedangkan perhitungan manual yang dilakukan menghasilkan nilai momen 41,67 N/m dan hasil reaksi 250 N. Dari hasil ini dapat disimpulkan bahwa kasus defleksi pada suatu balok menggunakan program ADINA sesuai dengan hasil perhitungan manual yg dilakukan.

LAMPIRAN III
PENURUNAN RUMUS



Gambar L3.1 Tampilan Profil IWF

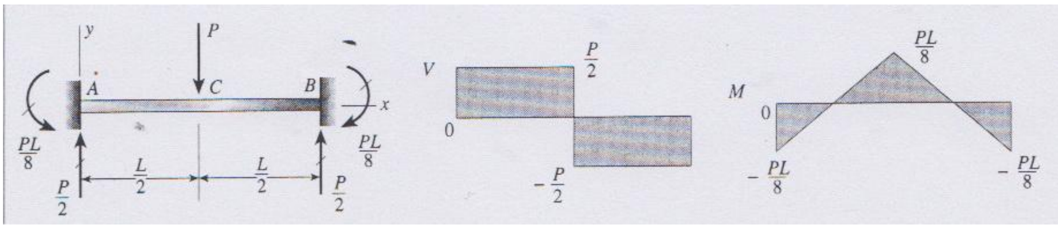
Penurunan rumus untuk profil IWF

$$I_x = \frac{1}{12} t_w \left(d - 2t_f\right)^3 + 2\left(\frac{1}{12} b\ t_f^{\ 3}\right) + 2\ b\ t_f \left(\frac{1}{2} d - \frac{1}{2}\ t_f\right)^2$$

$$I_y = 2\left(\frac{1}{12}\ t_f\ b^3\right) + \frac{1}{12}\left(d - 2t_f\right) t_w^{\ 3}$$

$$Z_x = 2\left[b\ t_f \left(\frac{1}{2}\ d - \frac{1}{2}\ t_f\right) + t_w \left(\frac{1}{2}\ d - t_f\right) \frac{1}{2}\left(\frac{1}{2}\ d - t_f\right)\right]$$

$$Z_y = \frac{1}{2}\ t_f\ b^2 + \frac{1}{4}\ t_w^{\ 2}\left(d - 2t_f\right)$$



Gambar L3.2
Tampilan Reaksi balok serta Diagram Gaya Geser
dan Momen Lentur (Mekanika Bahan, James M. Gere, Stephen P. Timoshenko)

$$Va = \text{Vb}$$
$$= \frac{P}{2}$$
$$Ma = \text{Mb}$$
$$= \frac{PL}{8}$$

$$C_1 = \frac{P}{2} \qquad C_2 = -M_A = -\frac{PL}{8} \qquad C_3 = 0 \qquad C_4 = 0$$

$$\left(EI,\ w_{xx}\right)_x = C_1$$

$$\left(EI,\ w_{xx}\right)_x = \frac{P}{2}$$

$$\left(EI,\ w_{xx}\right) = M = \frac{Px}{2} - \frac{PL}{8}$$

$$\left(EI,\ w_x\right) = \frac{C_1 x^2}{2} + C_2 x + C_3$$

$$\left(EI,\ w_x\right) = \frac{\frac{P}{2}x^2}{2} + \left(-\frac{PL}{8}\right)x$$

$$\left(EI,\ w_x\right) = \frac{1}{4}Px^2 + \left(-\frac{PL}{8}\right)x$$

$$\left(EI,\ w_x\right) = -\frac{Px}{8EI}\left(L - 2x\right)$$

$$\left(EI,\ w_x\right) = -\frac{2Px^2}{8EI} - \frac{PLx}{8EI}$$

$$\left(EI,\ w\right) = -\frac{1}{3}\frac{2Px^3}{8} - \frac{1}{2}\frac{PLx^2}{8}$$

$$\left(EI,\ w\right) = -\frac{2Px^3}{24} - \frac{PLx^2}{16}$$

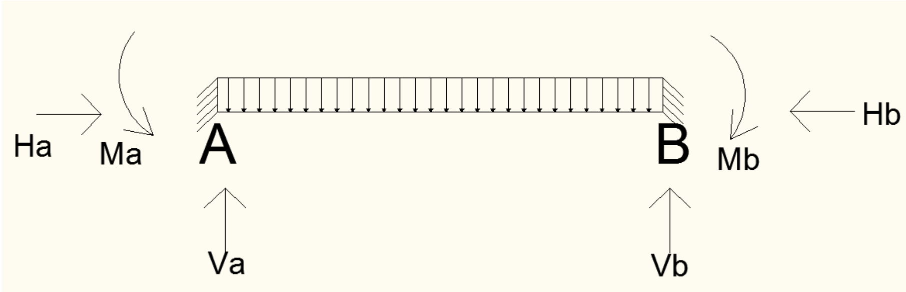
$$\left(EI,\ w\right) = -\frac{4Px^3}{48} - \frac{3PLx^2}{48}$$

$$\left(EI,\ w\right) = -\frac{Px^2}{48EI}\ \left(3L - 4x\right)$$

$$\left(EI,\ w_{\frac{1}{2}L}\right) = -\frac{P\left(\frac{1}{2}L\right)^2}{48EI}\ \left(3L - 4\frac{1}{2}L\right)$$

Maka rumus lendutan yang dihasilkan adalah

$$\delta = \frac{PL^3}{192EI}$$



Gambar L3.3 Tampilan Reaksi pada Balok dengan Perletakan Jepit - Jepit

Penurunan Rumus Lendutan untuk struktur Jepit-Jepit

$$(EI\ W_{xx})_{xx} = -q$$

$$(EI\ W_{xx})_{x} = -qx + a$$

$$(EI\ W_{xx}) = -\frac{1}{2}qx^2 + ax + b$$

$$(EI\ W_{x}) = -\frac{1}{6}qx^3 + \frac{1}{2}ax^2 + bx + c$$

$$(EI\ W) = -\frac{1}{24}qx^4 + \frac{1}{6}ax^3 + \frac{1}{2}bx^2 + cx + d$$

$$(EI\ W)\ (0) = -\frac{1}{24}qx^4 + \frac{1}{6}ax^3 + \frac{1}{2}bx^2 + cx + d$$

$$(EI\ W)\ (0) \rightarrow d = 0$$

$$(EI\ W_{x})\ (0) = -\frac{1}{6}qx^3 + \frac{1}{2}ax^2 + bx + c$$

$$(EI\ W_{x})\ (0) \rightarrow c = 0$$

$$(EI\ W)\ (L) = -\frac{1}{24}qx^4 + \frac{1}{6}ax^3 + \frac{1}{2}bx^2 + cx + d$$

$$(EI\ W)\ (L) = -\frac{1}{24}qL^4 + \frac{1}{6}aL^3 + \frac{1}{2}bL^2 = 0$$

$$(EI\ W_{x})\ (L) = -\frac{1}{6}qL^3 + \frac{1}{2}aL^2 + bL = 0$$

$$(EI\ W)\ (L) = -qL^2 + 4aL + 12b = 0$$
$$(EI\ W_x)\ (L) = -qL^2 + 3aL + 6b = 0 \quad \times 2$$

$$-qL^2 + 4aL + 12b = 0$$
$$-2qL^2 + 6aL + 12b = 0$$

$$qL^2 = 2aL$$
$$a = \frac{1}{2}qL$$

$$-qL^2 + 3aL + 6b = 0$$

$$-qL^2 + 3aL + 6b = 0$$
$$6b = qL^2 - 3aL$$
$$6b = qL^2 - \frac{3}{2}qL^2$$
$$\mathrm{b} = -\frac{1}{12}\mathrm{qL}^2$$

$$(EI\ W) = -\frac{1}{24}qx^4 + \frac{1}{12}qLx^3 - \frac{1}{24}qL^2x^2$$

$$W\max \rightarrow w,x = 0$$

$$-\frac{1}{6}qx^3 + \frac{1}{4}qLx^2 - \frac{1}{12}qL^2x = 0$$

$$2x^2 - 3Lx^2 + L^2 = 0$$

$$(2x - L)\ (x - L) = 0$$

$$X = \frac{1}{2}L\ ,\ X = L$$

Lendutan

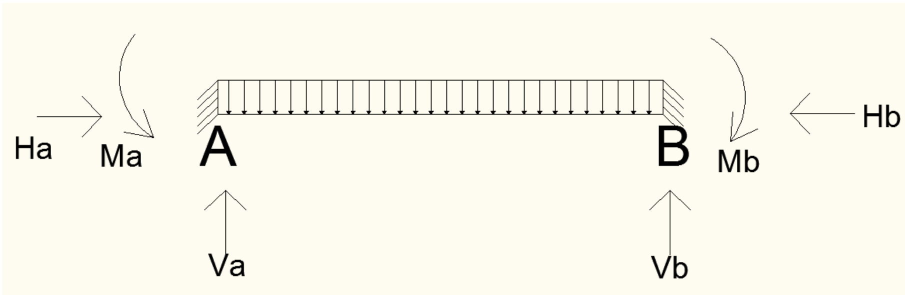
$$(EI\ W)\ (x) = -\frac{1}{24}qx^4 + \frac{1}{12}qLx^3 - \frac{1}{24}qL^2x^2$$

$$(EI\ W)\ (\frac{1}{2}L) = -\frac{1}{24}qx^4 + \frac{1}{12}qLx^3 - \frac{1}{24}qL^2x^2$$

$$(EI\ W)\ (\frac{1}{2}L) = -\frac{1}{24}q\left(\frac{1}{2}L\right)^4 + \frac{1}{12}qL\left(\frac{1}{2}L\right)^3 - \frac{1}{24}qL^2\left(\frac{1}{2}L\right)^2$$

$$(EI\ W)\ (\frac{1}{2}L) = -\frac{1}{384}qL^4 + \frac{1}{96}qL^4 - \frac{1}{96}qL^4$$

$$(W) = -\frac{qL^4}{384EI}$$



Gambar L3.4 Tampilan Reaksi pada Balok dengan Perletakan Jepit – Jepit

Rekasi dan Momen yang terjadi pada perletakan jepit – jepit

$$M_a = \mathrm{M_b} = \frac{qL^2}{12}$$

$$\mathrm{V_a} = \mathrm{V_b} = \frac{qL}{2}$$

Lendutan ke bawah di titik tengah dari balok sederhana akibat beban terbagi rata adalah

$$v = \frac{qx}{24EI}\left(\mathrm{L}^3 - 2\mathrm{LX}^2 + \mathrm{X}^3\right)$$

$$v' = \frac{q}{24EI}\left(\mathrm{L}^3 - 6\mathrm{LX}^2 + 4\mathrm{X}^3\right)$$

$$\delta = \frac{5qL^4}{384EI}$$

Lendutan ke atas di titik tengah akibat momen ujung adalah

$$\delta = \frac{M_a\mathrm{L}^2}{8EI} = \frac{\left(\frac{qL^2}{12}\ \mathrm{L}^2\right)}{8EI} = \frac{qL^4}{96}$$

Jadi lendutan akhir ke bawah pada balok adalah

$$\delta = \frac{qL^4}{96EI} - \frac{5qL^4}{384EI} = \frac{4qL^4}{384EI} - \frac{5qL^4}{384EI} = -\frac{qL^4}{384EI}$$

LAMPIRAN IV

VERIFIKASI *SOFTWARE*

L4.1 Verifikasi *Software*

Untuk memvalidasi hasil perangkat lunak (*software*) maka pada Lampiran IV ini disertakan hasil perhitungan secara manual dengan menggunakan dasar teori Analisis Struktur Metode Matrik berdasarkan teori Holzer [Holzer, 1985] dan hasil perhitungan dengan ETABS, dengan tinjauan studi kasus portal statis tak tentu. Secara umum dapat disimpulkan bahwa hasil analisis dengan software valid.

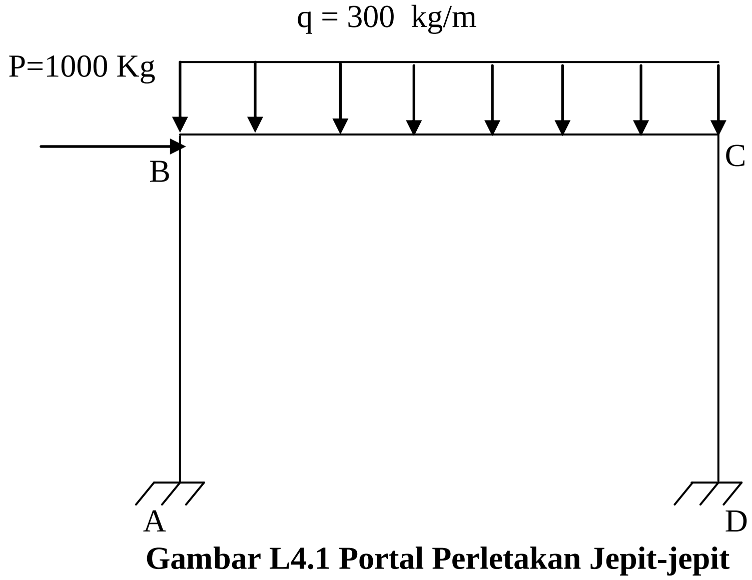
Diketahui struktur statis tak tentu dengan tinggi 4 meter dan lebar 4 meter. Adapun data struktur seperti yang tercantum dibawah ini.

B = 0,2 m   I = 0,000260417 m^4

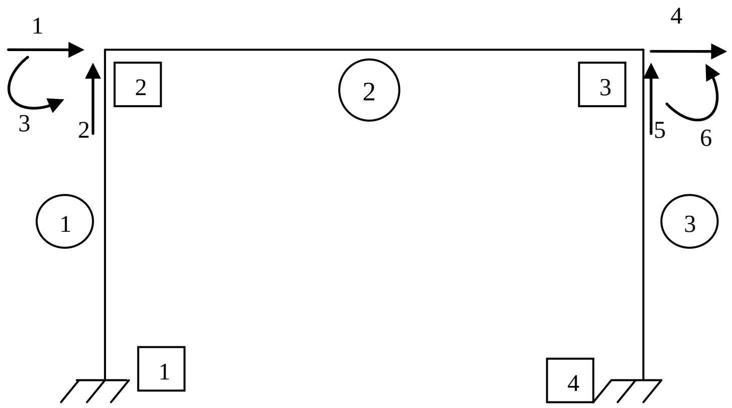
H = 0,25 m   A = 0,05 m^2

E = 10^9 kg/m^2

Dengan beban seperti yang terdapat pada Gambar L3.4



Gambar L4.1 Portal Perletakan Jepit-jepit



Gambar L4.2 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

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

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

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

b. Elemen 2 (Batang BC)

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

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

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

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

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

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

= 48828,125

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

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

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

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

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

Matrik kekakuan

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

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

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

c. Elemen 3 (Batang CD)

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

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

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

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

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

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

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

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

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

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

6 $g_{37} = \alpha_3.2L_{cd}^{\;2}$ = 130208,333

Matriks Kekakuan

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

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

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

K = K¹ + K² + K³

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

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

$$K.q = Q$$

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

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

4. Mencari gaya reaksi

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

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

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

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

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

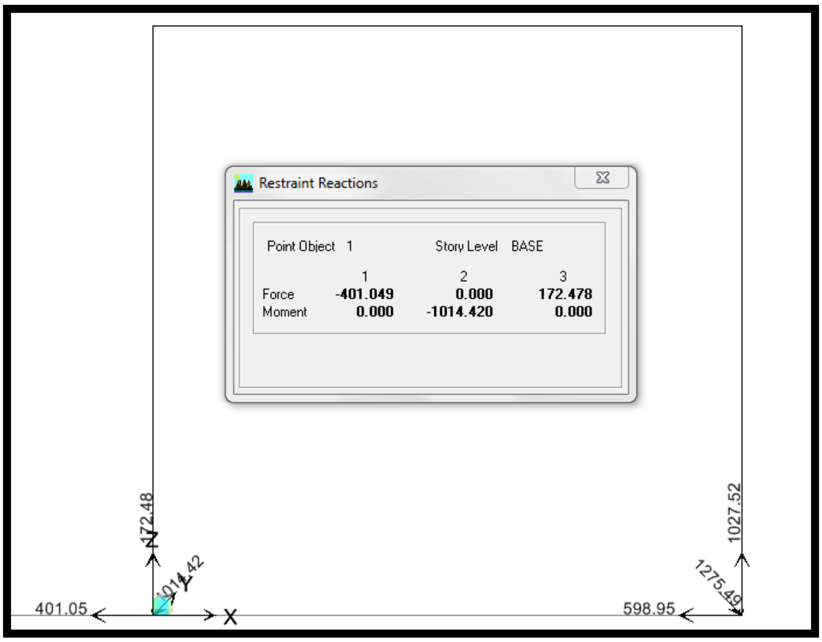
$$\begin{pmatrix} 12500000 & 0 & 0 & -1250000 & 0 & 0 \\ 0 & 48828{,}125 & 97656{,}25 & 0 & -48828{,}125 & 97656{,}25 \\ 0 & 97656{,}25 & 260416{,}6667 & 0 & -97656{,}25 & 130208{,}333 \\ -12500000 & 0 & 0 & 12500000 & 0 & 0 \\ 0 & -48828{,}125 & -97656{,}25 & 0 & 48828{,}125 & -97656{,}25 \\ 0 & 97656{,}25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

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

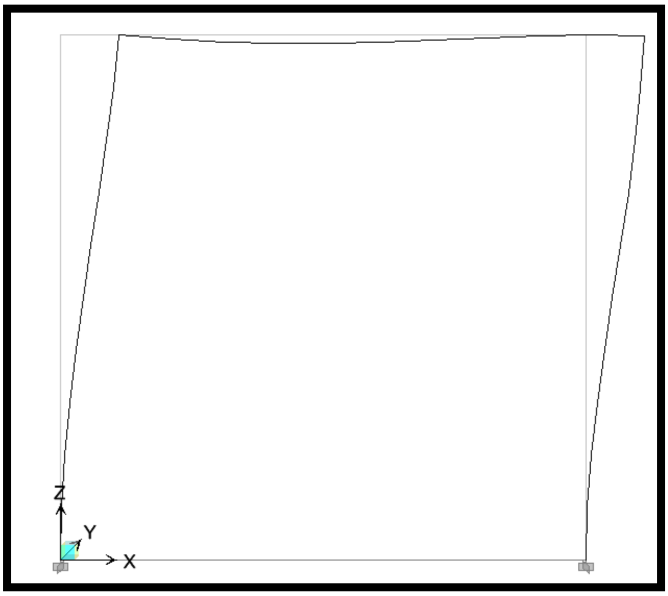
$$\bar{F}^{3} = K^{(3)}D + \hat{F}$$

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

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



Gambar L4.3 Reaksi Perletakkan *ETABS*



Dengan menggunakan metode *slope deflection*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Meninjau Titik B

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

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

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

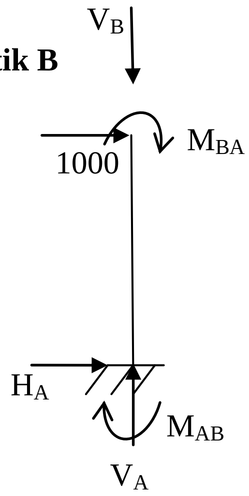
Meninjau Titik C

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

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

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

Titik B



$$M_B = 0$$

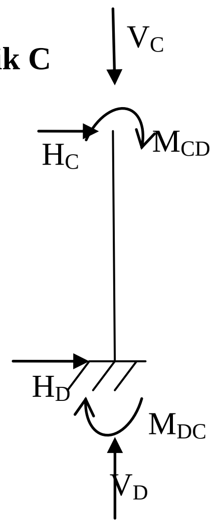
$$-4H_A + M_{AB} + M_{BA} = 0$$

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

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

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

Titik C



$$\sum M_C = 0$$

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

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

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

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

$$\sum H = 0$$

$$H_A - H_D + 1000 = 0$$

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

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

Dengan mensubstitusikan ke 3 persamaan diatas didapatkan:

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

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

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

Dengan didapatkan θ_B, θ_C,Δ maka dapat dihitung pula persamaan M_{AB}, M_{BA}, M_{BC}, M_{CB}, M_{CD}, M_{DC}.

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

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

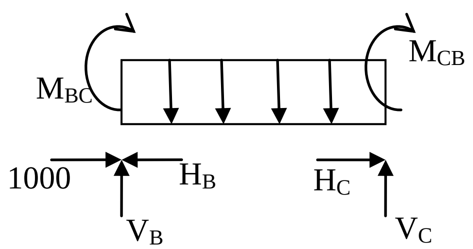
$$M_{BC} = \frac{12400}{21}\text{ kgm}$$

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

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

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

Tinjau Elemen 2



$$\sum Mc = 0$$

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

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

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

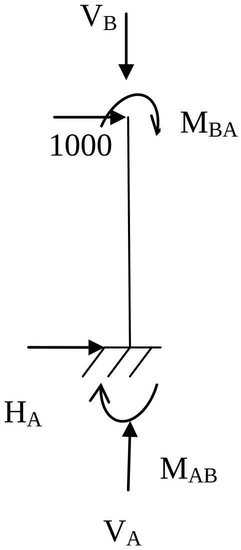
$$\sum Mc = 0$$

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

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

$$V_B = 1028,571 \text{kg}$$

Tinjau elemen 1



$$\sum M_B = 0$$

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

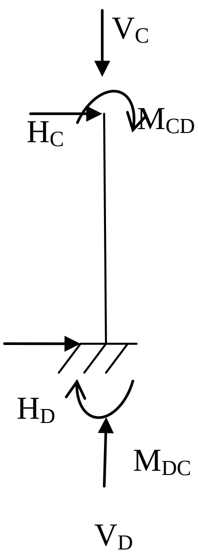
$$-\frac{21200}{21} - \frac{12400}{21} = 4H_A$$

$$H_A = -400 \text{ kg}$$

$$\sum V = 0$$

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

Tinjau elemen 3



$$\sum M_C = 0$$

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

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

$$H_D = -600 \text{ kg}$$

$$\sum V = 0$$

$$V_A = V_B = 1028,57 \text{ kg}$$