

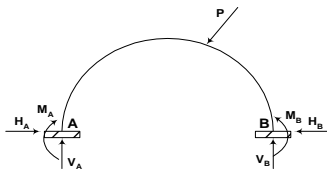
Bab 5 PELENGKUNG (ARCH)

Pelengkung merupakan suatu bentuk yang berbeda dengan bentuk-bentuk struktur yang sudah dipelajari. Pelengkung umumnya berbentuk seperti busur (arch), dapat merupakan parabola, busur lingkaran, dan lain sebagainya.

Bentuk pelengkung dapat memberikan suatu kemampuan yang lebih baik dalam menerima beban dibandingkan dengan struktur balok yang lurus / datar.

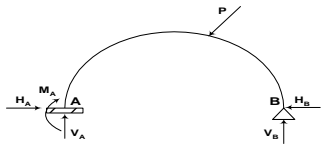
Jenis-jenis Pelengkung

1. Pelengkung Terjepit (hingeless arch)



$\mu = 6$
 $c = 0$
 $\mu > c + 3$
statis tak tentu tingkat 3

2. Pelengkung Jepit – Sendi (tidak umum)



$\mu = 5$
 $c = 0$
 $\mu > c + 3$
statis tak tentu tingkat 2

3. Pelengkung 2 Sendi (two – hinged arch)

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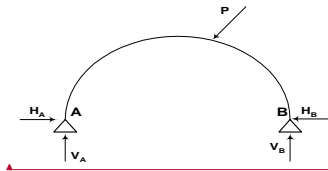
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Bab 5 halaman 2



$\mu = 4$
 $c = 0$
 $\mu > c + 3$
statis tak tentu tingkat 1

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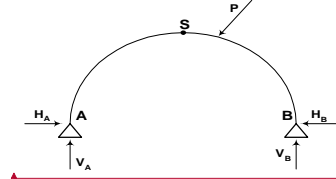
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4. Pelengkung 3 Sendi (three hinged arch)



$\mu = 4$
 $c = 1$
 $\mu = c + 3$
statis tentu

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Pada matakuliah STATIKA / Mekanika Teknik 1, hanya akan dipelajari mengenaitentang pelengkung 3 sendi.

Pelengkung dapat menahan momen yang kecil, karena momen positif yang timbul akibat beban dikurangi oleh momen negatif yang timbul akibat gaya pelengkung H.

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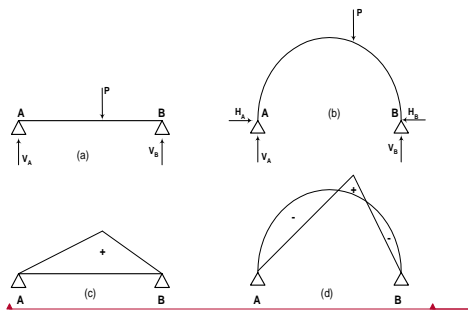
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Pada gambar (a) terlihat balok sederhana di atas dua tumpuan sendi dengan beban P , menghasilkan momen positif seperti gambar (c) akibat beban P tersebut. Jika balok sederhana pada gambar (a) diberi gaya horizontal H (ke arah dalam) pada dua tumpuan sendi A dan B, akan berubah balok sederhana menjadi pelengkung seperti gambar (b). Besarnya gaya horizontal di tumpuan A (H_A) dan di tumpuan B (H_B) adalah sama tetapi arahnya berlawanan ($H_A = -H_B$). Akibat gaya horizontal tersebut menyebabkan timbulnya momen negatif. Bayangkan terjadinya momen negatif tersebut dengan membuat potongan segmen AB secara *freebody* kiri atau *freebody* kanan. Sehingga momen positif yang diakibatkan oleh beban P akan berkurang akibat adanya momen negatif yang ditimbulkan oleh gaya horizontal. Lihat gambar (d).

Pada pelengkung akan timbul gaya aksial N yang besar, karena itu pelengkung dapat menahan beban dan bentangan yang lebih besar daripada struktur balok lurus biasa. Penggunaan struktur pelengkung sangat menguntungkan untuk bahan bangunan yang sifatnya kuat menahan gaya tekan tetapi lemah terhadap gaya tarik.

Pelengkung tidak selalu berupa struktur yang berbentuk melengkung, tetapi dapat pula berupa susunan rangka batang ataupun batang-batang lurus yang membentuk lengkung atau segitiga seperti gambar berikut.

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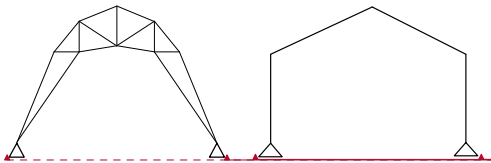
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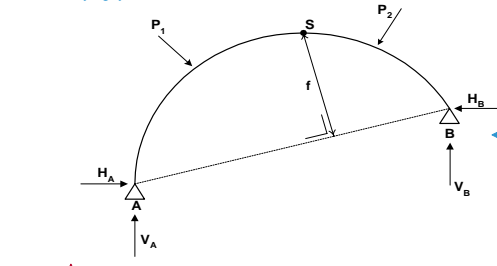
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ANALISIS REAKSI PELETAKAN PELENGKUNG TIGA SENDI

Langkah-langkah dalam menentukan reaksi peletakan pelengkung 3 sendi pada prinsipnya adalah sama dengan menentukan reaksi peletakan pada balok sederhana, yaitu dengan menggunakan 3 persamaan kesetimbangan: $\sum M = 0$, $\sum V = 0$, dan $\sum H = 0$. Berikut langkah - langkahnya :

- Buatlah persamaan momen di titik A adalah sama dengan 0 ($\sum M_A = 0$), sehingga akan diperoleh persamaan pertama dengan variabel V_B dan H_B .
- Buatlah persamaan momen di titik S adalah sama dengan 0 ($\sum M_S = 0$) dan tinjau freebody kanan, sehingga akan diperoleh persamaan kedua dengan variabel V_B dan H_B .
- Eliminasikan kedua persamaan tersebut, sehingga akan didapat besarnya gaya V_B dan H_B .



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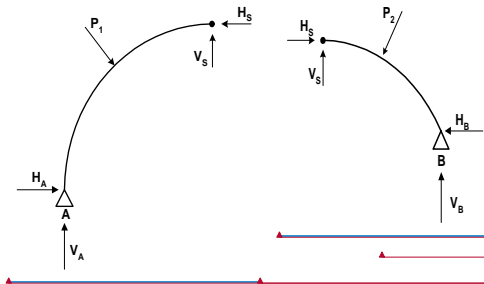
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Bab 5, halaman 5



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- d. Buatlah persamaan momen di titik B adalah sama dengan 0 ($\sum M_B = 0$), sehingga akan diperoleh persamaan ketiga dengan variabel V_A dan H_A .
- e. Buatlah persamaan momen di titik S adalah sama dengan 0 ($\sum M_S = 0$) dan tinjau freebody kiri, sehingga akan diperoleh persamaan keempat dengan variabel V_A dan H_A .
- f. Eliminasikan persamaan ketiga dan keempat tersebut, sehingga akan didapat besarnya gaya V_A dan H_A .
- g. Tinjau freebody kiri atau freebody kanan. Gunakan $\sum V = 0$ dan $\sum H = 0$ untuk memperoleh besarnya V_S dan H_S . Peninjau freebody kiri maupun freebody kanan akan mendapatkan gaya V_S dan H_S yang sama besarnya tetapi arahnya berlawanan.

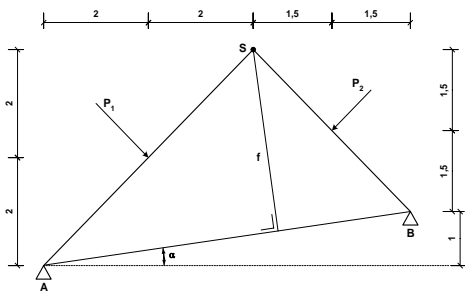
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Bab 5, halaman 6



Diketahui:

$$P_1 = 5\sqrt{2} \text{ ton}$$

$$P_2 = 3\sqrt{2} \text{ ton}$$

$$f = 2,4\sqrt{2} \text{ m}$$

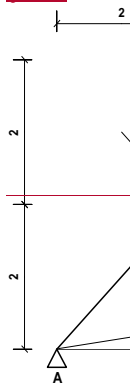
$$\operatorname{tg} \alpha = 1/7$$

Ditanya: $P_2 = 5\sqrt{2} \text{ ton}$

$$P_2 = 3\sqrt{2} \text{ ton}$$

$$f = 2,4\sqrt{2} \text{ m}$$

- a.) Hitung reaksi tumpuan di A dan di B!
b.) Tentukan persamaan dan gambar diagram gaya dalamnya!



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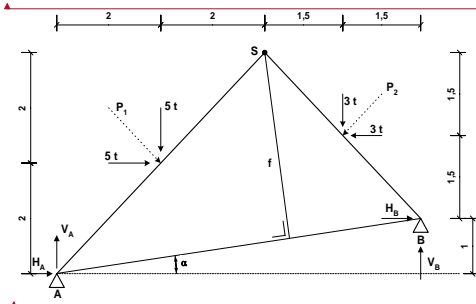
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Penyelesaian



MENGHITUNG REAKSI DI TUMPUAN

$\sum M_A = 0$

$H_B(1) + 5(2) + 5(2) + 3(5.5) - 3(2.5) - V_B(7) = 0$

$H_B + 20 + 16.5 - 7.5 - 7V_B = 0$

$7V_B - H_B = 29 \dots\dots\dots 1)$

$\sum M_B = 0$

$-H_B(3) + 3(1.5) + 3(1.5) - V_B(3) = 0$

$H_B + V_B = 3 \dots\dots\dots 2)$

Eliminasi persamaan 1 dan persamaan 2:

$7V_B - H_B = 29$

$V_B + H_B = 3$

$8V_B = 32 \leftrightarrow V_B = 4 \text{ (t)} \quad \leftrightarrow H_B = -1 \text{ (-)} = 1 \text{ (-)}$

$\sum M_B = 0$

$-H_A(1) + 5(1) - 5(5) - 3(1.5) - 3(1.5) + V_A(7) = 0$

$-H_A + 5 - 4.5 - 4.5 - 2.5 + 7V_A = 0$

$7V_A - H_A = 29 \dots\dots\dots 3)$

$\sum M_S = 0$

$-H_A(4) - 5(2) - 5(2) + V_A(4) = 0$

$-4H_A + 4V_A = 20$

$-H_A + V_A = 5 \dots\dots\dots 4)$

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Bab 5 halaman 8*

Eliminasi persamaan 3 dan persamaan 4:

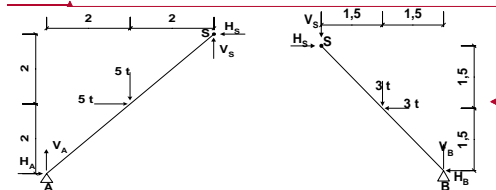
$$7V_A - H_A = 29$$

$$V_A - H_A = 5$$

$$6V_A = 24 \Leftrightarrow V_A = 4 \text{ (t)}$$

$$\Leftrightarrow H_A = -1 \text{ (-)}$$

MENGHITUNG REAKSI DI SENDI



a.) Freebody Kiri

b.) Freebody Kanan

Freebody Kiri

$$\sum H = 0$$

$$H_A + 5 - H_S = 0$$

$$-1 + 5 - H_S = 0$$

$$H_S = 4 \text{ (-)}$$

$$\sum V = 0$$

$$V_S + V_A - 5 = 0$$

$$V_S = -4 + 5$$

$$V_S = 1 \text{ (t)}$$

Freebody Kanan

$$\sum H = 0$$

$$H_S - 3 - H_B = 0$$

$$H_S - 3 - H_B = 0$$

$$H_S = 3 + 1$$

$$H_S = 4 \text{ (-)}$$

$$\sum V = 0$$

$$-V_S + V_B - 3 = 0$$

$$-V_S = 3 - 4$$

$$-V_S = -1$$

$$V_S = 1 \text{ (t)}$$

MENENTUKAN PERSAMAAN GAYA DALAM

Segmen AC ($0 \leq x_1 \leq 2$)

$$\sum M_1 = 0$$

$$M_{x_1} = -H_A(y_1) + V_A(x_1)$$

$$M_{x_1} = 1(y_1) + 4(x_1)$$

$$M_{x_1} = 5(x_1)$$

$$\sum H_1 = 0$$

$$N_{x_1} = -H_A \cos \alpha - V_A \sin \alpha$$

$$N_{x_1} = -(-1)(0.5\sqrt{2}) - 4(0.5\sqrt{2})$$

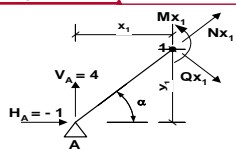
$$N_{x_1} = -2,121 \text{ ton}$$

$$\sum V_1 = 0$$

$$Q_{x_1} = H_A \sin \alpha - V_A \cos \alpha$$

$$Q_{x_1} = -1(0.5\sqrt{2}) - 4(0.5\sqrt{2}) = -$$

$$6,3639 \text{ ton}$$



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Segmen CS ($2 \leq x_2 \leq 4$)

$$\sum M_0 = 0$$

$$M_{x_2} = -H_A(y_2) + V_A(x_2) - 5(y_2 - 2) - 5(x_2 - 2)$$

$$M_{x_2} = (y_2) + 4(x_2) - 10(x_2 - 2)$$

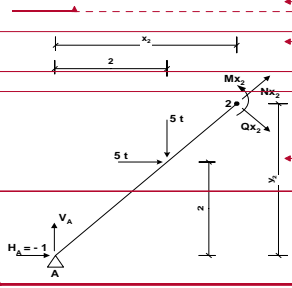
$$M_{x_2} = 5(x_2) - 10(x_2 - 2)$$

$$\sum H_0 = 0$$

$$N_{x_2} = -H_A \cos \alpha - V_A \sin \alpha - 5 \cos \alpha + 5 \sin \alpha$$

$$N_{x_2} = -(-1)(0.5\sqrt{2}) - 4(0.5\sqrt{2})$$

$$N_{x_2} = -2.121 \text{ ton}$$



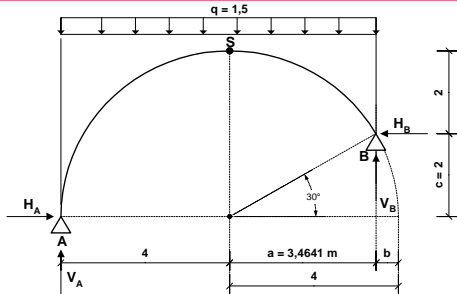
$$\sum V_1 = 0$$

$$Q_{x_1} = H_A \sin \alpha - V_A \cos \alpha$$

$$Q_{x_1} = -1(0.5\sqrt{2}) - 4(0.5\sqrt{2}) = -6.3639 \text{ ton}$$

Contoh 2

Tentukanlah persamaan gaya dalam (M,Q,N) dari struktur pelengkung 3 sendi di bawah ini! Jari-jari (r) = 4 dan q = 1,5 t/m



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$$c = r \cdot \sin 30^\circ = 4 (0,5) = 2 \text{ m}$$

$$a = c / \operatorname{tg} 30^\circ = 2 / \operatorname{tg} 30^\circ = 3,464 \text{ m}$$

$$b = 4 - a = 4 - 3,464 = 0,536 \text{ m}$$

Bab 5 halaman 10*

Menentukan Reaksi Peletakan V_A , H_A , V_B dan H_B

$$\sum M_B = 0$$

$$V_A(r+a) - H_A(c) - q \times (r+a) \times (1/2 \times (r+a)) = 0$$

$$V_A(7,4641) - H_A(2) - 1,5 \times 7,4641 \times (1/2 \times 7,4641) = 0$$

$$7,4641 V_A - 2 H_A = 41,7846 \quad \dots \text{persamaan (1)}$$

$$\sum M_S = 0 \text{ (freebody kiri)}$$

$$V_A(r) - H_A(r) - q \times r \times 0,5r = 0$$

$$V_A(4) - H_A(4) - 1,5 \times 4 \times 2 = 0$$

$$4V_A - 4H_A = 12 \quad \rightarrow 2V_A - 2H_A = 6 \quad \dots \text{persamaan (2)}$$

persamaan (1) \rightarrow (2)

$$\begin{array}{r} 7,4641 V_A - 2 H_A = 41,7846 \\ \underline{2V_A - 2H_A = 6} \\ \hline \end{array}$$

$$5,4641 V_A = 35,7846 \quad \rightarrow V_A = 6,546 \text{ t (↑)}; H_A = 3,549 \text{ t (→)}$$

$$\sum M_A = 0$$

$$-V_B(r+a) - H_B(c) + 1,5 \times (r+a) \times (1/2 \times (r+a)) = 0$$

$$-V_B(7,4641) - H_B(2) + 1,5 \times 7,4641 \times (1/2 \times 7,4641) = 0$$

$$-7,4641 V_B - 2 H_B = -41,7846 \quad \dots \text{persamaan (1)}$$

$$\sum M_S = 0 \text{ (freebody kanan)}$$

$$-V_B(a) + H_B(r-c) + q \times a \times (1/2 \times a) = 0$$

$$-V_B(3,4641) + H_B(2) + 1,5 \times 3,4641 \times (1/2 \times 3,4641) = 0$$

$$-3,4641 V_B + 2 H_B = -9 \quad \dots \text{persamaan (2)}$$

persamaan (1) \rightarrow (2)

$$\begin{array}{r} -7,4641 V_B - 2 H_B = -41,7846 \\ \underline{-3,4641 V_B + 2 H_B = -9} \\ \hline \end{array}$$

$$-10,9282 V_B = 50,7846 \quad \rightarrow V_B = 4,649 \text{ t (↑)}; H_B = 3,549 \text{ t (→)}$$

Menentukan V_S dan H_S secara freebody kiri

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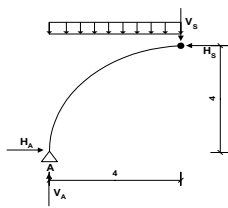
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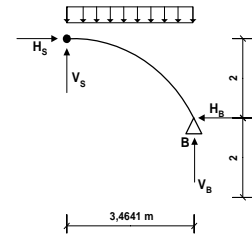
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$$\begin{aligned} \sum V_s &= 0 \\ V_s &= V_A - 1.5 \times 4 = 6.549 - 6 \\ V_s &= 0.549 \text{ (↓)} \\ \sum H_s &= 0 \\ H_s &= H_A \\ H_s &= 3.549 \text{ (←)} \end{aligned}$$

Menentukan V_s dan H_s secara freebody kanan



$$\begin{aligned} \sum V_s &= 0 \\ V_s &= -V_B + 1.5 \times 3.4641 \\ &= -4.647 + 5.1962 \\ V_s &= 0.549 \text{ (↑)} \\ \sum H_s &= 0 \\ H_s &= H_B \\ H_s &= 3.549 \text{ (←)} \end{aligned}$$

Menentukan Persamaan Gaya Dalam

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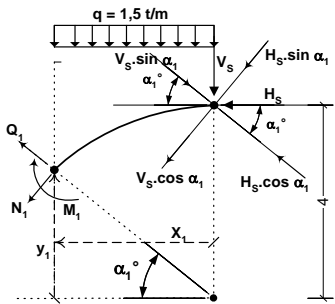
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Bab 5 halaman 12

Segmen A - S :
 $(0^\circ \leq \alpha_1 \leq 90^\circ)$ dan
 $(4 \geq x_1 \geq 0)$ dan $(0 \leq y_1 \leq 4)$

$$(x_1)^2 + (y_1)^2 = r^2 \rightarrow$$

$$y_1 = \sqrt{r^2 - x_1^2}$$

$$\alpha_1 = \text{arc tg } (y_1 / x_1)$$

Segmen A - S :

$$M_1 = -V_s(x_1) + H_s(4 - y_1) - q(x_1)(1/2 x_1)$$

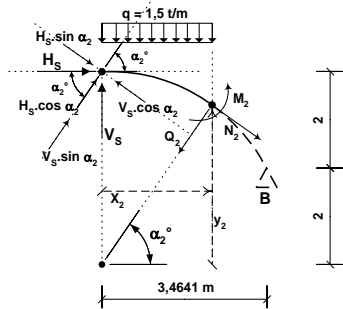
$$M_1 = -0,549(x_1) + 3,549(4 - y_1) - 0,75(x_1)^2$$

$$N_1 = -V_s \cos \alpha_1 - H_s \sin \alpha_1 - q x_1 \cos \alpha_1$$

$$N_1 = -0,549 \cos \alpha_1 - 3,549 \sin \alpha_1 - 1,5 x_1 \cos \alpha_1$$

$$Q_1 = V_s \sin \alpha_1 - H_s \cos \alpha_1 + q x_1 \sin \alpha_1$$

$$Q_1 = 0,549 \sin \alpha_1 - 3,549 \cos \alpha_1 + 1,5 x_1 \sin \alpha_1$$



Segmen S - B :
 $(30^\circ \leq \alpha_2 \leq 90^\circ)$ dan
 $(3,464 \geq x_2 \geq 0)$ dan
 $(2 \leq y_2 \leq 4)$

$$(x_2)^2 + (y_2)^2 = r^2 \rightarrow$$

$$y_2 = \sqrt{r^2 - x_2^2}$$

$$\alpha_2 = \text{arc tg } (y_2 / x_2)$$

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Bab 5 halaman 13

Segmen S – B :

$$M_2 = V_s(x_2) + H_s(4 - y_2) - q(x_2)(1/2 x_2)$$

$$M_2 = 0,549(x_2) + 3,549(4 - y_2) - 0,75(x_2)^2$$

$$N_2 = V_s \cos \alpha_2 - H_s \sin \alpha_2 - q x_2 \cos \alpha_2$$

$$N_2 = 0,549 \cos \alpha_2 - 3,549 \sin \alpha_2 - 1,5 x_2 \cos \alpha_2$$

$$Q_2 = V_s \sin \alpha_2 + H_s \cos \alpha_2 - 1,5 x_2 \sin \alpha_2$$

$$Q_2 = 0,549 \sin \alpha_2 + 3,549 \cos \alpha_2 - 1,5 x_2 \sin \alpha_2$$

Cara penggambaran diagram gaya-gaya dalam (M,N,Q) adalah sama dengan penggambaran diagram gaya dalam pada balok sederhana yaitu dengan memberikan nilai pada variabel x untuk menunjukkan lokasi titik dimana gaya dalam tersebut ditinjau. Tetapi penunjukkan lokasi titik yang ditinjau pada struktur pelengkung masih perlu memasukkan variabel lain yaitu y dan α (sudut sesuai gambar segmen yang ditinjau). Berikut hasil pentabelannya sesuai dengan persamaan-persamaan gaya dalam yang telah ditentukan sebelumnya.

Segmen A-S ($4 \geq x_1 \geq 0$)

X_1 (m)	Y_1 (m)	α_1 (degree)	M_1 (t-m)	N_1 (t)	Q_1 (t)
4.000	0.000	0.0	0.000	-6.549	-3.549
3.000	2.646	41.4	-3.591	-6.134	0.678
2.000	3.464	60.0	-2.196	-4.848	1.299
1.000	3.873	75.5	-0.848	-3.949	1.097
0.000	4.000	90.0	0.000	-3.549	0.549

Segmen S-B ($3,464 \geq x_2 \geq 0$)

X_2 (m)	Y_2 (m)	α_2 (degree)	M_2 (t-m)	N_2 (t)	Q_2 (t)
3.464	2.000	30.0	0.000	-5.799	0.750
3.000	2.646	41.4	-0.297	-5.311	0.048
2.000	3.464	60.0	0.000	-4.299	-0.348
1.000	3.873	75.5	0.250	-3.674	-0.034
0.000	4.000	90.0	0.000	-3.549	0.549

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