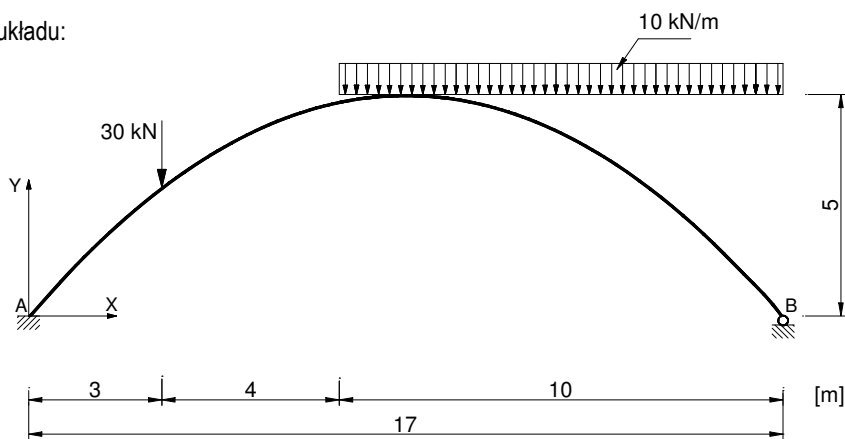


ŁUK

Schemat układu:



Stopień statycznej niewyznaczalności SSN = 2

Łuk ma kształt paraboli o równaniu:

$$y = \frac{4f}{l^2} x(l-x)$$

$$f = 5 \text{ m}$$

$$l = 17 \text{ m}$$

$$y = \frac{4 \cdot 5}{17^2} x(17-x)$$

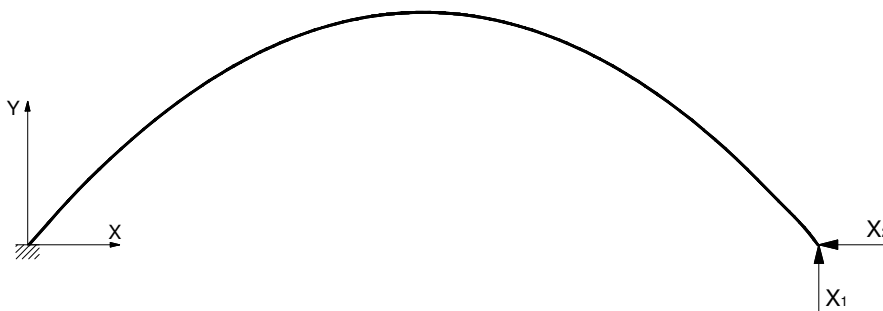
$$y = \frac{340}{289} x - \frac{20}{289} x^2$$

Funkcja stycznej w dowolnym punkcie:

$$\text{tg} \alpha = \frac{dy}{dx} = \frac{340}{289} - \frac{40}{289} x$$

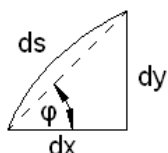
Pomijam wpływ T i N zgodnie z warunkiem $\frac{f}{l} = \frac{5}{17} \geq \frac{1}{5}$

Przyjęty układ podstawowy:



Układ równań kanonicznych:

$$\begin{cases} H = 0 \\ V = 0 \end{cases} \quad \begin{cases} \delta_{11}X_1 + \delta_{12}X_2 + \delta_{1P} = 0 \\ \delta_{21}X_1 + \delta_{22}X_2 + \delta_{2P} = 0 \end{cases} \quad \delta_{ik} = \sum_s \int \frac{M_i M_k}{EI} ds \quad \delta_{iP} = \sum_s \int \frac{M_i M_P}{EI} ds$$



$$\frac{dx}{ds} = \cos \varphi \rightarrow ds = \frac{dx}{\cos \varphi}$$

$$\delta_{ik} = \sum_s \int \frac{M_i M_k}{EI \cos \varphi} dx$$

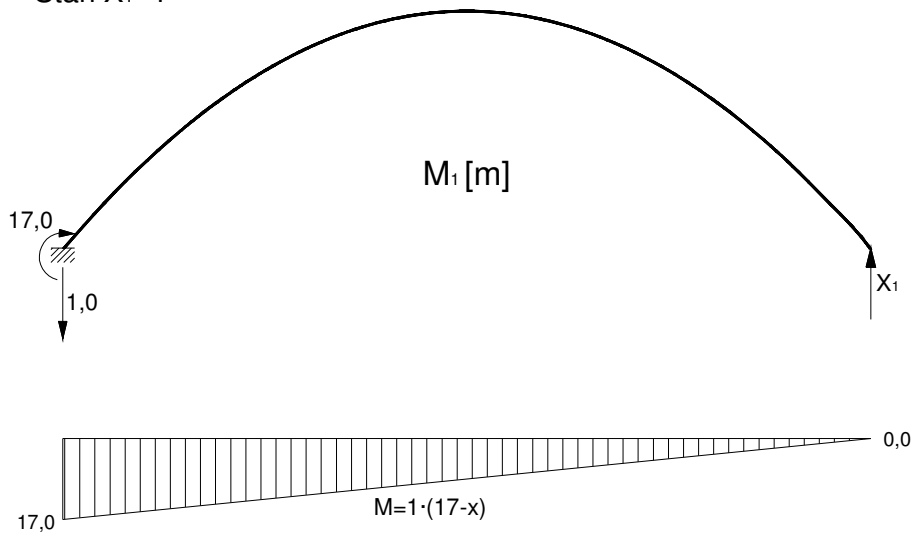
$$\delta_{iP} = \sum_s \int \frac{M_i M_P}{EI \cos \varphi} dx$$

Całki w łuku obliczone zostaną metodą Simsona:

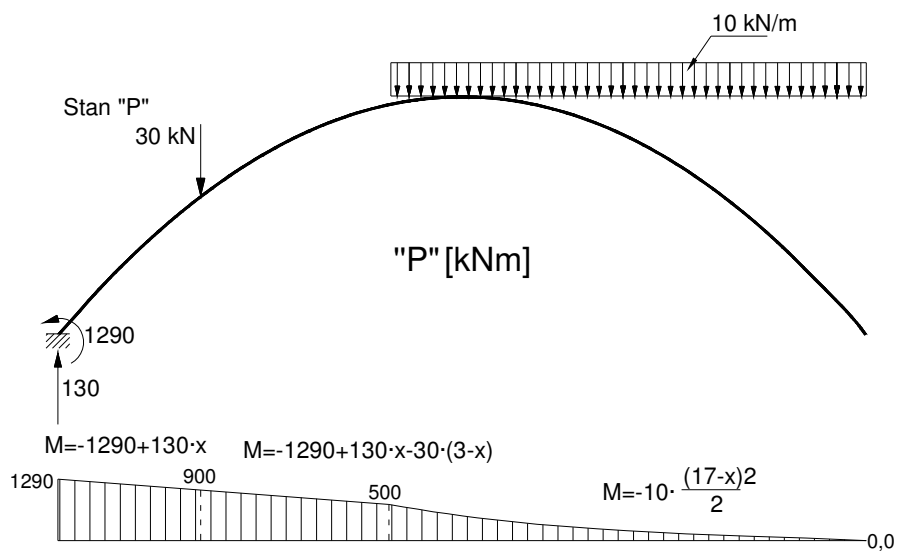
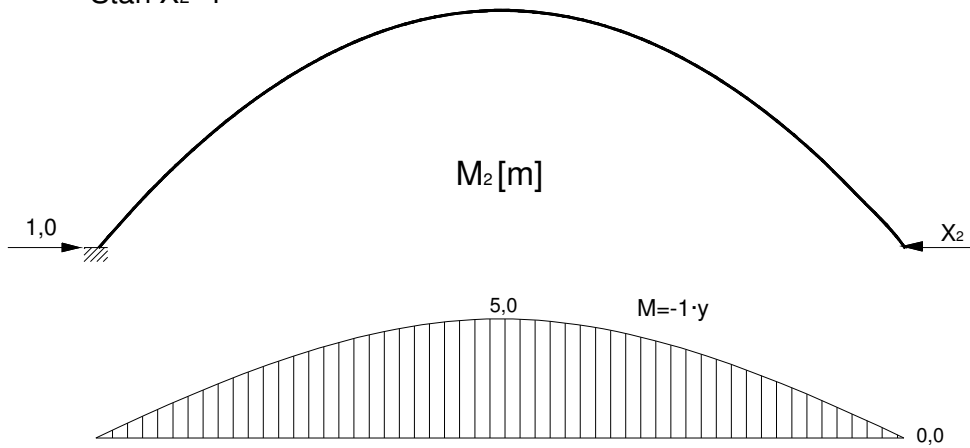
$$\int_a^b f(x) dx = \frac{\Delta x}{3} (f_0 + 4f_1 + 2f_2 + 4f_3 + \dots + 2f_{n-2} + 4f_{n-1} + f_n)$$

$$f(x) = \frac{M_i M_k}{\cos \varphi}; \quad \Delta X = 0,85 \text{ m}$$

Stan $X_1=1$



Stan $X_2=1$



Lp.	X	Y	$\frac{dy}{dx} = \operatorname{tg}\varphi$	φ	$\frac{1}{\cos \varphi}$	Stan			$\frac{M_1^2}{\cos \varphi}$	$\frac{M_2^2}{\cos \varphi}$	$\frac{M_1 M_2}{\cos \varphi}$	$\frac{M_1 M_p}{\cos \varphi}$	$\frac{M_2 M_p}{\cos \varphi}$	$M^{(n)}$
						M1	M2	MP						
0	0	0	1,17647	0,866302	1,544048	17,000	0,00	-1290,000	446,2298	0	0	-33860,96	0	20.6591
1	0,85	0,95	1,05882	0,813962	1,456402	16,150	-0,95	-1179,500	379,8625	1,314402954	-22,34485	-27742,9	1631,935	9.3265
2	1,7	1,8	0,94118	0,755104	1,373249	15,300	-1,80	-1069,000	321,4639	4,449327153	-37,81928	-22460,45	2642,406	3.9203
3	2,55	2,55	0,82353	0,688924	1,295454	14,450	-2,55	-958,500	270,494	8,423688696	-47,73424	-17942,46	3166,3159	4.4403
4	3,4	3,2	0,70588	0,614663	1,224038	13,600	-3,20	-860,000	226,3981	12,53415276	-53,27015	-14316,35	3368,5536	-1.1134
5	4,25	3,75	0,58824	0,531724	1,160181	12,750	-3,75	-775,000	188,602	16,31505021	-55,47117	-11464,04	3371,777	-14.2408
6	5,1	4,2	0,47059	0,439843	1,105194	11,900	-4,20	-690,000	156,5065	19,49561825	-55,23759	-9074,746	3202,8516	-21.4420
7	5,95	4,55	0,35294	0,339293	1,060456	11,050	-4,55	-605,000	129,4844	21,95409567	-53,31709	-7089,415	2919,171	-22.7169
8	6,8	4,8	0,23529	0,231091	1,027309	10,200	-4,80	-520,000	106,8812	23,66919421	-50,29704	-5448,846	2564,1627	-18.0655
9	7,65	4,95	0,11765	0,117109	1,006897	9,350	-4,95	-437,113	88,02542	24,67148476	-46,60169	-4115,188	2178,6292	-9.6004
10	8,5	5	0	0	1	8,500	-5,00	-361,250	72,25	25	-42,5	-3070,625	1806,25	-2.2340
11	9,35	4,95	-0,11765	-0,11711	1,006897	7,650	-4,95	-292,613	58,92611	24,67148476	-38,12866	-2253,924	1458,4212	3.8337
12	10,2	4,8	-0,23529	-0,23109	1,027309	6,800	-4,80	-231,200	47,50276	23,66919421	-33,53136	-1615,094	1140,0662	8.6027
13	11,05	4,55	-0,35294	-0,33929	1,060456	5,950	-4,55	-177,013	37,5428	21,95409567	-28,7092	-1116,898	854,09876	12.0729
14	11,9	4,2	-0,47059	-0,43984	1,105194	5,100	-4,20	-130,050	28,74609	19,49561825	-23,67325	-733,0253	603,66789	14.2444
15	12,75	3,75	-0,58824	-0,53172	1,160181	4,250	-3,75	-90,313	20,95578	16,31505021	-18,49039	-445,3102	392,92079	15.1171
16	13,6	3,2	-0,70588	-0,61466	1,224038	3,400	-3,20	-57,800	14,14988	12,53415276	-13,31754	-240,548	226,39813	14.6912
17	14,45	2,55	-0,82353	-0,68892	1,295454	2,550	-2,55	-32,513	8,423689	8,423688696	-8,423689	-107,402	107,40203	12.9665
18	15,3	1,8	-0,94118	-0,7551	1,373249	1,700	-1,80	-14,450	3,96869	4,449327153	-4,202142	-33,73386	35,71821	9.9430
19	16,15	0,95	-1,05882	-0,81396	1,456402	0,850	-0,95	-3,612	1,052251	1,314402954	-1,176045	-4,472065	4,9981902	5.6209
20	17	0	-1,17647	-0,8663	1,544048	0,000	0,00	0,000	0	0	0	0	0	0.0000
									2021,708	247,0731	-540,964	-123809,8	27064,8	
									$EI\delta_{11}$	$EI\delta_{22}$	$EI\delta_{12}=EI\delta_{21}$	$EI\delta_{1P}$	$EI\delta_{2P}$	

$$\delta_{11} = \sum \int \frac{M_1 M_1}{EI \cos \varphi} dx = \frac{2021,708}{EI}$$

$$\delta_{1P} = \sum \int \frac{M_1 M_P}{EI \cos \varphi} dx = \frac{-123809,8}{EI}$$

$$\delta_{22} = \sum \int \frac{M_2 M_2}{EI \cos \varphi} dx = \frac{247,0731685}{EI}$$

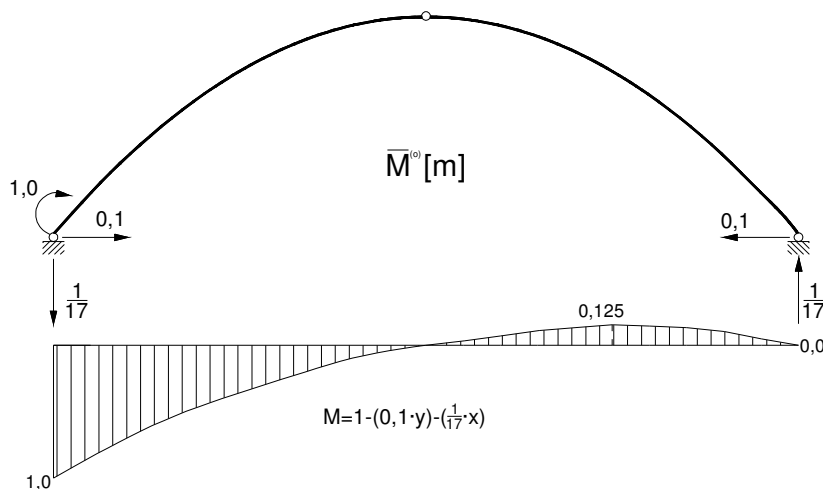
$$\delta_{2P} = \sum \int \frac{M_2 M_P}{EI \cos \varphi} dx = \frac{27064,8}{EI}$$

$$\delta_{12} = \sum \int \frac{M_1 M_2}{EI \cos \varphi} dx = \frac{-540,964}{EI}$$

$$\begin{cases} 2021,708 x_1 - 540,9640205 x_2 = 123809,82 \\ -540,9640205 x_1 + 247,0731685 x_2 = -27064,80 \end{cases} \Rightarrow \begin{cases} x_1 = 77,09751 kN \\ x_2 = 59,2626 kN \end{cases}$$

$$M^{(n)} = M_1 \cdot X_1 + M_2 \cdot X_2 + M_P$$

Sprawdzenie kinematyczne: $\bar{T} \cdot \varphi = \int \frac{\bar{M}^{(0)} M^{(n)}}{EI \cos \varphi} dx$



$\bar{M}^{(0)}$	$M^{(n)}$	$\frac{1}{\cos \varphi}$	$\frac{\bar{M}^{(0)} M^{(n)}}{EI \cos \varphi}$
1,0000	20,6591	1,5440	31,8986
0,8550	9,3265	1,4564	11,6136
0,7200	3,9203	1,3732	3,8761
0,5950	4,4403	1,2955	3,4226
0,4800	-1,1134	1,2240	-0,6542
0,3750	-14,2408	1,1602	-6,1957
0,2800	-21,4420	1,1052	-6,6353
0,1950	-22,7169	1,0605	-4,6976
0,1200	-18,0655	1,0273	-2,2271
0,0550	-9,6004	1,0069	-0,5317
0,0000	-2,2340	1,0000	0,0000
-0,0450	3,8337	1,0069	-0,1737
-0,0800	8,6027	1,0273	-0,7070
-0,1050	12,0729	1,0605	-1,3443
-0,1200	14,2444	1,1052	-1,8891
-0,1250	15,1171	1,1602	-2,1923
-0,1200	14,6912	1,2240	-2,1579
-0,1050	12,9665	1,2955	-1,7637
-0,0800	9,9430	1,3732	-1,0923
-0,0450	5,6209	1,4564	-0,3684
0,0000	0,0000	1,5440	0,0000
		Σ	-1,3E-12

$$EI \cdot \varphi_A = -1,3 \cdot 10^{-12} \approx 0$$

Wyznaczenie funkcji siły normalnej N i tnącej T od zmiennej φ :

- $x \in \langle 0,3 \rangle$

$$T = 52,9024 \cdot \cos \varphi - 59,2627 \cdot \sin \varphi$$

$$N = -52,9024 \cdot \sin \varphi - 59,2627 \cdot \cos \varphi$$

- $x \in \langle 3,7 \rangle$

$$T = 52,9024 \cdot \cos \varphi - 59,2627 \cdot \sin \varphi - 30 \cdot \cos \varphi$$

$$N = -52,9024 \cdot \sin \varphi - 59,2627 \cdot \cos \varphi + 30 \cdot \sin \varphi$$

- $x \in \langle 7,12 \rangle$

$$T = 52,9024 \cdot \cos \varphi - 59,2627 \cdot \sin \varphi - 30 \cdot \cos \varphi - 10 \cdot (x - 7) \cdot \cos \varphi$$

$$N = -52,9024 \cdot \sin \varphi - 59,2627 \cdot \cos \varphi + 30 \cdot \cos \varphi + 10 \cdot (x - 7) \cdot \sin \varphi$$

