Poznan University of Technology
Institute of Civil Engineering
Division of Road Engineering

Name and surname:
Sustainable Building Engineering first cycle
semester 6
academic year 2020/21

Thematic card of the course
Fundamentals of Road Construction
Design of section of the public road

The data for the design:

The map with contour line in the scale of 1: 5000.

Road class: "Z"

Design speed: 50 km/h

Number of roadway: 1

Number of traffic lanes: 2

Traffic category: KR2

The load-bearing capacity group of the subgrade: G1 (non-shed soil)

Coordinates of the start "A" and end "B" points of the horizontal alignment on MAP no 1:

	X [m]	Y [m]
A	**65**	**1180**
B	**1820**	**160**

The project should include:

Description part:

1. Technical description.
2. Geometric elements of the horizontal alignment.
3. Mileage of the horizontal alignment.
4. Land leveling log.
5. Geometric elements of the vertical alignment.
6. Example road surface construction.

Drawing part:

1. Indicative plan on a scale of 1: 5000,
2. Longitudinal profile in scale 1: 5000/500.
3. Normal sections on a scale of 1: 50.

Issued date: 2021/03/01 The project completion date: 2021/06/18

The project was issued by: Marcin Bilski, BEng, PhD

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1. TECHNICAL DESCRIPTION

1.1 Topic of the review

The subject of the study is a design of a section of a two-way public road of the collective class - "Z", outside the development area, with a single carriageway cross-section with two traffic lanes. The roadway is not bounded on any side by a curb.

1.2 Base of the review

The basis of the study is:

The topic of the design exercise in the subject "Basics of road engineering" with a contour map at a scale of 1: 5000,

Regulation of the Minister of Transport and Maritime Economy of 2 March 1999 on the technical conditions to be met by public roads and their location (consolidated text, Journal of Laws of 2016, item 124, as amended),

Regulation of the Minister of Transport and Maritime Economy of 30 May 2000 on the technical conditions to be met by road engineering structures and their location (Journal of Laws No. 63, item 735, as amended),

Catalog of typical flexible and semi-rigid pavement structures, General Directorate for National Roads and Motorways, Warsaw 2014, Polish standards.

1.3 Technical parameters of the road

No.	Parameter	Symbol	Unit	Value
1.	Design speed	v_p	km/h	60
2.	Number of roads	–	–	1
3.	Number of lanes	–	–	2
4.	Lane width	s	m	3,00
5.	Shoulder width	p	m	1,00
6.	The straight line slope of the lane for the planned route	i_n	%	2,0
7.	Straight line shoulder slope for planned route	–	%	6
8.	Maximum applied transverse slope on a circular arc in the plan	i_o	%	3
9.	The greatest allowable additional roadway inclination	i_{dmax}	%	1,6
10.	The smallest permissible additional slope of the road edge on the section with a transverse slope ≤ 2%`	i_{dmin}	%	0,3
11.	The greatest permissible length of a straight section for a route in the plan	–	m	1000
12.	The greatest straight length used for a route in the plan	–	m	841,91

13.	The smallest permissible length of a straight section between curvilinear sections with the same turning direction for the route in the plan	–	m	250
14.	The smallest permissible radius of a circular arc in the plan	–	m	150
15.	The smallest applied radius of a circular arc in the plan	–	m	350
16.	Largest applied radius of a circular arc in the plan	–	m	350
17.	Allowable increase in centripetal acceleration	k	m/s^3	0,7
18.	Minimum allowable road grade inclination	–	%	0,3
19.	Minimum allowable slope	–	%	0,5
20.	Minimmum used inclination of the road grade line	–	%	0,382
21.	Maximum allowable road grade inclination	–	%	8
22.	Maximum permissible inclination of the road grade line on the bridge structure	–	%	4
23.	Maximum inclination of the road grade line	–	%	1,795
24.	Minimum allowable radius of a convex curve	–	m	2500
25.	The minimum radius of a concave curve to be used	–	m	7000
26.	Minimum permissible radius of a concave curve	–	m	1500
27.	The minimum radius of a concave curve to be used	–	m	4000
28.	Slope of the embankments and excavations	–	1:n	1:1,5
29.	Maximum height of the embankment	h	m	5,13
30.	Maximum embankment depth	h	m	2,60
31.	Road gauge height	–	m	4,60
32.	Permissible load of a single driving axle on the road surface	–	kN	115
33.	Design life of the pavement	–	year	20
34.	Traffic category	–	–	KR5

1.4 The area surrounding the road

The area along which the planned road runs is of a lowland character. There are gentle undulations of the terrain, but there is no need to overcome high hills or deep valleys. The gentle gradients enable the design of an optimally short path. The highest point is 45.30 m above sea level, while the lowest is 31.00 m above sea level. designated by a river flowing from south to north.

1.5 Road grade plan

The starting point of the route is 24,70 m above sea level. and its end at 55.01 m above sea level. The designed grade line of the road consists of four sections with gradients of 0.382%; 1.050%; 0.490%; 1.795%. The route has 3 slopes of the grade line, which are rounded with arcs with a radius of 7000m, 4000m and 7000m.

1.6 Construction of the road Surface

For the KR2 category, the TYPE B pavement structure solution for the upper layers and TYPE 1 for the lower layers of the structure were adopted:

- wearing course made of mineral-asphalt mixture 4 cm
- 8 cm asphalt concrete binding layer
- 18 cm asphalt concrete base layer
- a layer of auxiliary substructure made of a mixture bound with a hydraulic binder 15 cm
- family land in a trench or embankment soil.

2. GEOMETRIC ELEMENTS OF THE HORIZONTAL ALIGNMENT

2.1 Coordinates of the route vertex points in the plan

Point	Coordinates [m]	
	X	Y
A	65,0	1180,0
W_1	989,0	1384,0
B	1820,0	160,0
W_2	1056,0	175,0

2.2 Distances between vertex points

$$AW1 = \sqrt{(W_{1x} - A_x)^2 + \left(W_{1y} - A_y\right)^2}$$

$$AW1 = \sqrt{(989 - 65)^2 + (1384 - 1180)^2} = 946\ m$$

$$BW2 = \sqrt{(W_{2x} - B_x)^2 + \left(W_{2y} - B_y\right)^2}$$

$$BW2 = \sqrt{(1056 - 1820)^2 + (175 - 160)^2} = 764\ m$$

$$W1W2 = \sqrt{(W_{1x} - W2_x)^2 + \left(W_{1y} - W_{2y}\right)^2}$$

$$W1W2 = \sqrt{(989 - 1056)^2 + (1384 - 175)^2} = 1211\ m$$

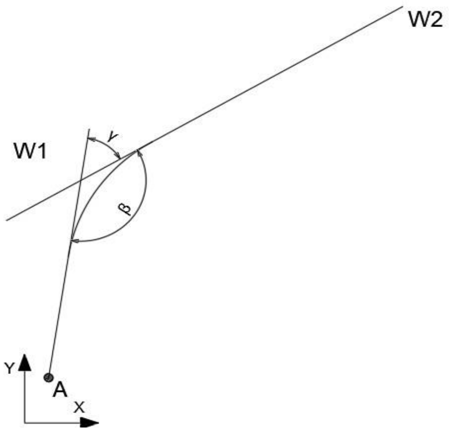
$$AW2 = \sqrt{(A_x - W_{2x})^2 + \left(A_y - W_{2y}\right)^2}$$

$$AW2 = \sqrt{(65 - 1056)^2 + (1180 - 175)^2} = 1411\ m$$

$$BW1 = \sqrt{(B_x - W_{1x})^2 + \left(B_y - W_{1y}\right)^2}$$

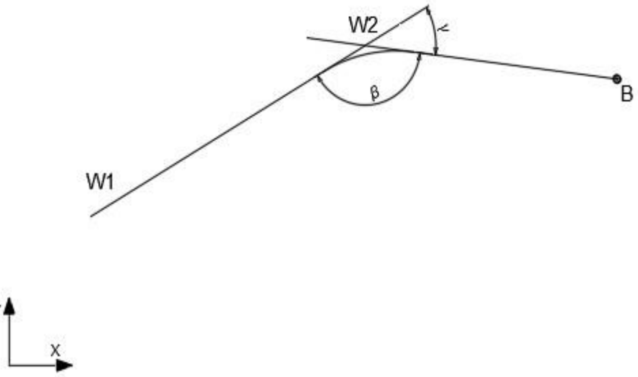
$$BW1 = \sqrt{(1820 - 989)^2 + (160 - 1384)^2} = 1479\ m$$

2.3 Route turning angles in the plan



$$\propto = 180° - arccos\frac{(Aw1^2 - Aw2^2 + W1W2^2)}{2 * AW1 * W1W2}$$

$$\propto = 180° - arccos\frac{(946^2 - 1411^2 + 1211^2)}{2 * 946 * 1211} = 99{,}1° = 1{,}73rad$$



$$\propto = 180° - arccos\frac{(W1W2^2 - W1B^2 + W2B^2)}{2 * W1W2 * W2B}$$

$$\propto = 180° - arccos\frac{(1211^2 - 1479^2 + 764^2)}{2 * 1211 * 764} = 85{,}9° = 1{,}5rad$$

	Route turning angle in the plan ∝	
	[º]	[rad]
$\propto_1$	99,1	1,73
$\propto_2$	85,9	1,5

2.4 Winding stretch of the road

$$K = \frac{\sum_{i=1}^{n} |\gamma_n|}{L} \ [°/km], \text{gdzie}$$

$$K = \frac{99{,}1 + 85{,}9}{2{,}92} = 63{,}36°/km$$

2.5 Adopting parameters of circular arches for the route in the plan

	R(1) [m]	**i_o [%]**	**Section scheme**
W1	350	3,0	one-sided tilt
W2	350	3,0	one-sided tilt

2.6 Checking the adopted circular arches for the route in the plan

a) Roll-over stability condition

$$R_{min} = \frac{v^2}{g \cdot \left(\frac{b}{2h} \pm i_0\right)}, [m]$$

$$R_{min}^{(2)} = \frac{13{,}89^2}{9{,}81 * (\frac{1{,}5}{2 * 1{,}2} + 0{,}03)} = 30{,}03\ m$$

	i_o [%]	**$R_{min\ (2)}$ [m]**	
		+ i_o	**− i_o**
W1	3,0	**30,03**	—
W2	3,0	**30,03**	—

b) Casting stability condition

$$R_{min} = \frac{v^2}{g \cdot (\varphi_R \pm i_0)}, [m]$$

$$R_{min}^{(3)} = \frac{13{,}89^2}{9{,}81 * (0{,}2 + 0{,}03)} = 85{,}51\ m$$

	i_o [%]	**$R_{min\ (3)}$ [m]**	
		+ i_o	**− i_o**
W1	3,0	**85,51**	—
W2	3,0	**85,51**	—

c) Driving comfort condition

$$R_{min} = \frac{v^2}{g \cdot (\mu \pm i_0)} , [m]$$

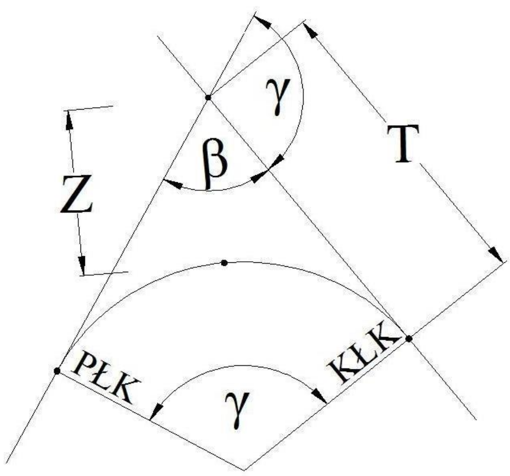
$$R_{min}^{(4)} = \frac{13{,}89^2}{9{,}81 * (0{,}1 + 0{,}03)} = 151{,}28\, m$$

	i_0 [%]	$R^{(4)}_{min}$	
		+ i_0	**− i_0**
W1	3,0	**151,28**	—
W2	3,0	**151,28**	—

A LIST OF ALL R_{min}

	$R_{min}^{(1)}$	$R_{min}^{(2)}$	$R_{min}^{(3)}$	$R_{min}^{(4)}$	i_0[%]	R [m]
W1	350	30,03	85,51	151,28	3,0	**350**
W2	350	30,03	85,51	151,28	3,0	**350**

2.7 Calculation of the basic elements of the circular arch



$$T1 = R * tg\frac{\propto}{2}$$

$$f = R * (\frac{1}{cos\frac{\propto}{2}} - 1)$$

$$S = \frac{\pi * R * \alpha}{180}$$

2.7.1 Arc 1

$\propto = 99{,}1^{\circ}$ $R_1 = 350$ m

$$T1 = 350 * tg\frac{99{,}1}{2} = 416{,}5\ m$$

$$f1 = 350 * \left(\frac{1}{cos\frac{1{,}73}{2}} - 1\right) = 196{,}88\ m$$

$$S1 = \frac{\pi * 350 * 99{,}1}{180} = 605{,}06\ m$$

2.7.2 Arc 2

$$T2 = 350 * tg\frac{85{,}9}{2} = 339{,}5\ m$$

$$f2 = 350 * \left(\frac{1}{cos\frac{1{,}5}{2}} - 1\right) = 129{,}45\ m$$

$$S2 = \frac{\pi * 350 * 85{,}9}{180} = 524{,}47\ m$$

2.8 Calculation of the widening on the arc

$$\frac{40}{R} = \frac{40}{350} = 0{,}11\ m$$

	R [m]	$\propto$ [°]	T [m]	f [m]	S [m]	$\frac{40}{R}$
Arc 1	350	99,1	416,5	196,88	605,06	0,11
Arc 2	350	85,9	339,5	129,45	524,47	0,11

2.9 Determining the"a" parameter of the clothoid

a) Dynamic condition

$$a_{min} = \sqrt{\frac{v^3}{k}}\ [m]$$

$$k\ for\ 50\frac{km}{h} = 0{,}8\frac{m}{s^3}$$

$$a_{min} = \sqrt{\frac{13{,}89}{0{,}8}} = 57{,}88\ m$$

b) Esthetic condition

$$a_{min} = \frac{1}{3}R\ [m]$$
$$a_{max} = R\ [m]$$

$$a_{min} = \frac{1}{3} * 350 = 116{,}67\ m$$

$$a_{max} = 350\ m$$

	R [m]	a_{min} [m]	a_{max} [m]
Arc 1	**350**	**116,67**	**350**
Arc 2	**350**	**116,67**	**350**

c) Construction of the road ramp condition

$$a_{min} = \sqrt{\frac{R \cdot B}{2} \cdot \frac{i_n + i_0}{i_{d\,max}}}\ [m]$$

$$i_{d\,min} = 0{,}1 \cdot \frac{B}{2} = 0{,}1 \cdot \frac{6}{2} = 0{,}3\%$$

$$i_{d\,max} = 1{,}6\%\ for\ v = 50\frac{km}{h}$$

$$0{,}003\ \leq\ id\ \leq\ 0{,}016;\ assumed\ id\ =\ 0{,}016$$

$$a_{min} = \sqrt{\frac{350 \cdot 6}{2} \cdot \frac{0{,}02 + 0{,}03}{0{,}016}} = 57{,}28m$$

	R [m]	B [m]	i_n [%]	i_o [%]	i_d [%]	a_{min} [m]
Arc 1	350	6,00	2,0	3,0	1,6	**57,28**
Arc 2	350	6,00	2,0	3,0	1,6	**57,28**

d) Geometric condition

$$a_{max} = R \cdot \sqrt{\gamma}\ [m]$$

$$a_{1\,max} = 350\ *\ \sqrt{1{,}73} = 460{,}35\ m$$

$$a_{2\,max} = 350\ *\ \sqrt{1{,}5} = 428{,}66\ m$$

	R [m]	**γ** [rad]	a_{max} [m]
Arc 1	350	1,73	**460,35**
Arc 2	350	1,5	**428,66**

e) Circular arc displacement condition

$$a_{min} = 1{,}863 \cdot 350^{\frac{3}{4}} = 150{,}75\ m$$

$$a_{max} = 2{,}783 \cdot 350^{\frac{3}{4}} = 225{,}20 m$$

	R [m]	**a_{min} [m]**	**a_{max} [m]**
Arc 1	350	**150,75**	**225,20**
Arc 2	350	**150,75**	**225,20**

f) Proportionality condition

$$a_{min} = R \cdot \sqrt{\frac{\gamma}{5}}\ [m]$$

$$a_{max} = R \cdot \sqrt{\frac{\gamma}{2}}\ [m]$$

$$a_{1\ min} = 350 * \sqrt{\frac{1{,}73}{5}} = 205{,}88\ m$$

$$a_{2\ min} = 350 * \sqrt{\frac{1{,}5}{5}} = 191{,}70\ m$$

$$a_{1\ max} = 350 * \sqrt{\frac{1{,}73}{2}} = 325{,}52\ m$$

$$a_{2\ max} = 350 * \sqrt{\frac{1{,}5}{2}} = 303{,}11\ m$$

	R [m]	γ [rad]	**a_{min} [m]**	**a_{max} [m]**
Arc 1	350	1,73	**205,88**	**325,52**
Arc 2	350	1,5	**191,70**	**303,11**

2.10 LIST OF ALL „a" PARAMETERS

	R [m]	**a_{min} [m]** dynamic	**a_{min} [m]** esthetic	**a_{min} [m]** construction	**a_{min} [m]** displacement	**a_{min} [m]** proportion
Arc 1	350	57,88	116,67	57,28	150,75	205,88
Arc 2	350	57,88	116,67	57,28	150,75	191,70

	R [m]	**a_{max} [m]** esthetic	**a_{max} [m]** geometric	**a_{max} [m]** displacement	**a_{max} [m]** proportion
Łuk 1	350	350	460,35	225,20	325,52
Łuk 2	350	350	428,66	225,20	303,11

2.11 „a" PARAMETER ASSUMING

$$a_{min}^{(\max)} \leq a \leq a_{max}^{(\min)}$$

	R [m]	$a_{min}^{(\max)}$ $[m]$	$a_{max}^{(\min)}$ $[m]$	**a [m]**
Arc 1	350	205,88	225,20	**215,54**
Arc 2	350	191,70	225,20	**208,45**

2.12 Calculation of the characteristic values of a clothoidal transition curve

a) Clothoid length

$$L = \frac{a^2}{R}\,[m]$$

$$L_1 = \frac{215{,}54^2}{350} = 132{,}74\,m$$

$$L_2 = \frac{208{,}48^2}{350} = 124{,}18\,m$$

	R [m]	a [m]	**L [m]**
Arc 1	350	215,54	**132,74**
Arc 2	350	208,48	**124,18**

b) Tangent angle at the end of the transition curve

$$\tau = \frac{L}{2 \cdot R}\ [rad]$$

$$\tau_{min} = 3° \leq \tau \leq \tau_{max} = 30°$$

$$\tau_{1\,min} = \frac{132{,}74}{2 * 350} = 0{,}1896\, rad$$

$$\tau_{1\,min} = \frac{124{,}18}{2 * 350} = 0{,}1774\, rad$$

	R [m]	**L** [m]	τ [rad]	[°]
Arc 1	350	132,74	0,1896	**10,86**
Arc 2	350	124,18	0,1774	**10,16**

c) Coordinates of the end of the transition curve

$$X = L - \frac{L^5}{40a^4} + \frac{L^9}{3456a^8} - (\ldots)[m]$$

$$Y = \frac{L^3}{6a^2} - \frac{L^7}{336a^6} + \frac{L^{11}}{42240a^{10}} - (\ldots)[m]$$

$$X_1 = 132{,}74 - \frac{132{,}74^5}{40 * 215{,}54^4} + \frac{132{,}74^9}{3456 * 215{,}54^8} = 132{,}26\text{ m}$$

$$X_2 = 124{,}18 - \frac{124{,}18^5}{40 * 208{,}45^4} + \frac{124{,}18^9}{3456 * 208{,}45^8} = 123{,}79\text{ m}$$

$$Y_1 = \frac{132{,}74^3}{6 * 215{,}54^2} - \frac{132{,}74^7}{336 * 215{,}54^8} + \frac{132{,}74^{11}}{42240 * 215{,}54^{10}} = 8{,}39\text{ m}$$

$$Y_2 = \frac{124{,}18^3}{6 * 208{,}45^2} - \frac{124{,}18^7}{336 * 208{,}45^8} + \frac{124{,}18^{11}}{42240 * 208{,}45^{10}} = 7{,}35\text{ m}$$

	L [m]	**a** [m]	**X** [m]	**Y** [m]
Arc 1	132,74	215,54	**132,26**	**8,39**
Arc 2	124,18	208,45	**123,79**	**7,35**

d) Coordinates of the center of circular arc

$$X_s = X - (R * sin\tau)[m] \qquad Y_s = Y + (R * sin\tau)[m]$$

$$X_{s\,1} = 132{,}26\text{-}(350 * \sin(0{,}1896)) = 66{,}30\text{ m}$$

$$X_{s\,2} = 123{,}79\text{-}(350 * \sin(0{,}1774)) = 62{,}03\text{ m}$$

$$Y_{s\,1} = 8{,}39 + (350 * \cos(0{,}1896)) = 352{,}12\text{ m}$$

$$Y_{s\,2} = 7{,}35 + (350 * \cos(0{,}1774)) = 351{,}86\text{ m}$$

	R [m]	**X** [m]	**Y** [m]	τ [rad]	**Xs** [m]	**Ys** [m]
Arc 1	350	132,26	8,39	0,1896	**66,30**	**352,12**
Arc 2	350	123,79	7,35	0,1774	**62,03**	**351,86**

e) Circular arc offset

$$H = YC_i - R * (1 - cos\tau)[m]$$

$$H_{min} = 0{,}5m \leq H \leq H_{max} = 2{,}5\ m$$

$$H_1 = 8{,}39\text{-}350*(1\text{-}cos(0{,}1896)) = 2{,}12\ m$$

$$H_2 = 7{,}35\text{-}350*(1\text{-}cos(0{,}1744)) = 1{,}86\ m$$

	R [m]	**Y** [m]	τ [rad]	**H** [m]
Arc 1	350	8,39	0,1896	**2,12**
Arc 2	350	7,35	0,1774	**1,86**

f) Normal

$$N = \frac{Y}{\cos\tau}\ [m]$$

$$N_1 = \frac{8{,}39}{\cos(0{,}1896)} = 8{,}54\ m$$

$$N_2 = \frac{7{,}35}{\cos(0{,}1774)} = 7{,}47\ m$$

	Y [m]	τ [rad]	N [m]
Arc 1	8,39	0,1896	**8,54**
Arc 2	7,35	0,1774	**7,47**

g) Short tangent

$$T_K = \frac{Y}{\sin\tau}\ [m]$$

$$T_k = \frac{8{,}39}{\sin(0{,}1896)} = 44{,}52\ m$$

$$T_k = \frac{7{,}35}{\sin(0{,}1774)} = 41{,}65\ m$$

	Y [m]	τ [rad]	**T_k** [m]
Arc 1	8,39	0,1896	**44,52**
Arc 2	7,35	0,1774	**41,65**

h) Long tangent

$$T_D = X - Y \cdot \cot\tau \ [m]$$

T_{D1} = 132,26 -8,39*cot(0,1896) = 88,54 m

T_{D2} = 123,79 -8,39*cot(0,1774) = 76,99 m

	X [m]	**Y** [m]	τ [rad]	**T$_D$** [m]
Arc 1	132,26	8,39	0,1896	**88,54**
Arc 2	123,79	7,35	0,1774	**76,99**

i) Section T_s

$$T_S = (R + H) \cdot \tan\frac{\gamma}{2} \ [m]$$

$T_{S1} = (350 + 2{,}12)*\tan(\frac{1{,}73}{2}) = 413{,}17$ m

$T_{S2} = (350 + 1{,}86)*\tan(\frac{1{,}50}{2}) = 327{,}79$ m

	R [m]	**H** [m]	**γ** [rad]	**T$_s$** [m]
Arc 1	350	2,12	1,73	**413,17**
Arc 2	350	1,86	1,50	**327,79**

j) Total tangent

$$T_0 = X_S + T_S \ [m]$$

$T_{01} = 66{,}30 + 413{,}17 = 479{,}47\ m$

$T_{02} = 62{,}03 + 327{,}79 = 389{,}82\ m$

	X$_s$ [m]	**T$_s$** [m]	**T$_0$** [m]
Arc 1	66,30	33,48	**479,47**
Arc 2	62,03	30,76	**389,82**

k) Central angle of the reduced arc

$$\alpha = \gamma - 2 \cdot \tau \ [m]$$

α_1 = 1,73-2-2*0,1896 = 1,35 m

α_2 = 1,50-2*0,1774 = 1,15 m

	γ [rad]	τ[rad]	α [rad]	[°]
Arc 1	1,73	0,1896	1,35	**77,35**
Arc 2	1,50	0,1744	1,15	**75,89**

l) Length of the reduced circle arc

$$Ł = R \cdot \alpha \ [m]$$

$$Ł_1 = 350 * 1,35 = 472,5\ m$$

$$Ł_2 = 350 * 1,15 = 402,5\ m$$

	R [m]	α [rad]	**Ł** [m]
Arc 1	350	1,35	**472,50**
Arc 2	350	1,15	**402,50**

3. MILEAGE OF THE HORIZONTAL ALIGNMENT

$+AW_1$	+	946,00	
		0+946,00	W_1
$-T01$	–	479,47	
		0+466,53	PKP_1
$+L_1$	+	132,74	
		0+599,27	$KKP_1=PŁK_1$
$+Ł_1/2$	+	236,25	
		0+835,52	ŚŁK1
$+Ł_1/2$	+	236,25	
		0+1071,77	$KŁK_1=KKP_1$
$+L_1$	+	132,74	
		0+1204,51	PKP_1
$-T01$	–	479,47	
		0+725,04	W_1*
$+W_1W_2$	+	1211,00	
		1+936,04	W_2
$-T02$	–	389,82	
		1+546,22	PKP_2
$+L_2$	+	124,18	
		1+670,40	$KKP_2=PŁK_2$
$+Ł_2/2$	+	201,25	
		1+871,65	ŚŁK2
$+Ł_2/2$	+	201,25	
		2+072,90	$KŁK_2=KKP_2$
$+L_2$	+	124,18	
		2+197,08	PKP_2
$-T02$	–	389,82	
		1+807,26	W_2*
$+W_2B$	+	764,00 →	2+571,26

4. LAND LEVELING LOG

No.	Kilometration	Ordinate [m]
0.	0+000,00	24,20
1.	0+100,00	24,80
2.	0+200,00	25,00
3.	0+300,00	26,00
4.	0+400,00	26,50
5.	0+500,00	26,80
6.	0+600,00	27,00
7.	0+700,00	25,50
8.	0+800,00	24,90
9.	0+900,00	23,50
10.	1+000,00	22,50
11.	1+100,00	21,00
12.	1+200,00	20,00
13.	1+300,00	20,00
14.	1+400,00	20,00
15.	1+500,00	20,00
16.	1+600,00	20,00
17.	1+700,00	20,00
18.	1+800,00	21,50
19.	1+900,00	24,00
20.	2+000,00	25,80
21.	2+100,00	27,20
22.	2+200,00	28,80
23.	2+300,00	31,00
24.	2+400,00	33,00
25.	2+500,00	34,80
26.	2+600,00	37,50

5. GEOMETRIC ELEMENTS OF THE VERTICAL ALIGNMENT

5.1 Determining the parameters of the road grade line on sections with a constant slope

a) ordinate of the grade points of the line

Point	Mileage	Ordinate [m.n.p.m.]
A	0+000,00	24,20
Z1	1+200,00	20,00
Z2	1+700,00	20,00
B	2+600,00	37,50

b) inclination of the grade line on sections with constant inclination

$$i = \frac{H_k - H_p}{L} * 100 \ [m]$$

$$i_{n1} = \frac{20 - 24{,}20}{200} * 100 = -2{,}1\%$$

$$i_{n2} = \frac{20 - 37{,}50}{900} * 100 = -1{,}94\%$$

$$i_{n3} = 0\%$$

c) the angle of refraction of the grade line

$$\alpha = |i_n - i_{n+1}| \ [\%]$$

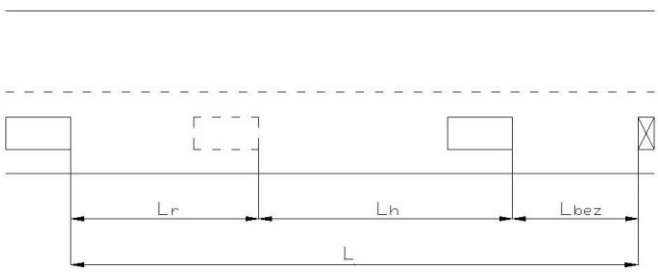
$$\alpha = |-2{,}1 + 1{,}94| = 0{,}16\%$$

d) average inclination of the grade line

$$i_{śr} = \frac{i_n + i_{n+1}}{2}$$

$$i_{śr} = \frac{-2{,}1 + (-1{,}94)}{2} = -2{,}02 \qquad i_{śr} = \frac{1{,}94 + 0}{2} = -0{,}97$$

5.2 Determination of the stopping visibility distance required



$$L = L_r + L_h + L_{bez}$$

$$L_z \geq L = v \cdot t + \frac{v^2}{2 \cdot g \cdot (0{,}95 \cdot \varphi + f - |i_{śr}|} + 10 \ [m]$$

$$L_z \geq 19{,}44 * 1 + \frac{19{,}44^2}{2 * 9{,}81 * (0{,}95 * 0{,}35 + 0{,}018 - |-0{,}0097|} + 10 = 86{,}00 \text{ m}$$

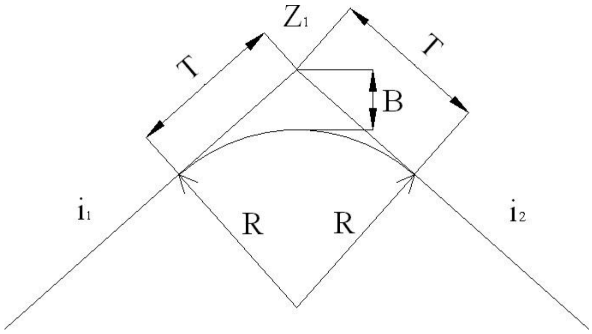
5.3 Determination of the radius of circular arcs in the longitudinal section

a) the minimum radius for esthetic reasons

$$R_{min} = \frac{100 \cdot v}{\alpha} [m],$$

$$\mathrm{R_{min}} = \frac{100*60}{8} = 750{,}00\ \mathrm{m}$$

5.4 Values of the geometry of the grade line



a) Tangent of a vertical arc

$$T = R \cdot \tan\frac{\alpha}{2}\ [m]$$

$$\mathrm{T} = 7000*\tan\frac{0{,}0016}{2} = 56{,}00\ \mathrm{m}$$

b) Vertical arc narrow

$$B = \frac{T^2}{2R}\ [m]$$

$$\mathrm{B} = \frac{56{,}00^2}{2*7000} = 0{,}22\ \mathrm{m}$$

c) Length of the vertical arc

$$\text{Ł} = 2*\mathrm{T}\ [\mathrm{m}]$$

$$\text{Ł} = 2*56{,}00 = 112{,}00\ \mathrm{m}$$

6. DESCRIPTION OF THE ROAD SURFACE STRUCTURE

Traffic category: KR2

Duration of pavement operation: 20 years

Type of pavement structure: flexible

Substrate type of soil: non-planting land

Ground load capacity group: G1

CBR Load Index: 10%

Secondary modulus of deformation E2: 100 MPa

The road surface according to KTKNPP,

the lower layers of the pavement: TYPE 1, the upper layers of the pavement: TYPE B.

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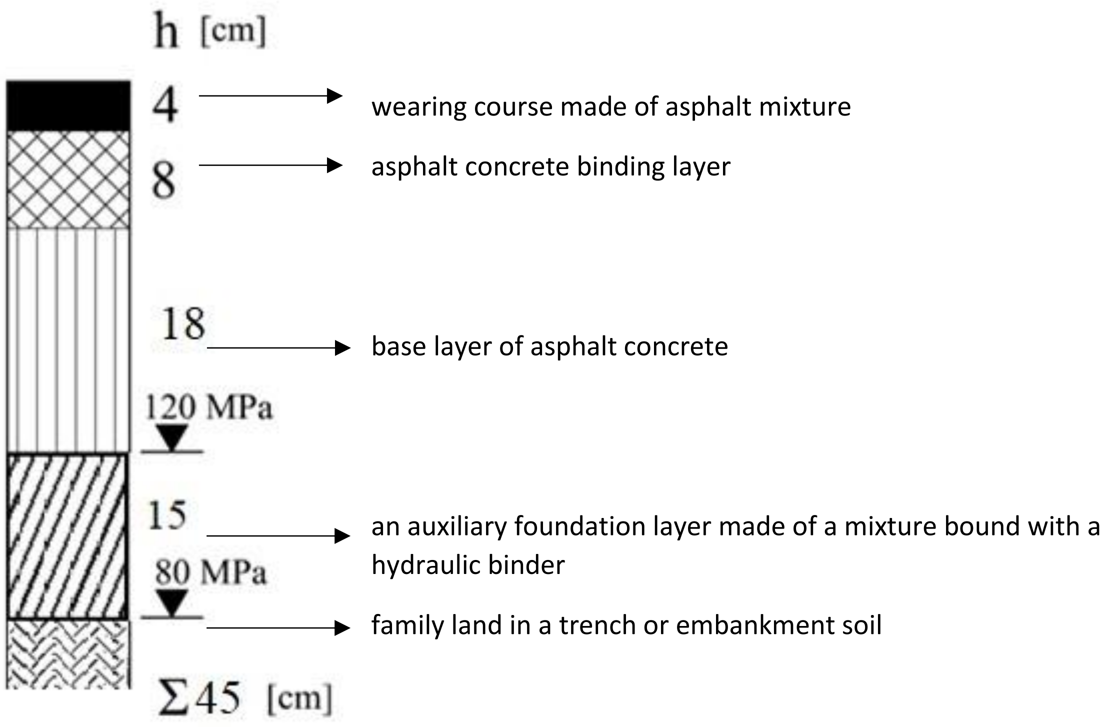
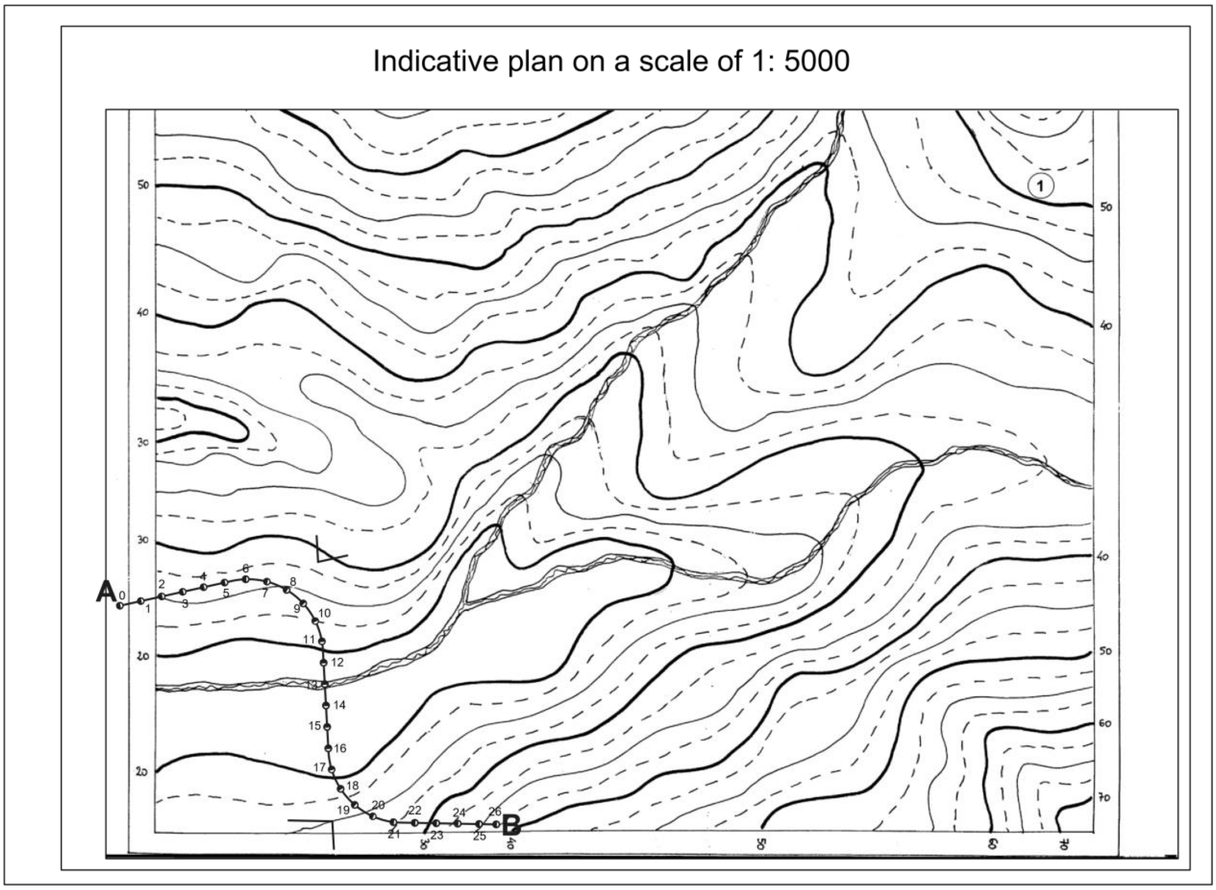
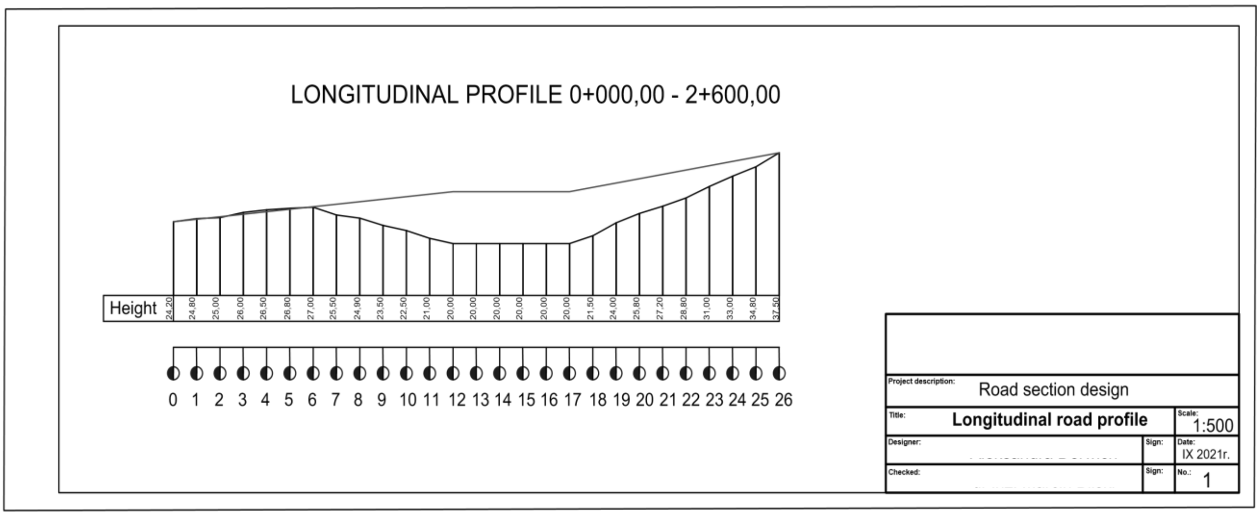


7. Drawings

7.1 Indicative plan on the map



7.2 Longitudinal profile



7.3 Normal profile