AT-GRADE JUNCTIONS (CONTINUATION)

PLOTTING OF ALIGNING ELEMENTS OF INNER CURVES „CA“ AND „BC“ FOR LEFT TURN

Plotting procedure:

- **Colours:**
  - *green .....working (temporary) dimensions*
  - *red .....centreline and physical edges*
  - *blue .....road marking, ghost islands*
  - *black.....(final numeric) dimensions*
- **Step I.**
  - **constructing of centrelines** of intersecting roads (**angle** α) – see *fig. 0740*

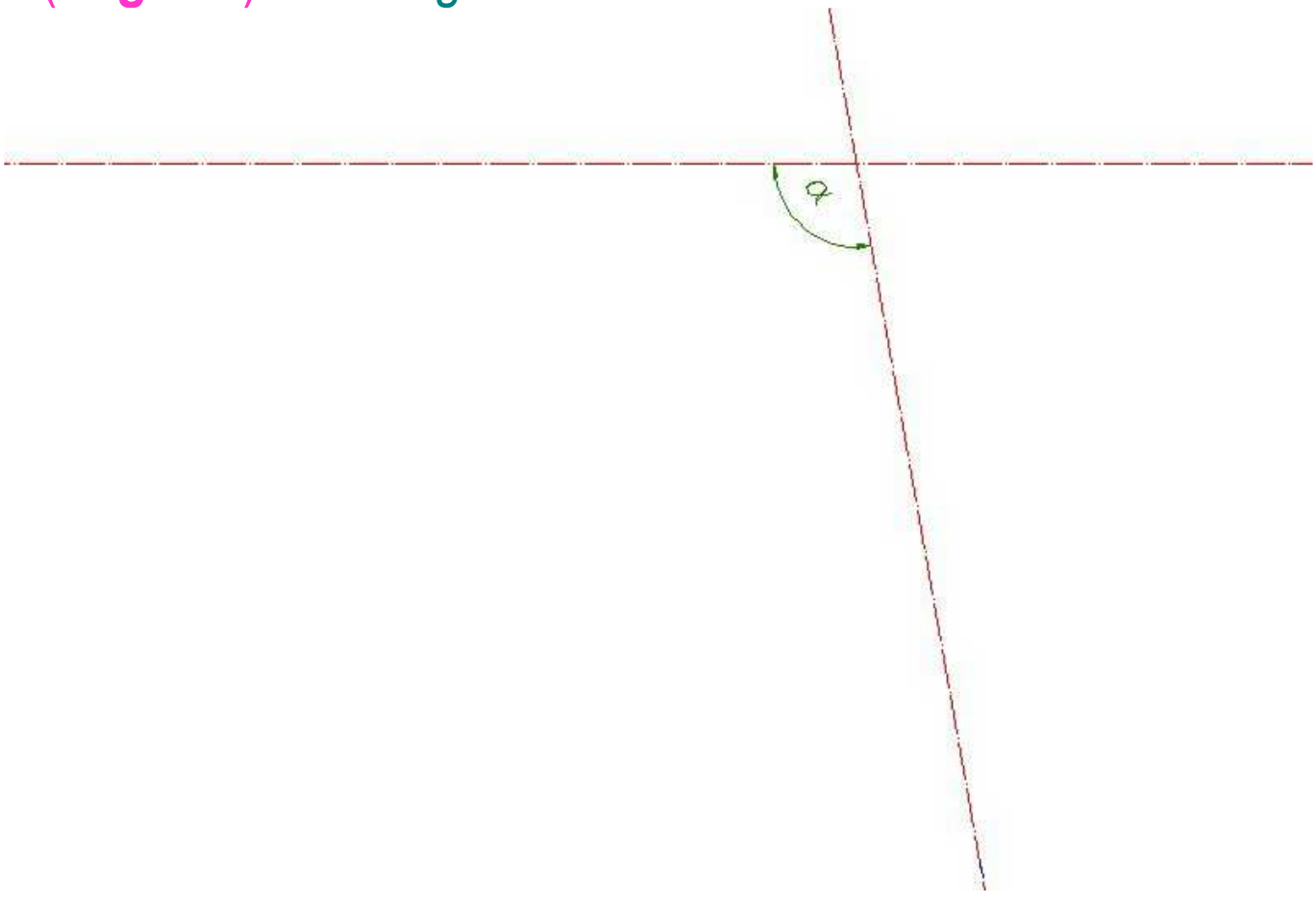


fig. 0740 (construction of centrelines of intersecting roads)

- plotting of **mainline edges** (width a = a_H) and **auxiliary lanes edges** (width a_p) – see *fig. 0750*
  - *SÚK **III** + SÚK **IV** ... use only **2 dimension „a_H“** symmetrically around the centreline*
  - *SÚK **V** ..... use only **2 dimensions „a_H“ and central dimension „a_p“***
  - *SÚK **VI** ..... according to fig. 0750*

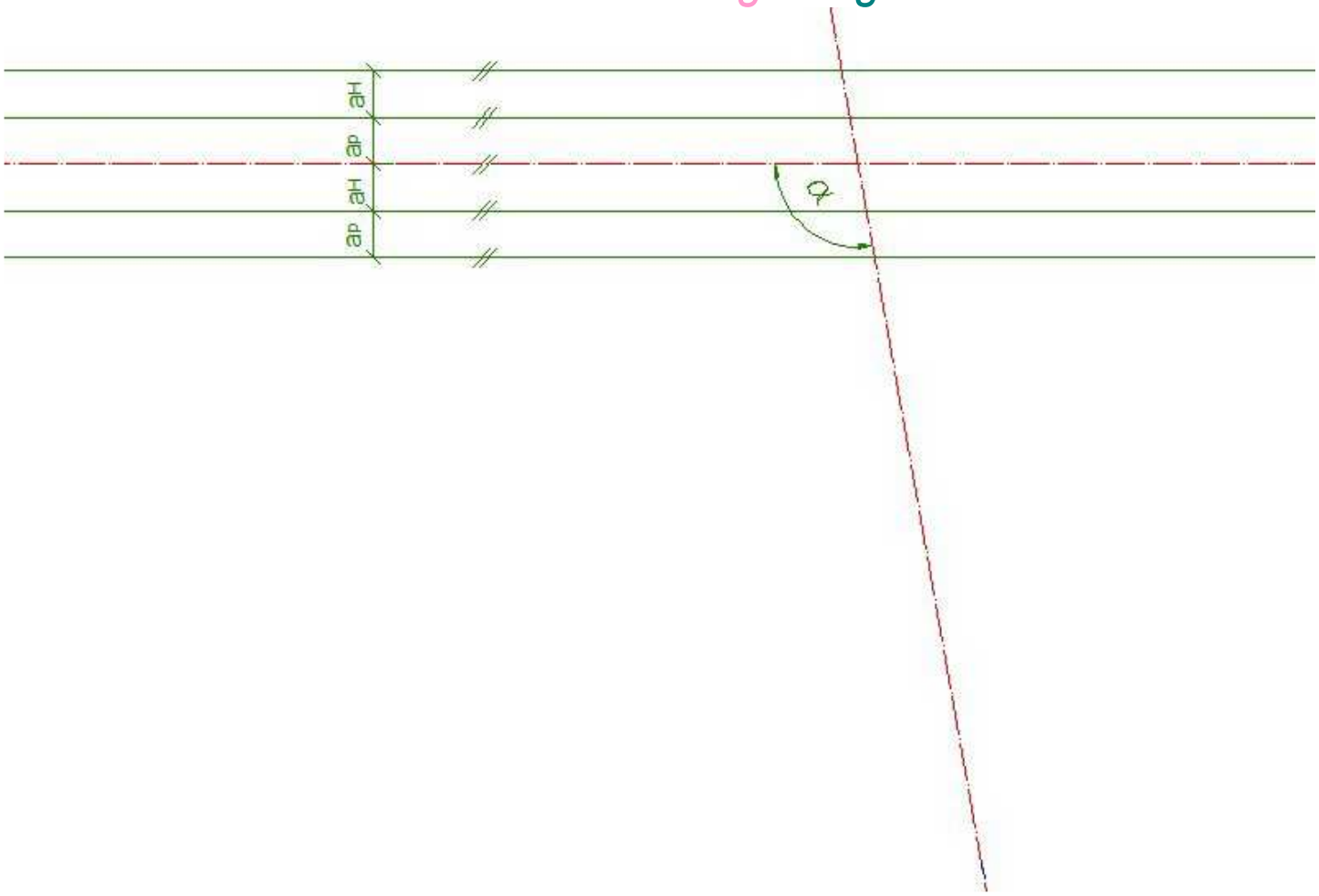


fig. 0750 (plotting of mainline edges and auxiliary lanes edges)

- plotting of **eccentricity „e“** and **dimensions „e + 0,5“** (offset of raised traffic island from guiding strip of minor road) – see *fig. 0760*

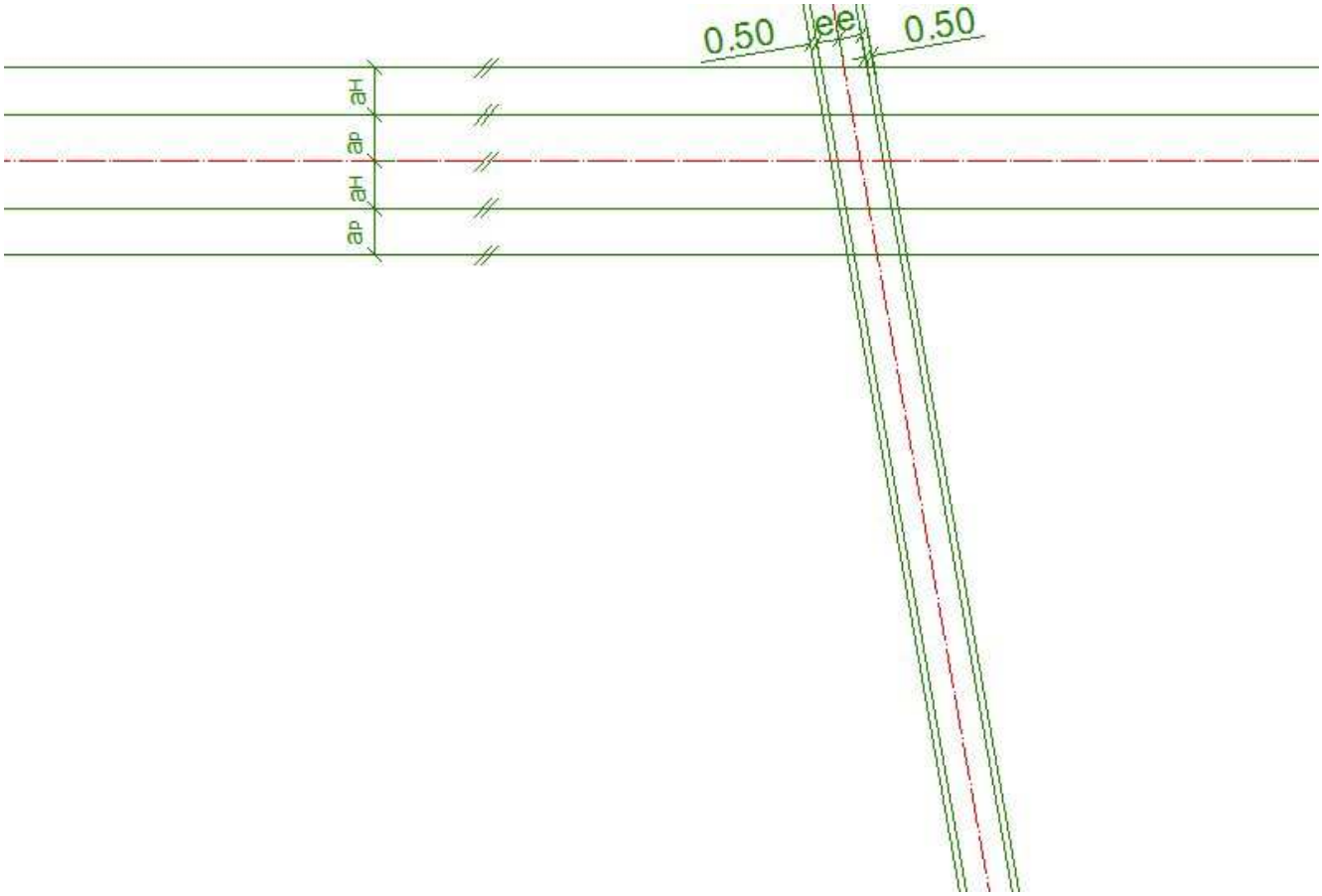


fig. 0760 (plotting of eccentricity „e“ and dimensions „e + 0,5“)

- plotting of tangents T_{CA}

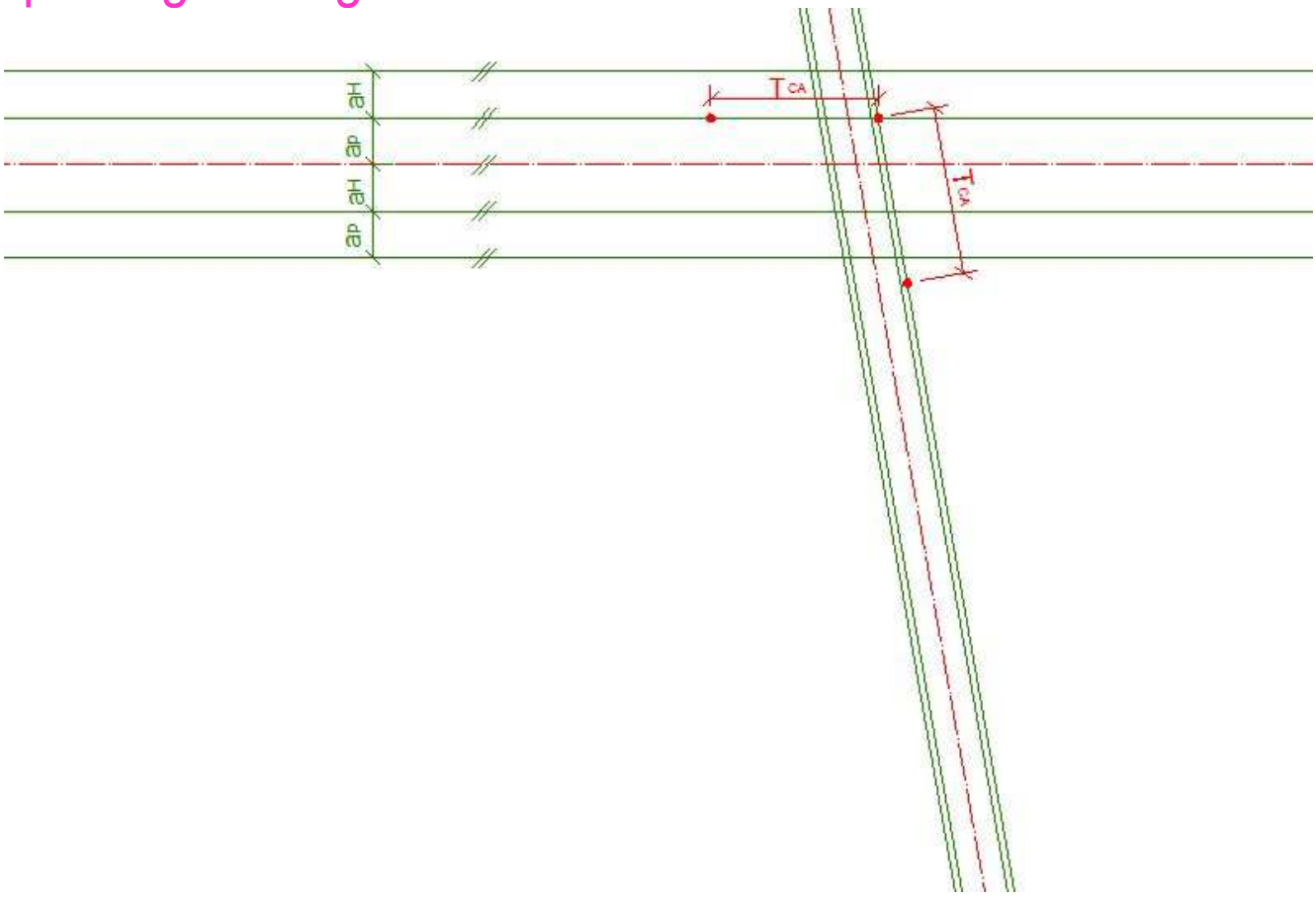


fig. 0770 (plotting of tangents T_{CA})

- *SÚK **III** + SÚK **IV**...2 points of **horizontal dimension** T_{CA} are plotted **on** the major road **centreline** (dimension $a_H = a$) and **vertical dimension** T_{CA} is **pushed***
- *SÚK **V** + SÚK **VI**....2 points of **horizontal dimension** T_{CA} are plotted according to fig. 0770*

- plotting of tangents T_{BC} – the same for all intersection types

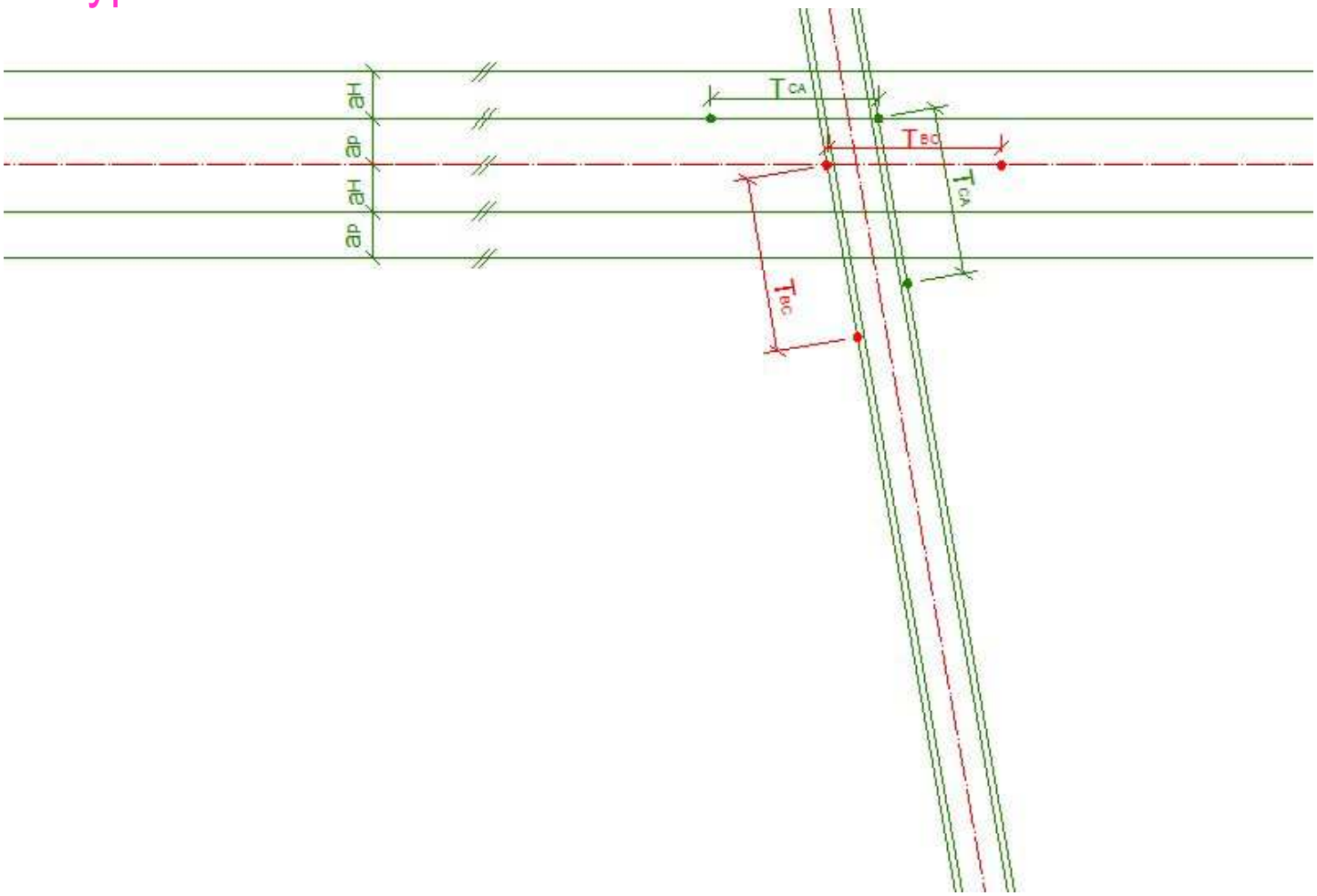


fig. 0780 (plotting of tangents T_{BC})

❖ **Step II.**

- Plotting of **parallel line** (with the major road centreline) **at distance „L“** (according to *fig. 0710* and *fig. 0730*) from

the outer edge of mainline „AB“ on the major road – see *fig. 0790*

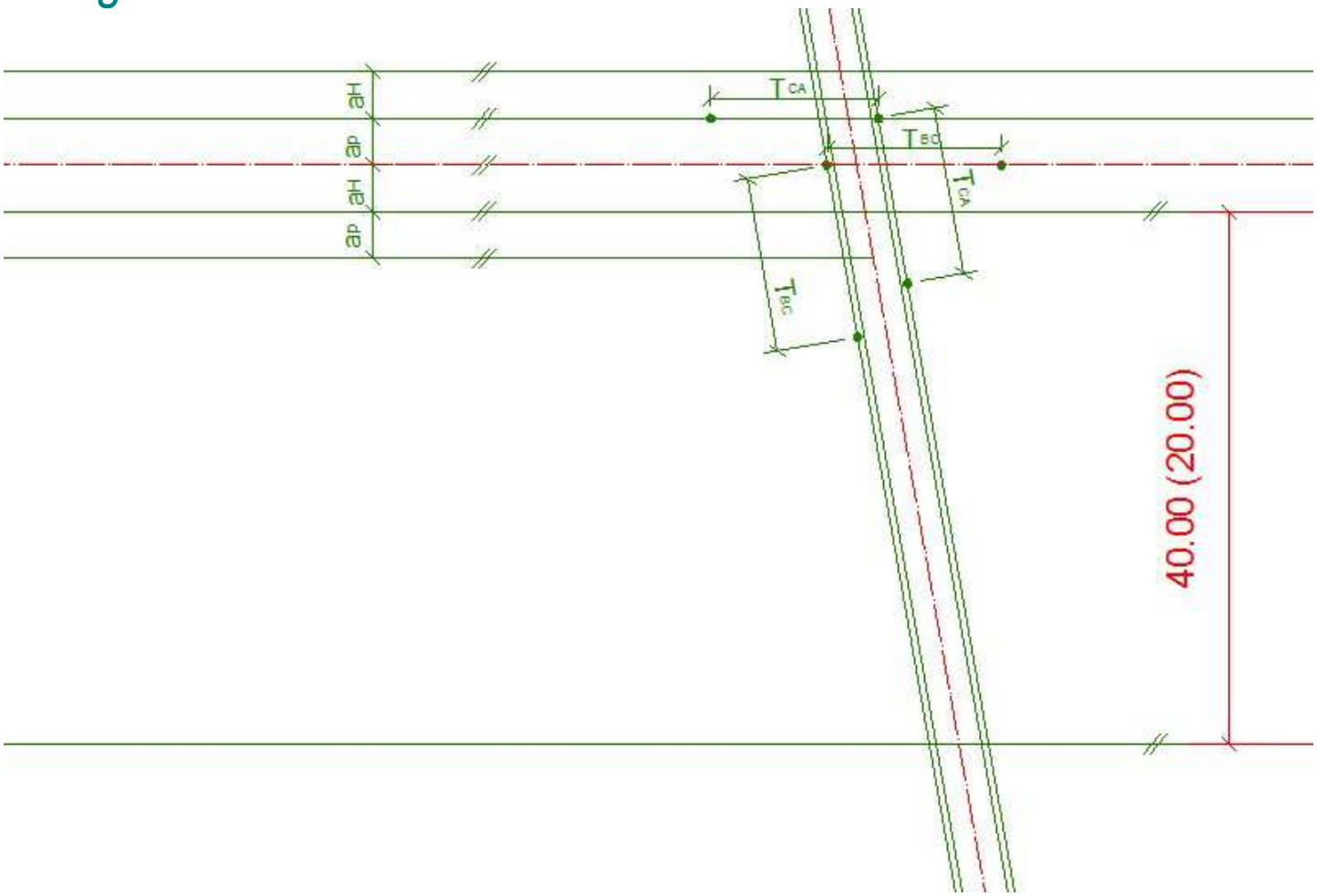


fig. 0790 (plotting of parallel line at distance „L“)

- plotting of **traffic island** (for SÚK **V** + SÚK **VI**) or **ghost island** (for SÚK **III** + SÚK **IV**) on a minor road:
  - ***plotting of curves*** *with radiuses* R_{CA} *(see fig. 0800) and* R_{BC} *(see fig. 0810) by insertion into tangents* T_{CA} *and* T_{BC}

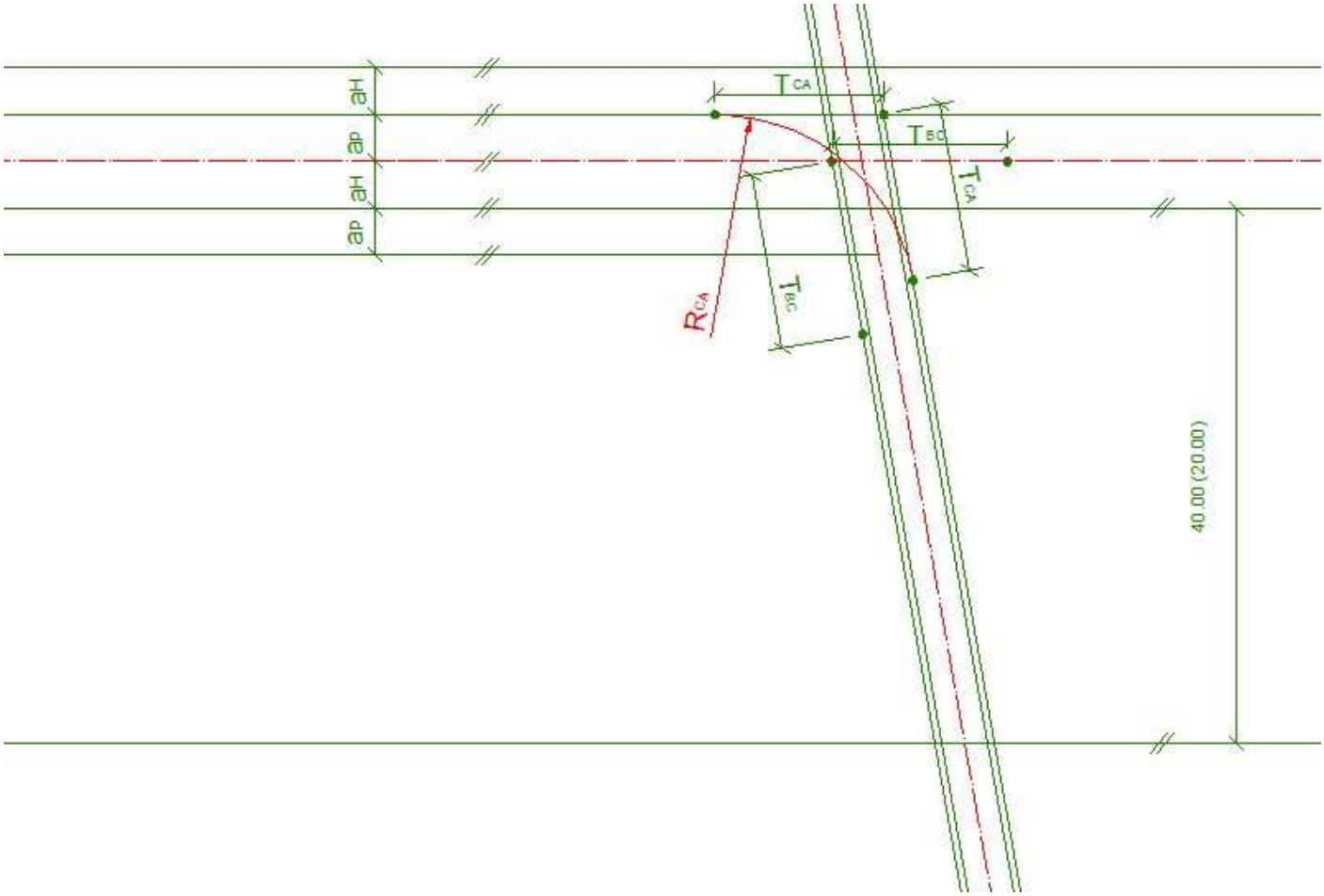


fig. 0800 (plotting of a curve with radius R_{CA})

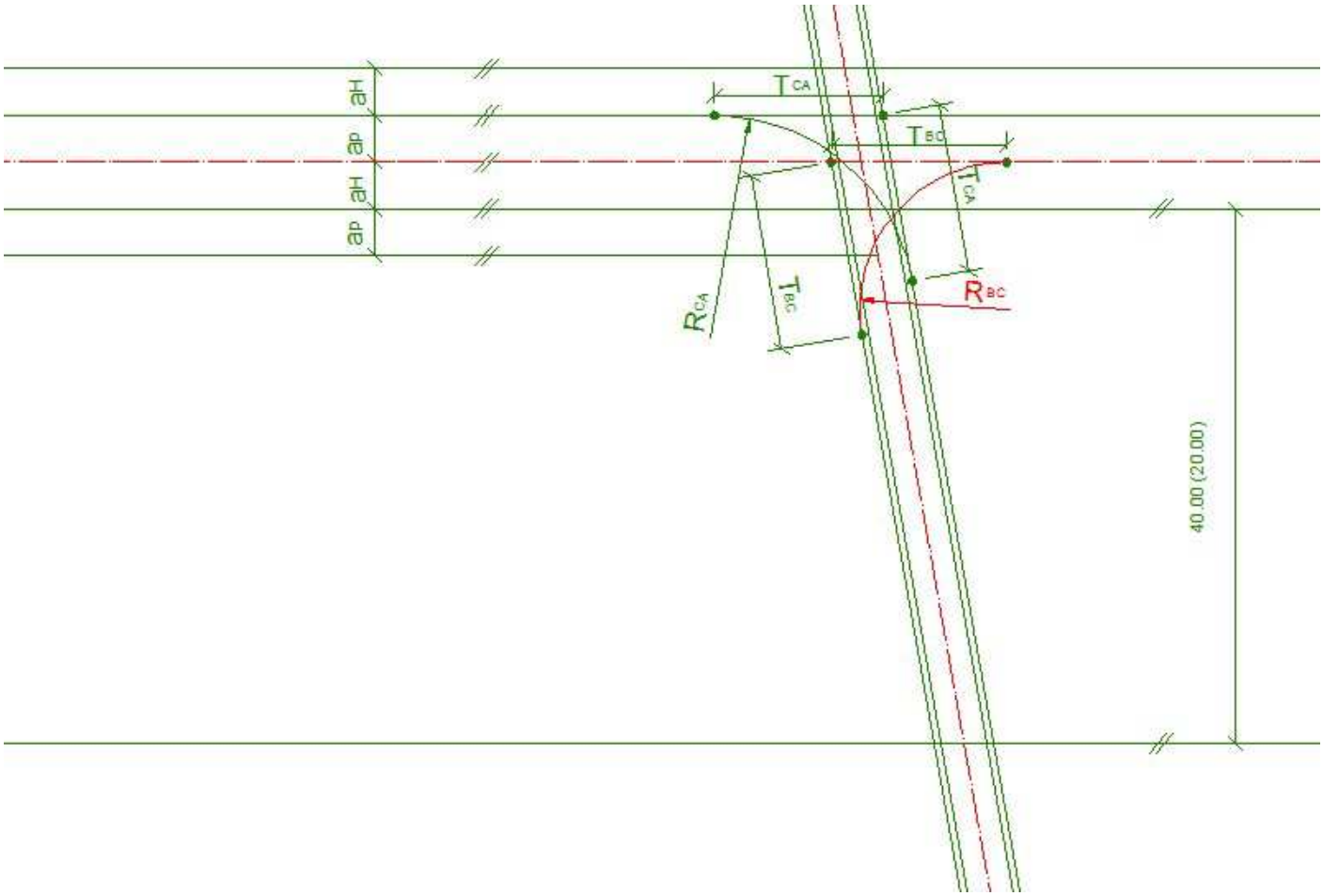


fig. 0810 (plotting of a curve with radius R_{BC})

- *plotting of **inner edges of traffic island** on a minor road – see fig. 0820 and fig. 0830 (here as a equidistant lines at 0,5 m from radii R_{CA} and R_{BC} $\Rightarrow$ not carried out for SÚK III and SÚK IV – only ghost island is used)*

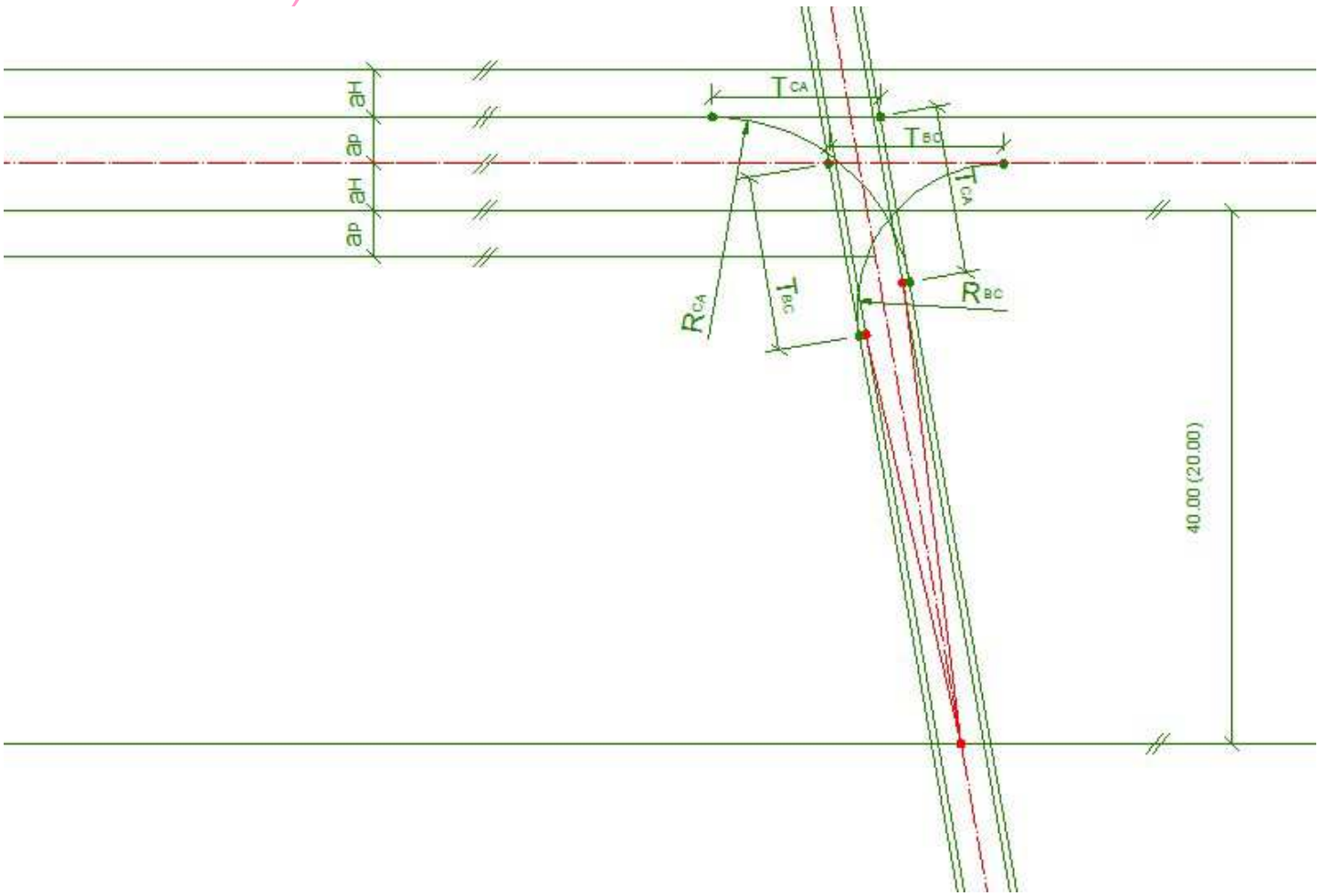


fig. 0820 (plotting of inner edges of traffic island)

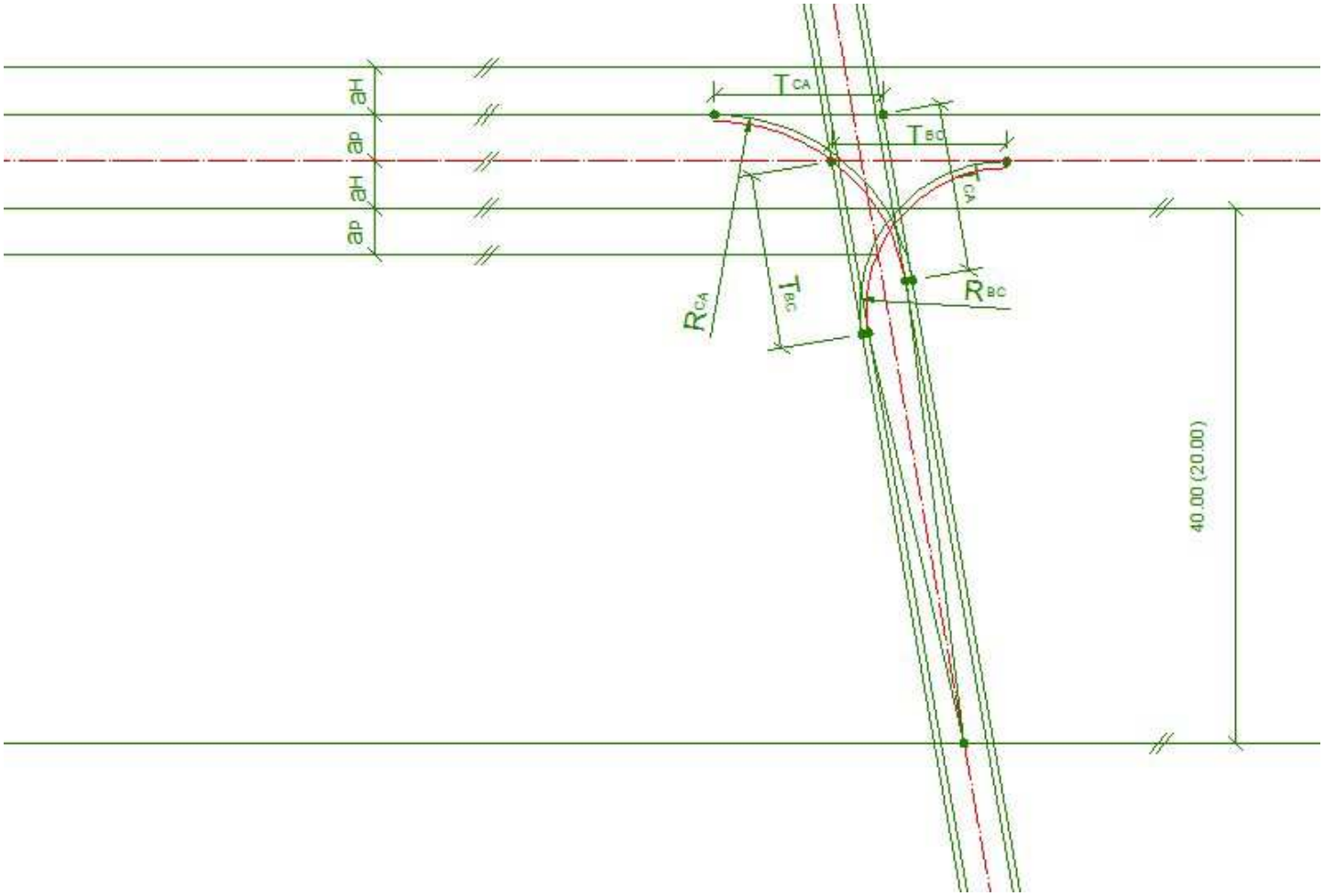


fig. 0830 (plotting of equidistant lines at 0,5 m from radii R_{CA} and R_{BC})

- *plotting of **outer edges of traffic island** on a minor road parallel to the inner edges from fig. 0820 (future road marking) – see fig. 0840*

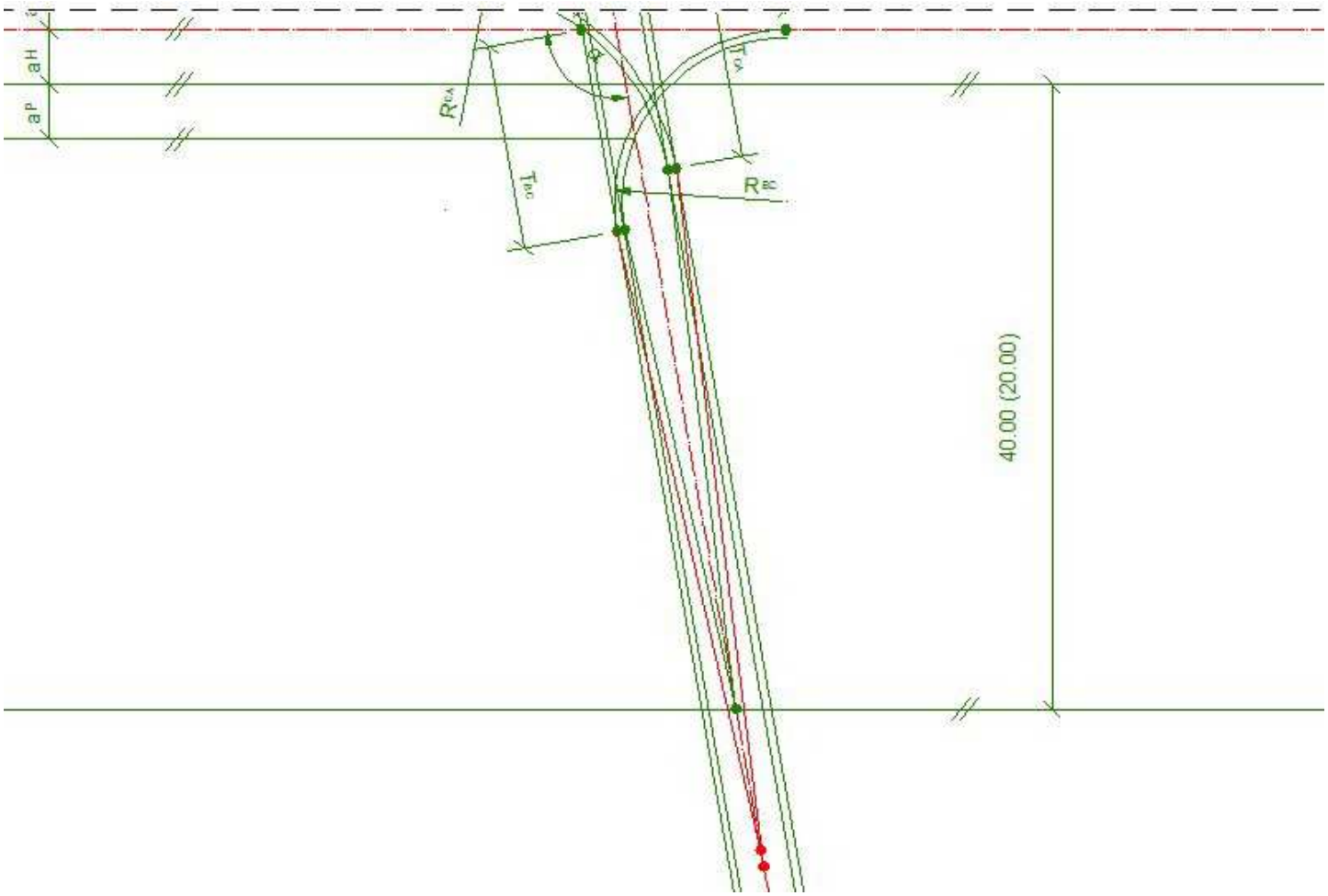


fig. 0840 (plotting of outer edges of a traffic island)

- *marking of **enveloping curves of** traffic island **road marking** – it cannot exceed the outer edge of mainline „AB“ towards the middle of the junction (see fig. 0850)*

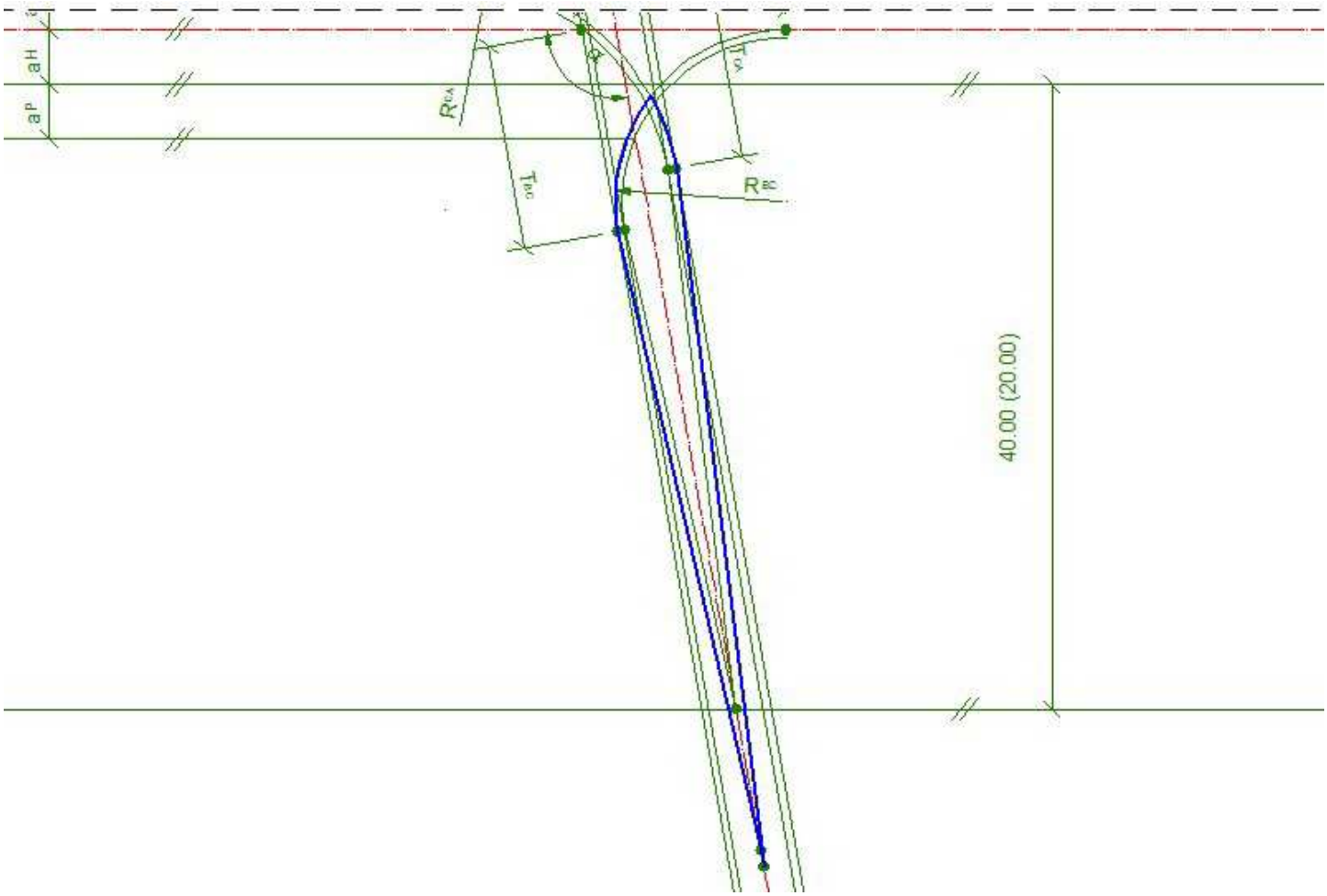


fig. 0850 (plotting of outer edges of traffic island)

- *SÚK **III** + SÚK **IV** ⇒ marking of the area between enveloping curves of traffic island road marking (see fig. 0850) as „**ghost island**“ according to the rules in fig. 1080*
- *SÚK **V** + SÚK **VI** ⇒ constructing of **physical edges of traffic island** with rounded ends (see fig. 0860)*

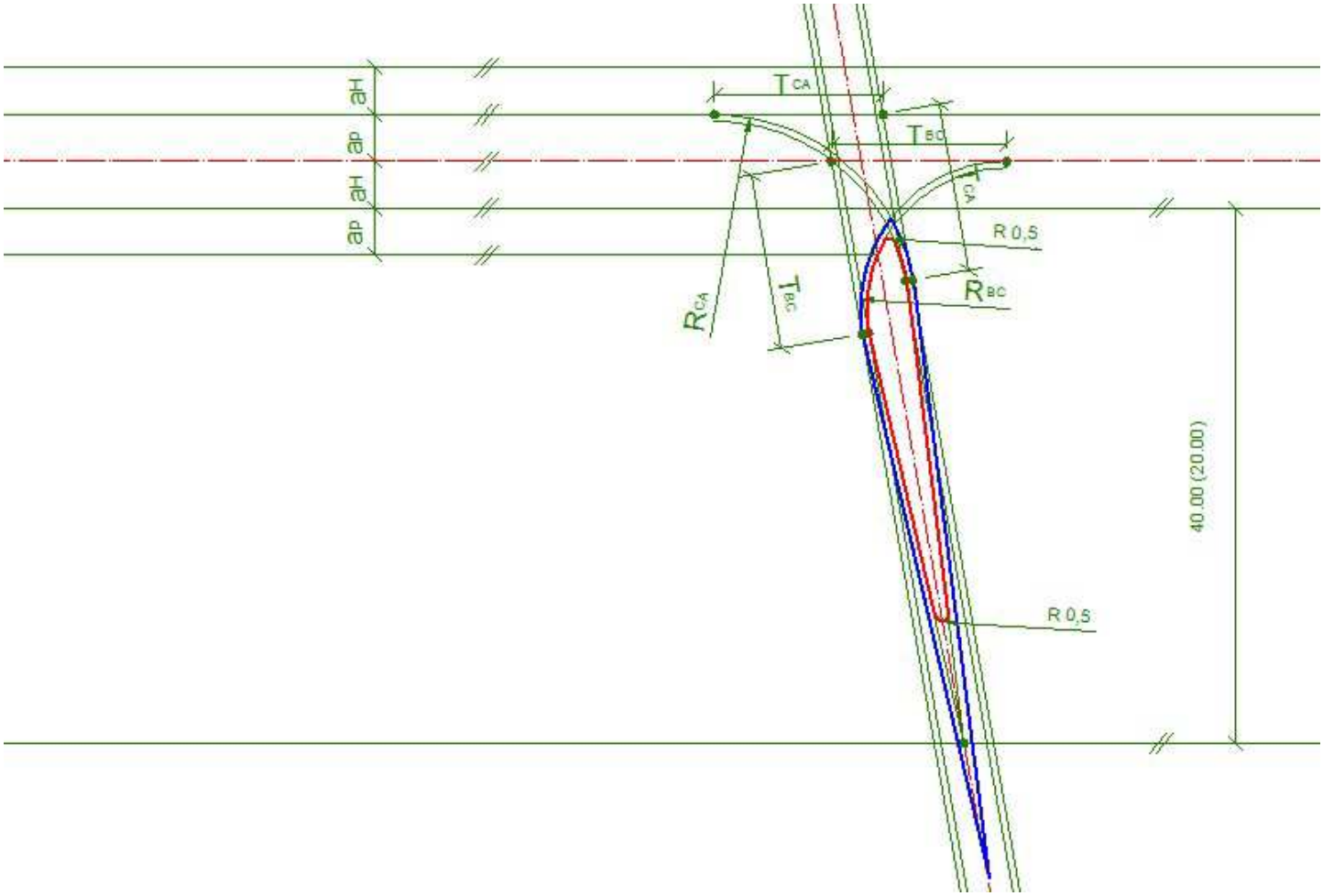


fig. 0860 (constructing of physical edges of traffic island with rounded ends)

❖ **Step III.**

- plotting of dimension for defining **left turn** inner curves at the beginning of **traffic island** (according to *fig. 0870*):
  - *curve **CA** .....dimension* $a_{ve(CA)} = a_v + \Delta a_{CA} = a_{CA}'$
  - *curve **BC** .....dimension* $a_{ve(BC)} = a_v + \Delta a_{BC} = a_{BC}'$

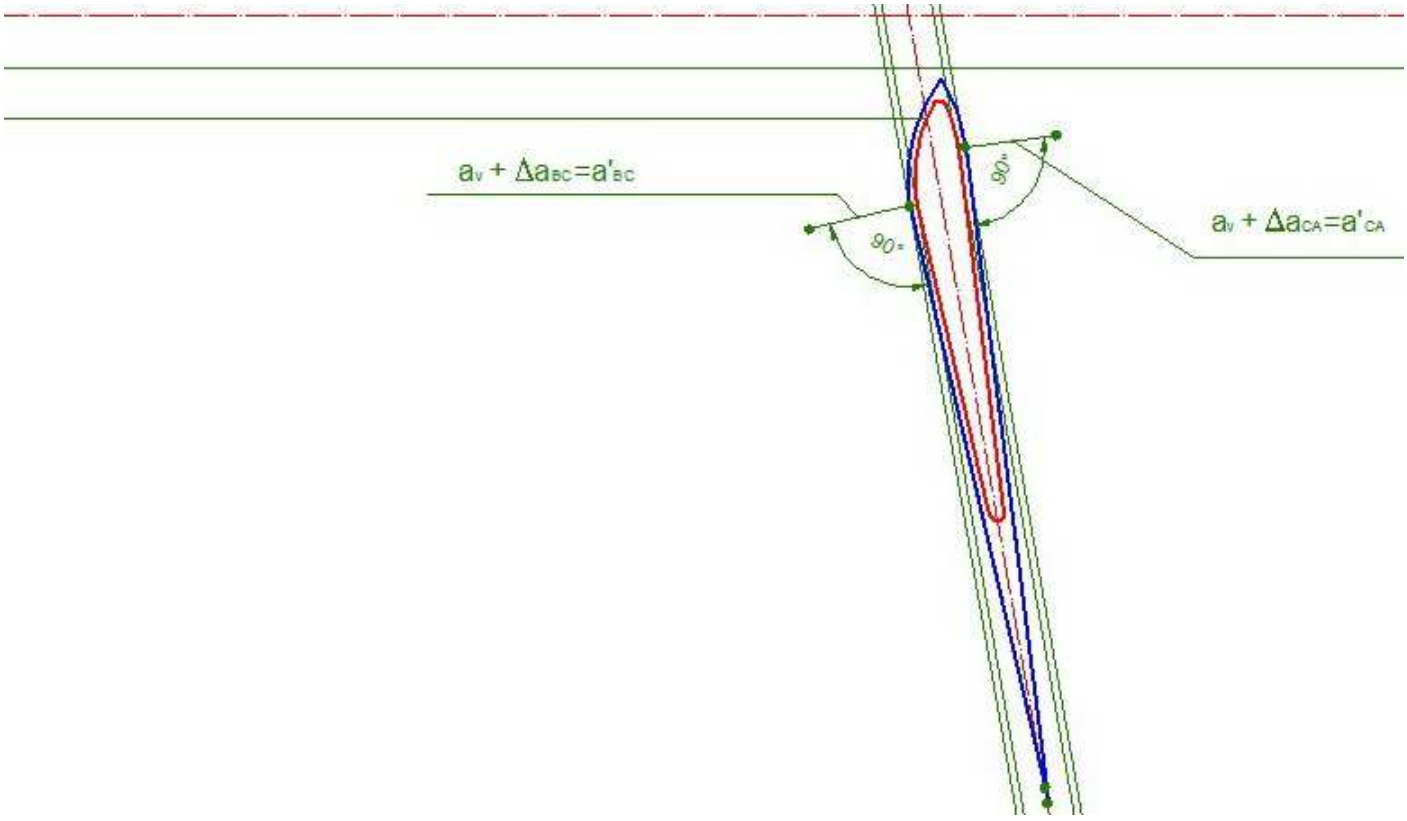


fig. 0870 (plotting of dimension for defining left turn inner curves at the beginning of traffic island)

- plotting of **dimensions „a_v“** at the end of a traffic island (according to *fig. 0880*)

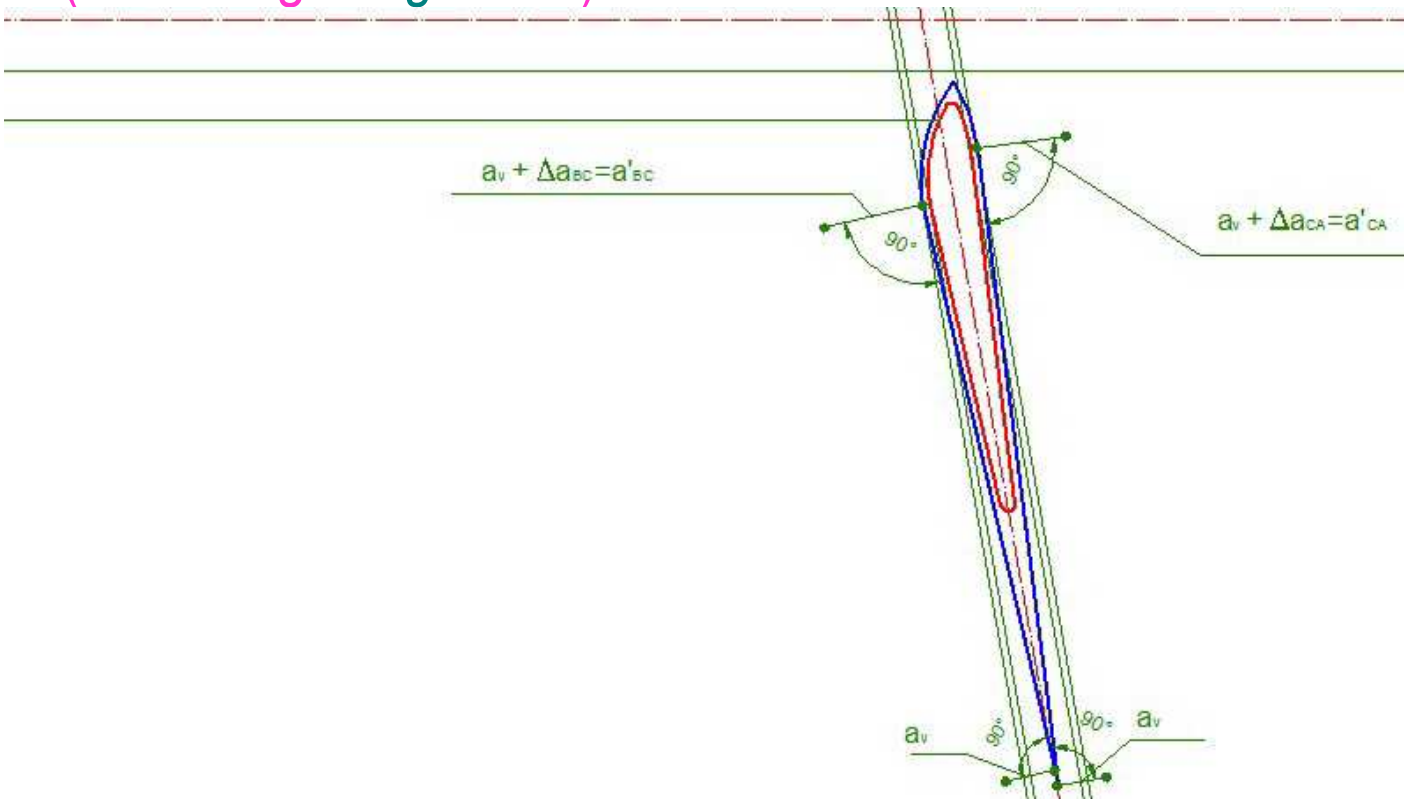


fig. 0880 (plotting of dimension for defining left turn inner curves at the beginning of traffic island)

- construction of lines defining the **outer edges** of widening **minor road lanes** – see *fig. 0890*
  - ***future tangents*** *for right turn „CB“ and „AC“*
  - *determining (measuring)* ***central angles*** *„τ_{CB}“ and „τ_{AC}“ (see fig. 0890) right turn curves „CB“ and „AC“*

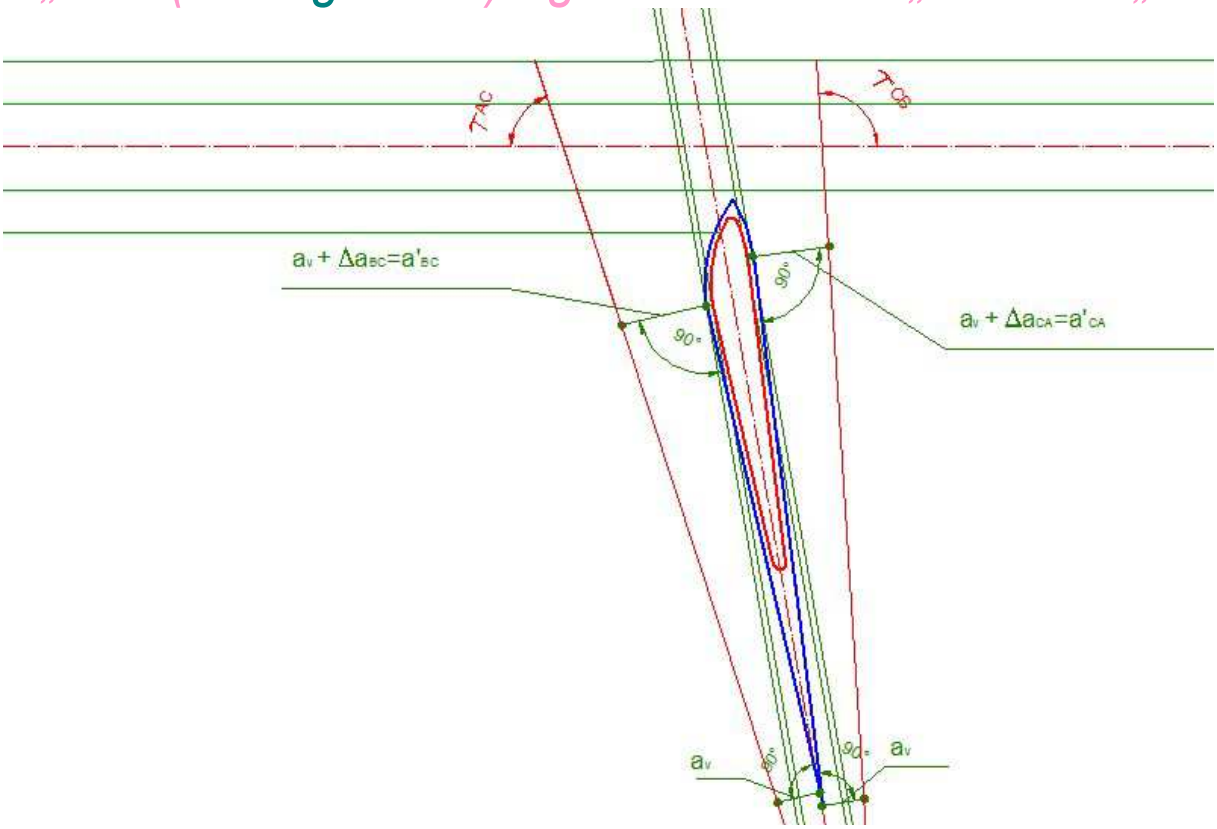


fig. 0890 (dimensions for defining road lanes at the end of a traffic island)

CALCULATION OF ALIGNING ELEMENTS OF RIGHT TURN „AC“ AND „CB“

- curves for right turn are designed as composed circular curves with radii ratio 2:1:2 or 2:1:3
  - *geometric shape of right turn curve must comply with all types design vehicles ⇒ bus or lorry*
  - *design verification ⇒ application of so-called „swept path“ (program AUTOTURN)*

❖ for the use of the exercise ⇒ use symmetrical transition curve of clothoidic shape

Curve radii of connectors or corners

- design of **right turn** and use of **values** for a **connector or** a **corner** according to the following table:

turn	SÚK III	SÚK IV	SÚK V	SÚK VI
curve **AC**	connector	corner	connector	connector
curve **CB**	corner	corner	corner	connector

A. corner:

- minimal **turn radii „R_o“** - see *fig. 0900*

Nejmenší R_0 v m		Vozidlo
dovolený	doporučený	
5,00	6,00	osobní a dodávkový automobil
7,00	8,00	malý a střední nákladní automobil, linkový autobus
9,00	10,00	velký nákladní automobil, dálkový autobus, návěsová souprava
12,00	15,00	kloubový autobus, přívěsová souprava

fig. 0900 (minimal radii of circular curves of road lane edges according to vehicle type in meters)

- for the use of the exercise ⇒ use values **R_o according to road class of road** from which **right turn leaves**:
  - ***major** road class ..... $R_o = R_{AC}$*
  - ***minor** road class ..... $R_o = R_{CB}$*
- **minimal values R_o of corners** according to road class:
  - *first-class and second-class roads ..... $R_{o,min}$ = 12 m*

- *third-class roads ..... $R_{o,min}$ = 7 m*
  (the radius allows smooth ride to 12 meters long bus with entering the opposite direction lane)

- **for the use of the exercise ⇒ values R_o of corners:**
  - *first-class and second-class roads:*
    - *$\tau_{AC} / \tau_{CB} \geq 90°$ ..... choose $R_o \in \langle 12m;13m \rangle$*
    - *$\tau_{AC} / \tau_{CB} \leq 90°$ ..... choose $R_o \in \langle 14m;15m \rangle$*
  - *third-class roads:*
    - *$\tau_{AC} / \tau_{CB} \geq 90°$ ..... choose $R_o \in \langle 7m;8m \rangle$*
    - *$\tau_{AC} / \tau_{CB} \leq 90°$ ..... choose $R_o \in \langle 9m;10m \rangle$*

B. connector:

- choose **turn radii R_{AC} and R_{CB}** according to the set speed „v_k“ from *fig. 0910* (**choose „p“ [%]** – connector crossfall **– mark it in the drawing** afterwards)

Návrhová rychlost na větvi v_k (km/h)	60	50	40	35	30	25	20	15
Součinitel příčného tření f	0,17	0,19	0,23	0,25	0,28	0,31	0,34	0,40
Příčný sklon p (%)								
2,5	146	92	56	35	24	15	9	5
3	142	90	49	35	23	15	9	5
4	135	86	47	34	22	14	9	4
5	129	82	45	32	22	14	8	4
6	124	79	44	31	21	13	8	4
7	118	76	42	30	21	13	8	4
8	114	73	41	30	20	13	8	4

Uvedené hodnoty jsou vypočítány ze vzorce:

$$R_{min} = \frac{v_k^2}{127\,(f + +0{,}01\,p)}$$

a zaokrouhleny na celé metry.

fig. 0910 (minimal connector curve radius depending on the speed „v_k“ and crossfall „p“)

- τ_{AC} / τ_{CB} **≥ 90°** ⇒ *choose* R_{AC} / R_{CB} *rather* ***smaller*** *(for values p = 5~6% in table in fig. 0910)*
- τ_{AC} / τ_{CB} **≤ 90°** ⇒ *choose* R_{AC} / R_{CB} *rather* ***bigger*** *(up to 10 meters bigger than the value for p = 2,5% in table in fig. 0910)*

Resulting width of right turn lanes

- right turn „**AC**“ ..... $a_{ve(AC)} = a_{AC}'$
- right turn „**CB**“ ..... $a_{ve(CB)} = a_{CB}'$

A. corner:

- determine resulting **enveloping curves width** of road lanes $a_{ve(AC)} = a_{AC}'$ and $a_{ve(CB)} = a_{CB}'$
  - *for left turn „AC“ and „CB“ use widening* Δa_{AC} *and* Δa_{CB}
  - *determine according to values* R_{AC} *a* R_{CB} *from the following table*

R	[m]	7	8	9	10	11	12	13	14	15
Δa	[m]	5,30	4,60	4,10	3,75	3,50	3,30	3,10	2,95	2,80

$$a_{ve(AC)} = a_{AC}' = a_v + \Delta a_{AC} \qquad a_{ve(CB)} = a_{CB}' = a_v + \Delta a_{CB}$$

B. connector:

- determine $a_{ve(AC)} = a_{AC}'$ and $a_{ve(CB)} = a_{CB}'$ from table in *fig. 0920*:
  - ***according to*** *values* R_{AC} ***a*** R_{CB} *by interpolation*
  - *use values from* ***column*** C^a *(„**all vehicle types**“)*

Poloměr vnitřního okraje jízdního pruhu v m	Směrodatná vozidla pro návrh		
	OA [a]	N [a]	C [a]
15	3,50	4,70	6,50
20	3,30	4,30	5,55
25	3,20	4,00	5,05
30	3,10	3,85	4,80
35	3,05	3,70	4,50
40	3,00	3,60	4,30
45	2,95	3,55	4,20
50	2,95	3,50	4,05

Hodnoty v tabulce jsou vypočteny ze vzorce:

$$a_{ve} = \check{S}_A + \Delta a = \check{S}_A + \frac{S_m}{R} + 0{,}5 \text{ m}$$

kde a_{ve} je šířka jízdního pruhu větve v m,
$\check{S}_A$ šířka vozidla v m,
Δa rozšíření jízdního pruhu větve v m,
S_m číslo charakterizující směrodatné vozidlo,
R poloměr vnitřního okraje jízdního pruhu větve v m.

Výsledné hodnoty jsou zaokrouhleny na 5 cm.

[a] OA osobní a dodávkový automobil ($\check{S}_A$ = 2,17; S_m = 12,5).
N velký nákladní automobil a automobil pro svoz odpadků ($\check{S}_A$ = 2,50; S_m = 24,5).
C všechny druhy vozidel ($\check{S}_A$ = 2,55; S_m = 50).

fig. 0920 (values of road lanes width a_{ve} of one-way connector of at-grade junction including widening [m])

Lengths of transition curves L_{AC} and L_{CB}

A. corner:

- **determine** suitable transition curves lengths **„L_{AC}“ and „L_{CB}“** in outer **curves „AC“ a „CB“** (we assume symmetric transition curves „L“) according to the already known values of „R_{AC}“ and „R_{CB}“:
  - *first estimate.....L [m] = R [m]*
  - *gradually increase „L“ (decrease if needed) by steps of 5 m*
  - *use the greatest value „L“, which complies with:*

$$\frac{R_{AC} \bullet \pi}{180} \bullet \left(\tau_{AC} - \frac{180 \bullet L_{AC}}{\pi \bullet R_{AC}} \right) \geq 0 \qquad [\tau_{AC}] = °$$

$$\frac{R_{CB} \bullet \pi}{180} \bullet \left(\tau_{CB} - \frac{180 \bullet L_{CB}}{\pi \bullet R_{CB}} \right) \geq 0 \qquad [\tau_{CB}] = °$$

B. connector:

- **determine** suitable transition curves lengths **„L_{AC}“ and „L_{CB}“** of outer **curves „AC“ and „CB“** (rounded to **multiplies of 5 meters** – we assume symmetrical transition curves „L“) according to the already known **„v_k“**:
  - $L_{AC} \geq v_{k,AC}$
  - $L_{CB} \geq v_{k,CB}$
  - $[L_{AC}] = [L_{CB}] = m$
  - $[v_{k,AC}] = [v_{k,CB}] = km/h$

Aligning elements

- **Known values** for right turn curves (without the effect of connector or connector):
  - *central angles* ..... τ_{AC}, τ_{CB}
  - *turn radii* ..... R_{AC}, R_{CB}
  - *transition curve lengths* ..... L_{AC}, L_{CB}
- **calculate** the following **aligning elements** of curves **„AC“ a „CB“** for simple constriction of right turn:

$$\beta = \frac{L}{2 \bullet R}; [\beta] = \text{rad}$$

$$\Delta R = \frac{L^2}{R} \bullet \left(\frac{1}{24} - \frac{\beta^2}{672} - \frac{\beta^4}{3168} \right); [\beta] = \text{rad}$$

$$x = L - \frac{L^3}{40 \bullet R^2} + \frac{L^5}{3456 \bullet R^4}$$

$$y = \frac{L^2}{6 \bullet R} - \frac{L^4}{336 \bullet R^3} + \frac{L^6}{42240 \bullet R^5}$$

$$T = (x - R \bullet \sin\beta) + (R + \Delta R) \bullet tg\frac{\tau}{2}$$

- *beware of the units at „β“ and „τ“:*

$$\beta[rad] = \frac{\beta[°] \bullet \pi}{180} \qquad \beta[°] = \frac{\beta[rad] \bullet 180}{\pi}$$

$$z = \frac{R + \Delta R}{\cos\frac{\tau}{2}} - R$$

$$O_k = R \bullet arc(\tau - 2 \bullet \beta)$$

$$O_k = \frac{R \bullet \pi \bullet (\tau - 2 \bullet \beta)}{180}; [\tau] = [\beta] = °$$

$$A = \sqrt{R \bullet L}$$

- *control:*

$$O_k \geq 0$$

(length of outer curve without transition curves > 0)

OVERVIEW OF CURVE ALIGNING ELEMENTS

- table for left turn curves („CA“, „BC“):

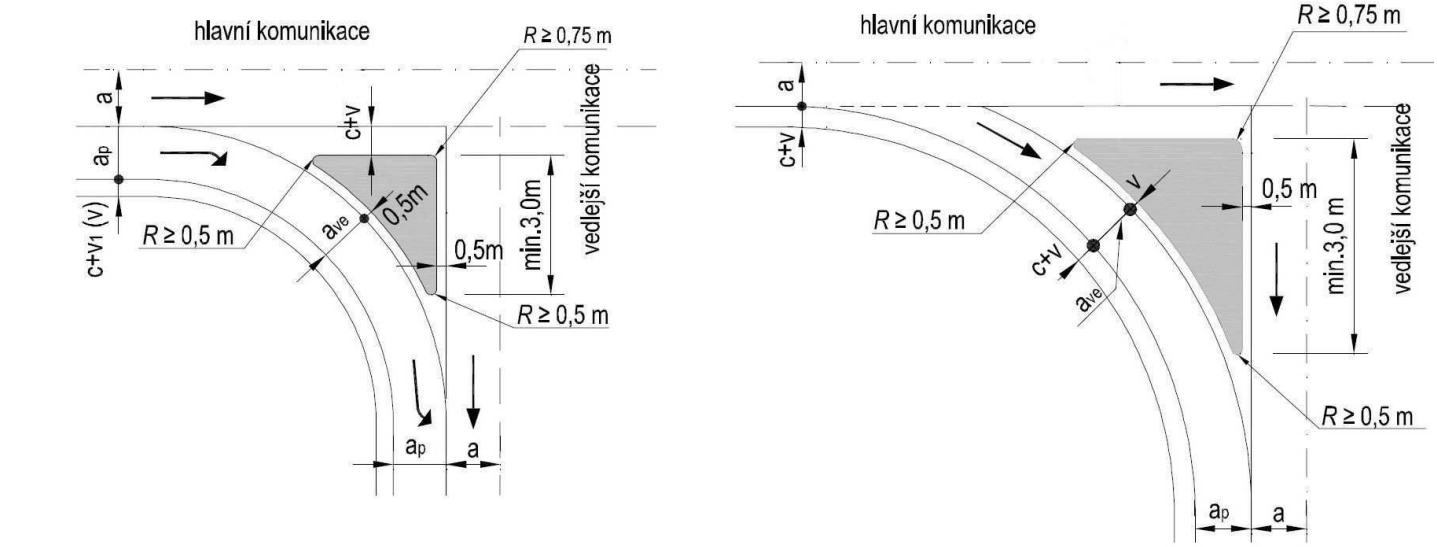
Intersection inner curves	R [m]	Δa [m]	a + Δa [m]	e [m]
CA	...	...	...	...
BC	...	...	...	...

- table for right turn curves („AC“, „CB“):

Junction outer connectors (curves)								
	R	Δa	a+Δa	τ	L	v_k	p	f
	[m]	[m]	[m]	[°]	[m]	[km/h]	[%]	[1]
AC	...	...	...	...	...	...	...	...
CB	...	...	...	...	...	...	...	...
	ΔR	β	x	y	T	z	O_k	A
	[m]	[°]	[m]	[m]	[m]	[m]	[m]	[m]
AC	...	...	...	...	...	...	...	...
CB	...	...	...	...	...	...	...	...

CHANNELISING ISLANDS

- they occurs **at minor road lanes** for channelising **traffic flows turning** from or **connecting** to the major road by **junction connectors**
- **offset** from road lane edge (see *fig. 0930*):



a) hlavní komunikace s odbočovacím pruhem a krajnicí

b) hlavní komunikace bez odbočovacího pruhu a s krajnicí

fig. 0930 (shape of channelising triangular islands at crossroads or T-junction)

- ***minor** road .....at least **0,50 m***

- ***major*** *road .....* ***width of*** *hard shoulder and the edge of marking (**c + v**)*

- **area < 7 m²** or **length** of **one edge < 3,00 m** ⇒ instead of the island it is possible to realized only **triangular ghost island** (according to the rules in *fig. 1210*)
- **for the use of the exercise** ⇒ triangular channelising **traffic islands** (or ghost island) use **for right turn**:
  - *SÚK **III** + SÚK **V** ..... in the direction of **AC***
  - *SÚK **VI** ..... in the direction of **AC** and **CB***

T-JUNCTION DESIGN

❖ Step IV. – construction of connector

- **use of IV.** In accordance of junction type (**the procedure** is shown **for** direction **AC with diverge lane** on the major road ⇒ SÚK VI):
  - *SÚK **III** + SÚK **V** .... for turn **AC** (**without diverge lane** on major road)*
  - *SÚK IV ..... step IV. is not used*
  - *SÚK **VI** ..... for turn **AC** (**according to** the procedure in **step IV.**) and **analogously** for turn **CB** (**without diverge lane** on minor road and **with merge lane** on major road according to the rules in fig. 0670 and fig. 1010)*
- **plotting** of shortened merge lane **width „a_p“ = 3 m** (according to the values in *fig. 0580*) on minor road (see *fig. 0940*)

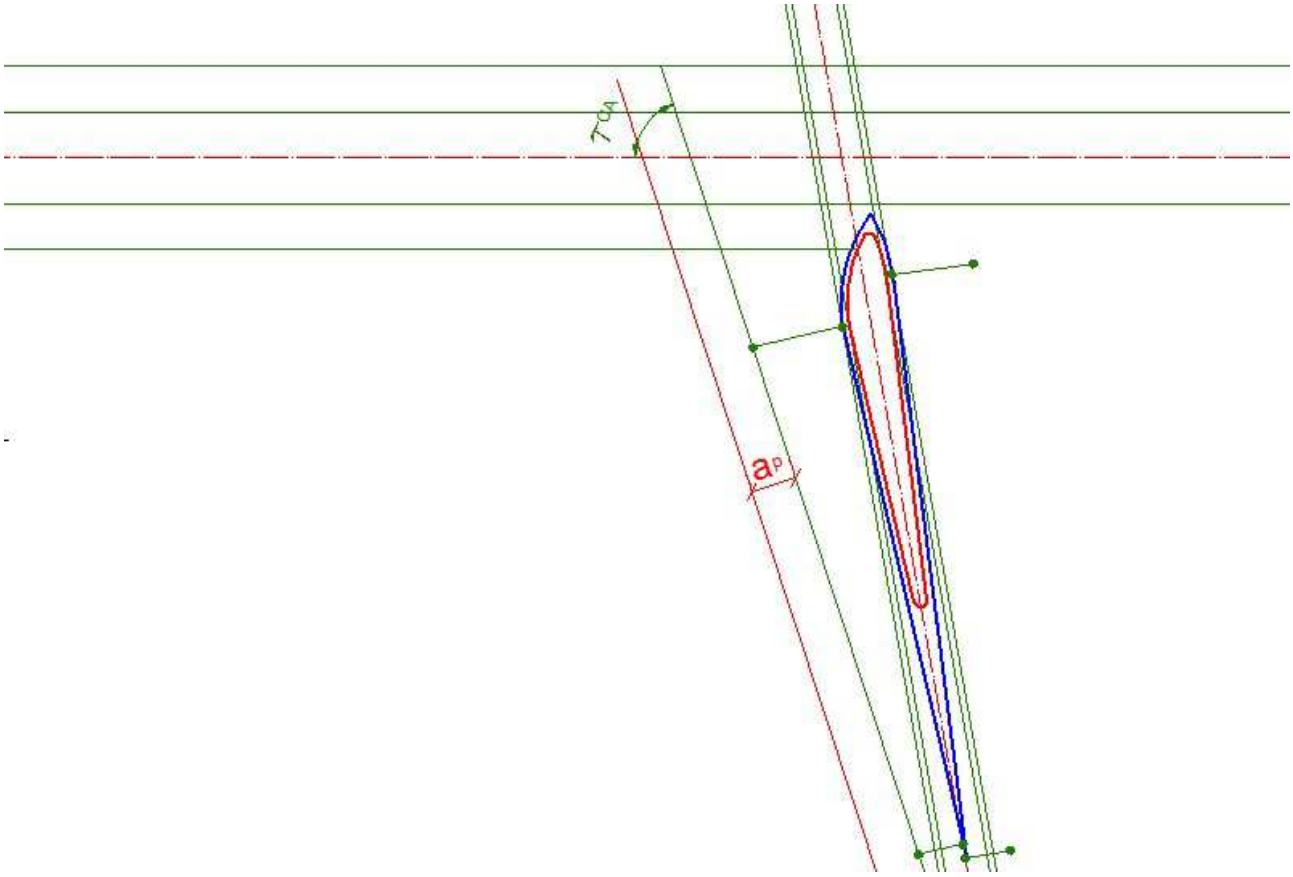


fig. 0940 (plotting of shortened merge lane width „ap“ = 3 m on minor road)

- *does not apply for SÚK IV*
- *for analogous design of **CB** (for SÚK VI) the dimension **is already plotted** (see fig. 0750 ~ fig. 0780)*

- construct **inner edges of the connector** for turn **AC using** plotting points **TS, SC, CS** and **ST** according to the calculated elements' parameters (L, R, x, y, … etc.) – plotting of **tangents „T_{AC}“** (see *fig. 0950*) + **dimensions „x“ and „y“** (see *fig. 0960*) + insertion of circular part of **curve with radius „R_{AC}“** (see *fig. 0980*) ⇒ future inner **guiding strip** (create transition curve using „spline“ function – see *fig. 0990*)

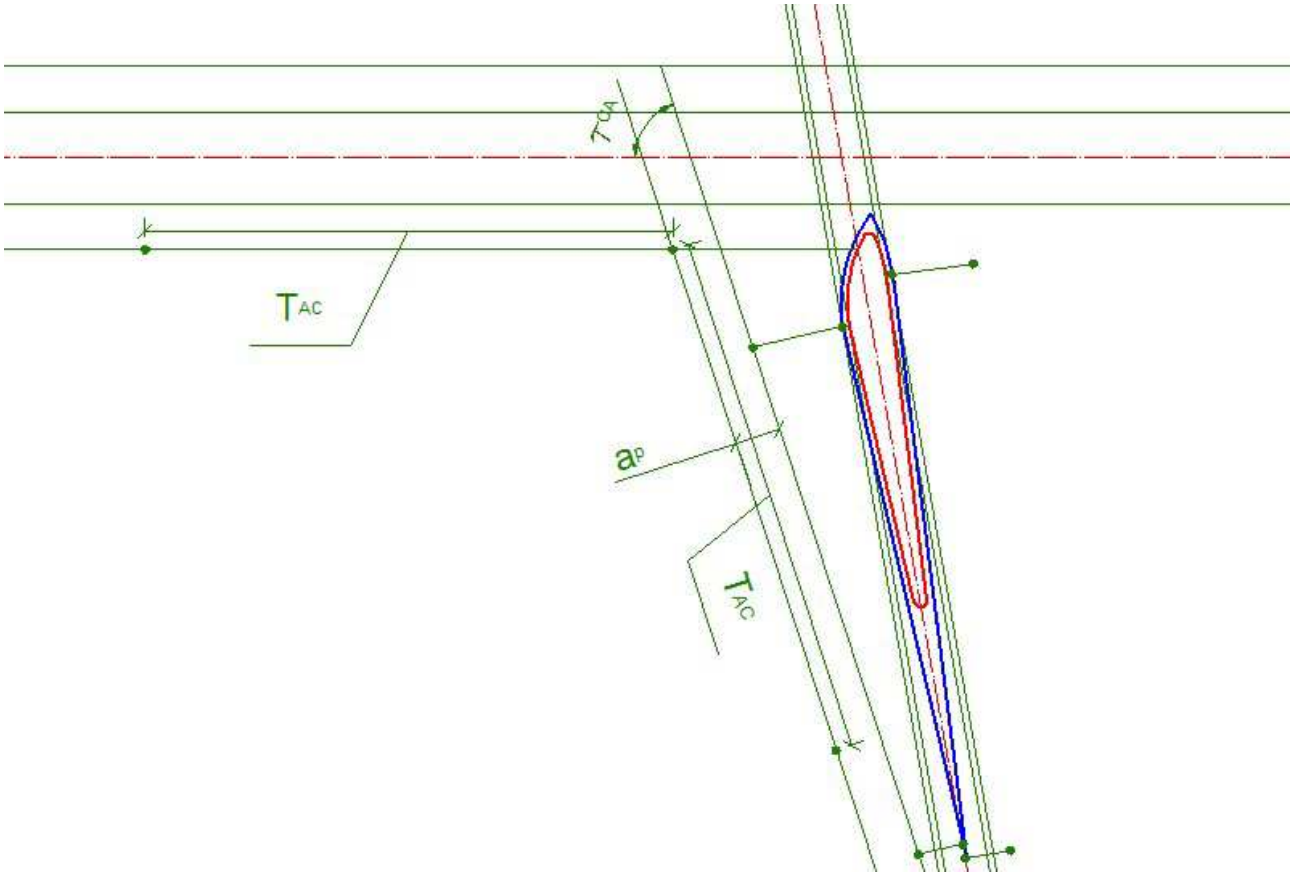


fig. 0950 (plotting of tangents „T_{AC}“ at construction of connector inner edge for turn AC)

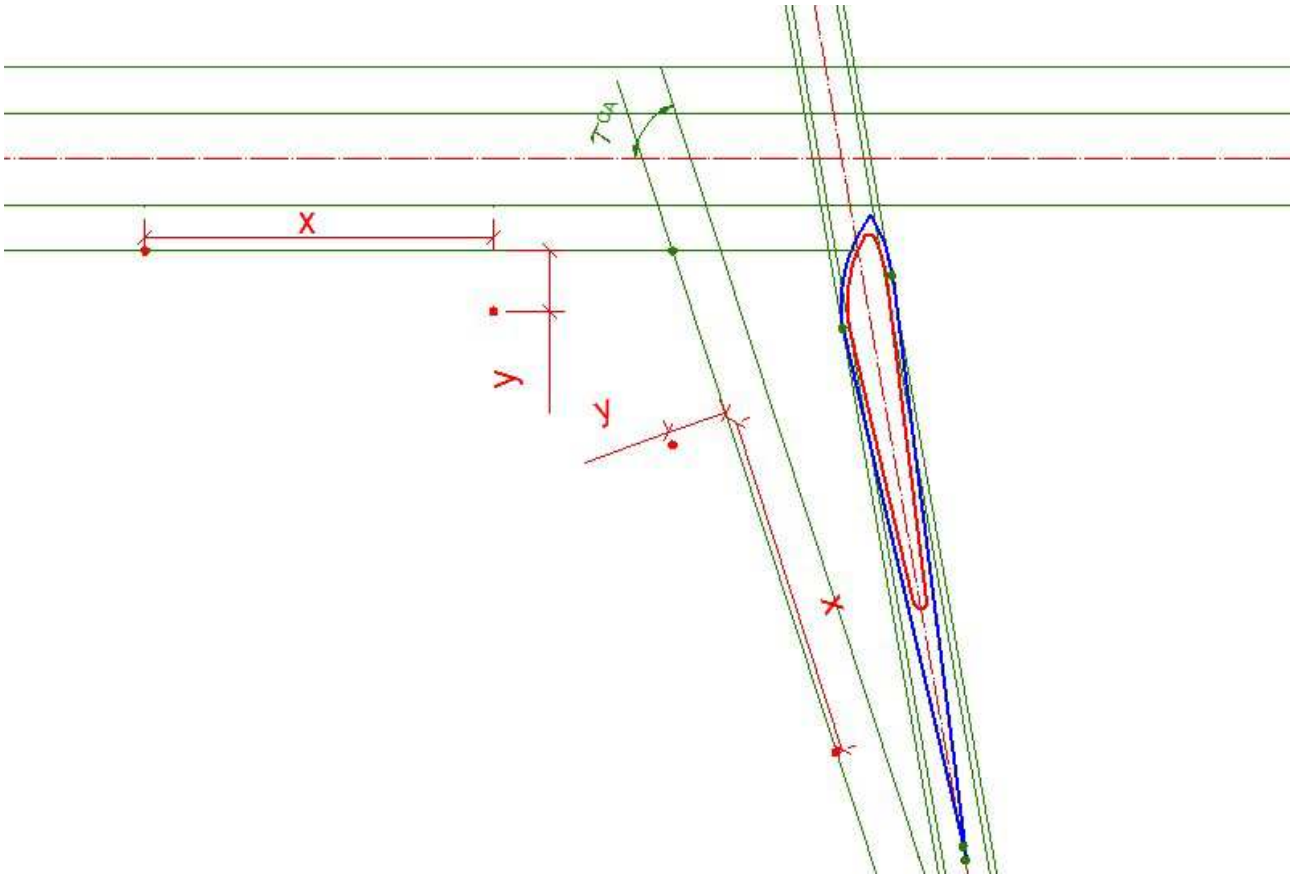


fig. 0960 (dimensions „x“ and „y“ at construction of connector inner edge for turn AC)

- *SÚK IV .....the procedure is not used*
- *SÚK **III** + SÚK **V** ....2 points of **horizontal dimension „T_{AC}“ and horizontal dimension „x“** are plotted **on the edge between** dimensions **„a_H“ and „a_p“ below** the major road **centreline** (see also fig. 0860) – dimension a_H = a (according to fig. 0560 and fig. 0570) and dimension „a_p“ is not used (see also scheme in fig. 0970)*

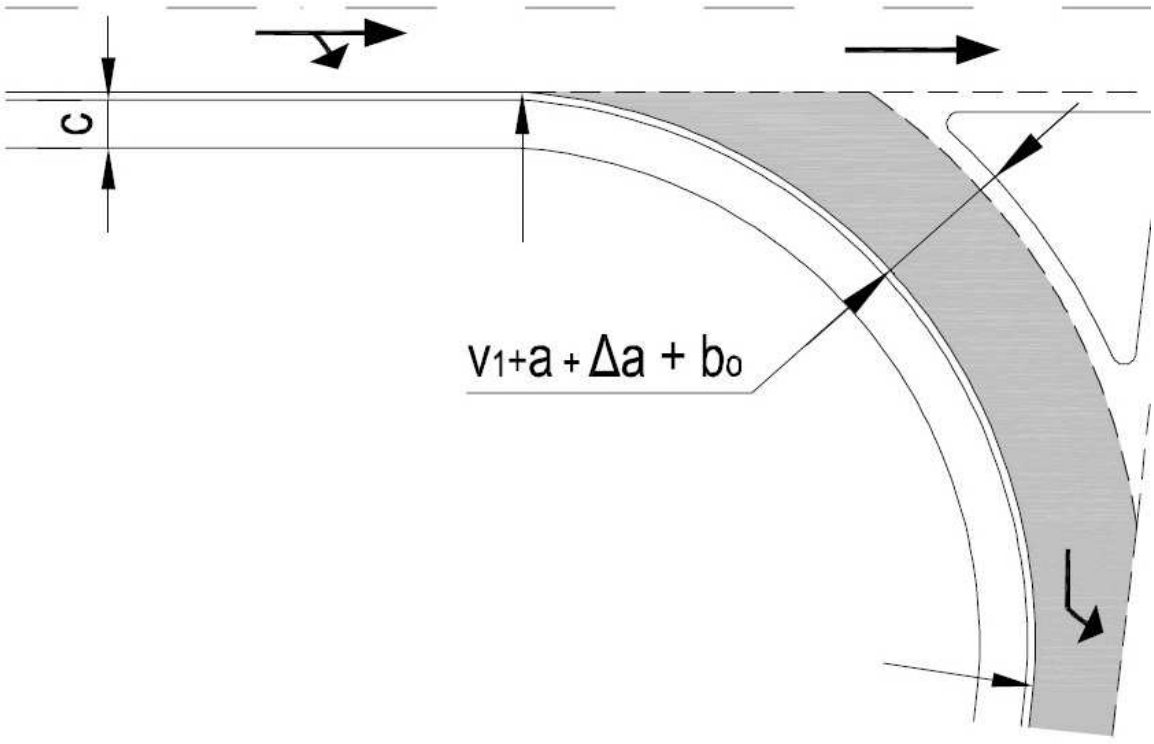


fig. 0970 (at-grade junction connector with direct exit from mainline and entry to merge lane)

- *SÚK **VI** .....2 points of **horizontal dimension „T_{AC}“ and horizontal dimension „x“** are plotted according to fig. 0950 and fig. 0960*

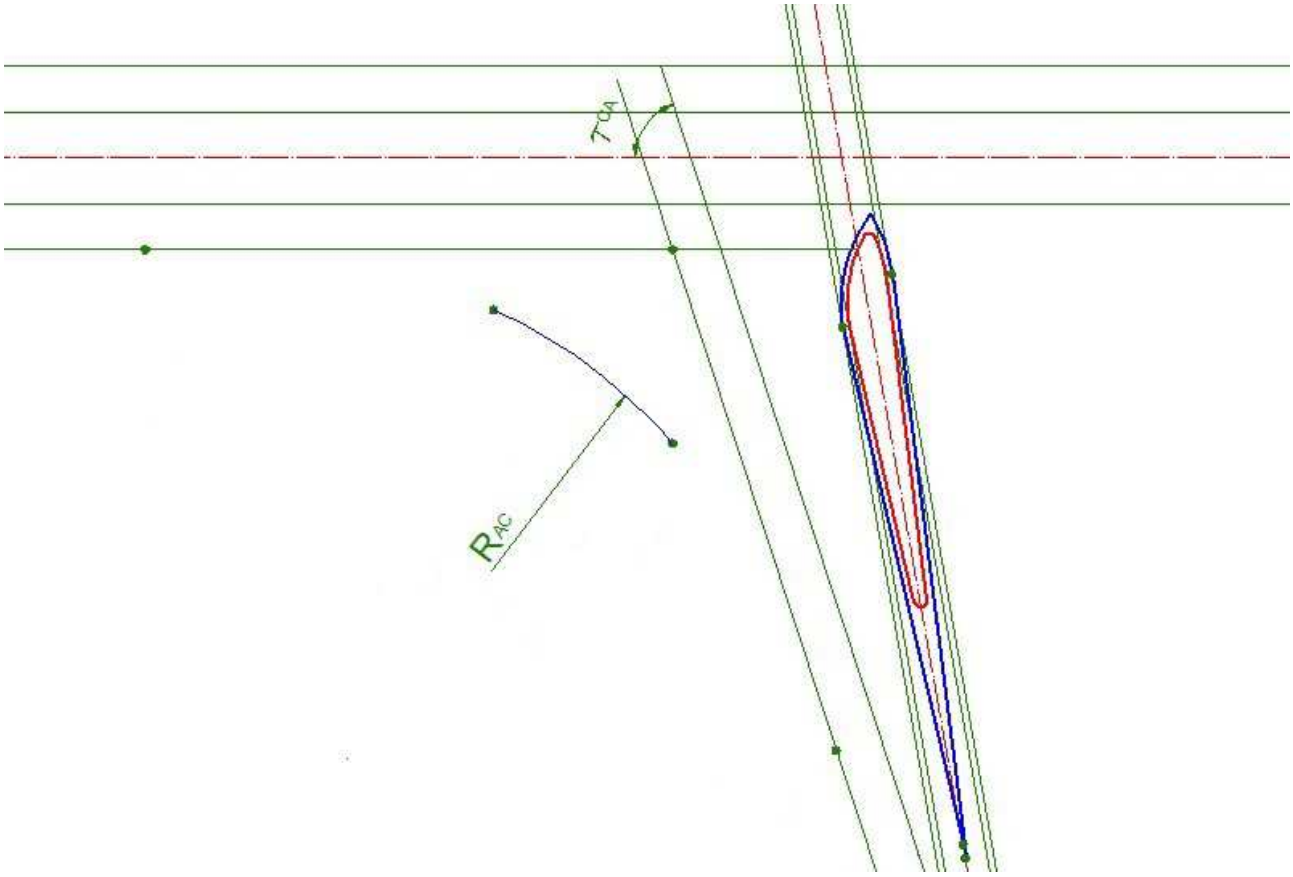


fig. 0980 (inserting circular part of curve with radius „R_{AC}“ at construction of connector inner edge for turn AC)

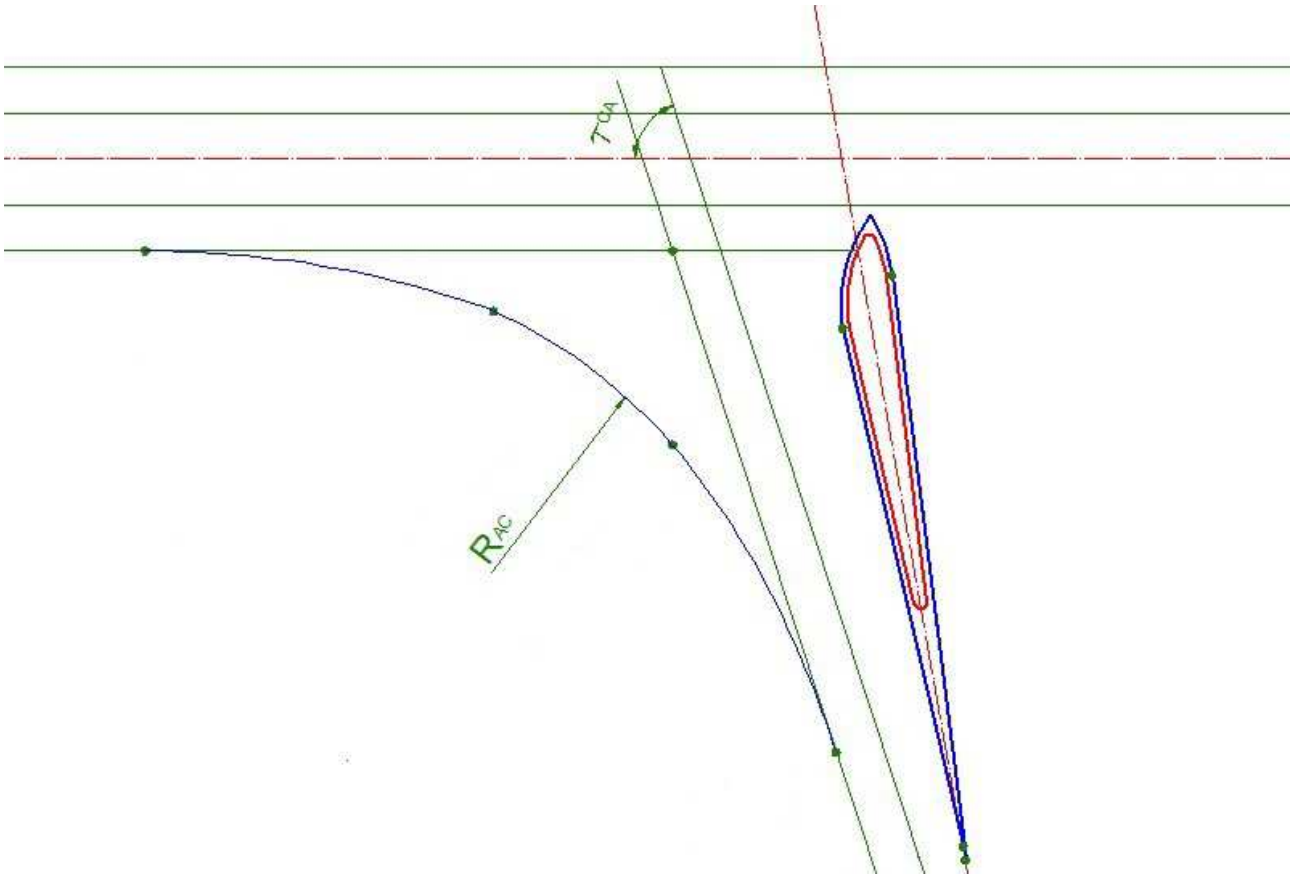
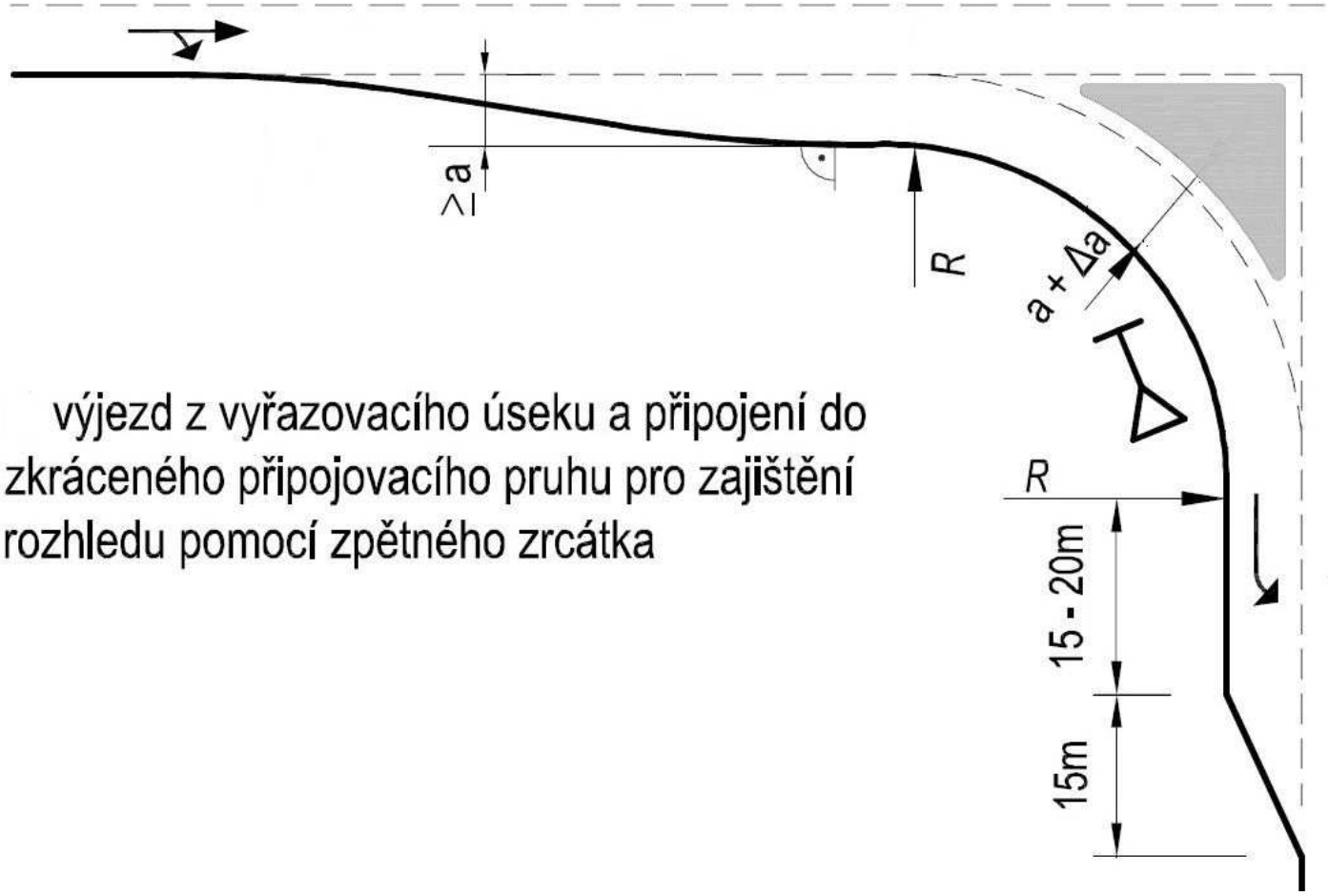


fig. 0990 (future inner guiding strip which is created by inserting transition curve at connector for turn AC)

- *perform analogously as well for **SÚK VI** for connector **CB** with turn **radius „R_{CB}“** ⇒ **tangents „T_{CB}“ and dimensions „x“ and „y“** with calculated values **for turn CB** are plotted on **red vertical line** on the right side in fig. 0890 and **on the outermost edge** of merge lane (**dimensions „a_p“**) **below** the major road **centreline** in fig. 0780*

- construction of **shortened merge lane on minor road** according to *fig. 1000* and *fig. 1010* (it is not carried out for SÚK IV)



výjezd z vyřazovacího úseku a připojení do zkráceného připojovacího pruhu pro zajištění rozhledu pomocí zpětného zrcátka

fig. 1000 (at-grade junction connector with connection to shortened merge lane)

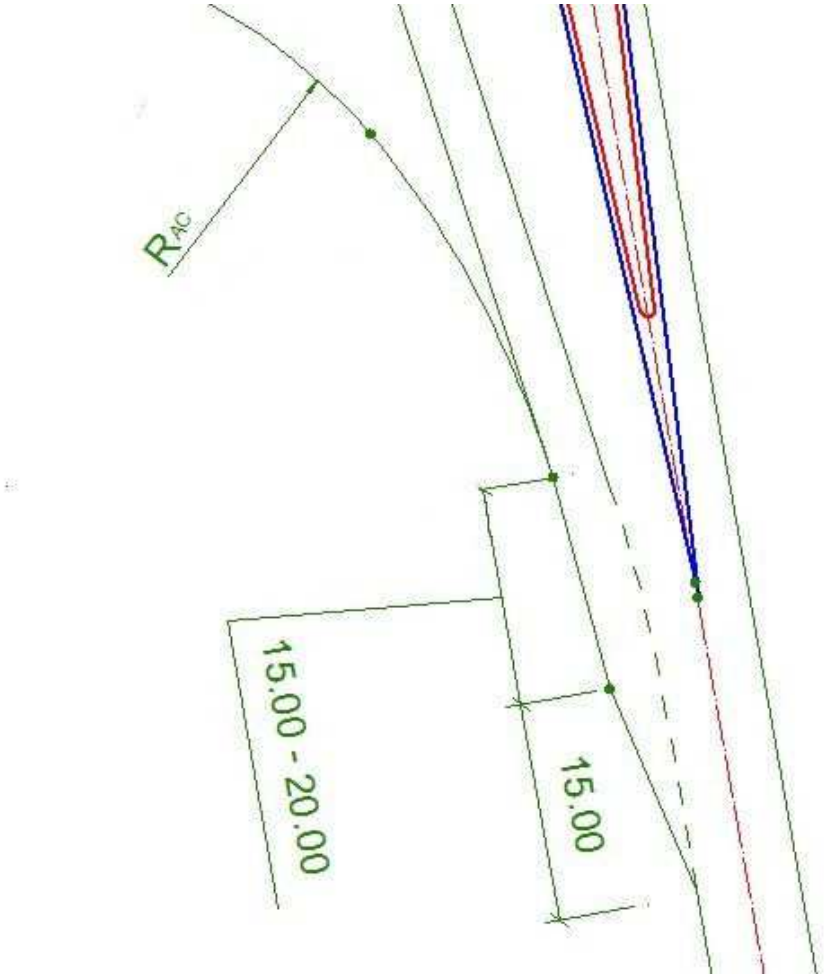


fig. 1010 (construction of shortened merge lane on minor road)

- construction of **connector outer edge** for turn **AC** (using **equidistant line from** connector **inner edge** at distance of connector width „$a_{ve(AC)}$ = a_{AC}' = **a_{AC} + Δa_{AC}**“ ⟹ future outer **guiding strip** – see *fig. 1020*)
  - *SÚK IV .....the procedure is not used*
  - *SÚK **VI** .....perform **analogously** also **for** connector **CB** (use values „$a_{ve(CB)}$ = a_{CB}' = a_{CB} + Δa_{CB}“)*

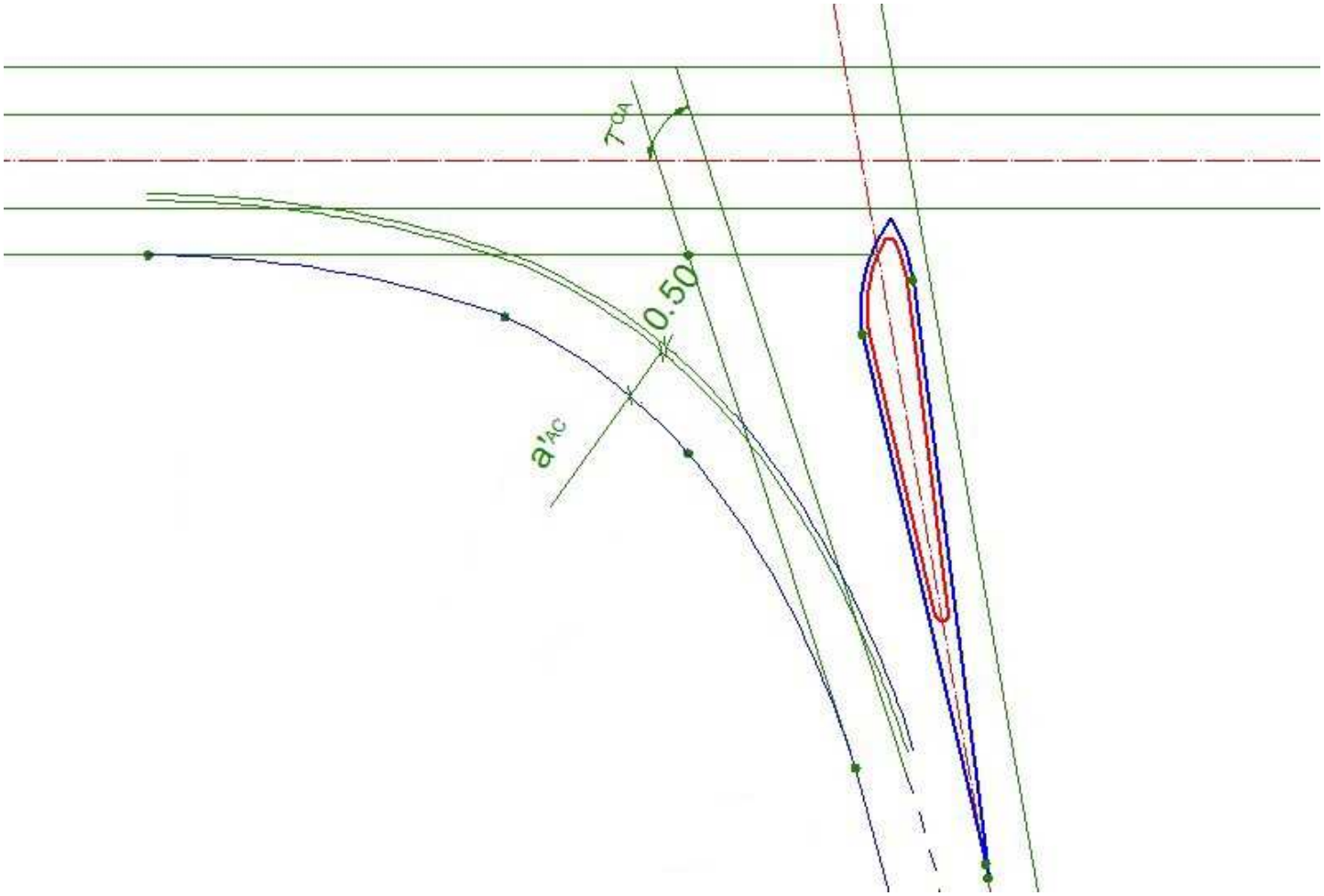


fig. 1020 (construction of connector outer edge for right turn)

- **equidistant line** at distance of safety distance **b_o = 0,5 m from outer guiding strip** forms the edge of eventual directing traffic island (see *fig. 1020*) – perform analogously at SÚK VI for the second directing traffic island
- plotting of **width** („$a_{ve(BC)} = a_{BC}' =$ **$a_{BC} + \Delta a_{BC}$**“ as equidistant lines to radius R_{BC}) **of left turn BC** and safety distance **b_o = 0,5 m** according to *fig. 1030*
  - *SÚK IV .....the procedure is not used*
  - *SÚK **VI** .....perform **analogously** for **left turn CA** (use width „$a_{ve(CA)} = a_{CA}' = a_{CA} + \Delta a_{CA}$“ as equidistant lines to radius „R_{CA}“)*

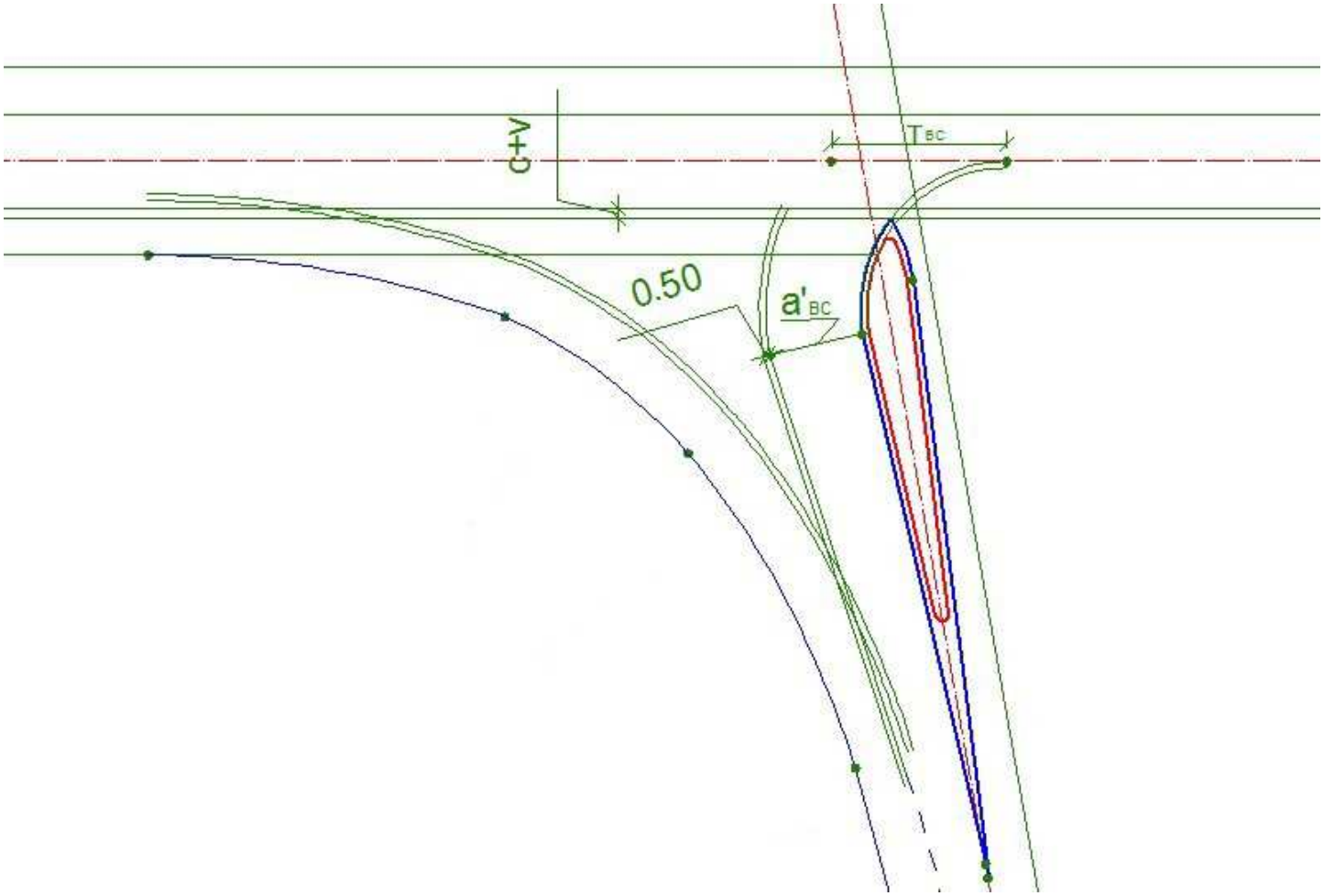


fig. 1030 (plotting of width of left turn BC and safety distance b_o = 0,5 m)

- plotting of **width** of hard shoulder „**c + v**“ on the **major road** – see *fig. 0930* and *fig. 1030*
  - *SÚK **III** + SÚK **V** ....**left** directing **island***
  - *SÚK IV .....the procedure is not used*
  - *SÚK **VI** .....**both** directing **islands***
- **enveloping curve of directing island** – blue **road marking** according to *fig. 1040* (**area < 7 m²** or **length** of one **edge < 3,00 m** ⇒ use **ghost island** instead of traffic island according to the rules in *fig. 1210*)

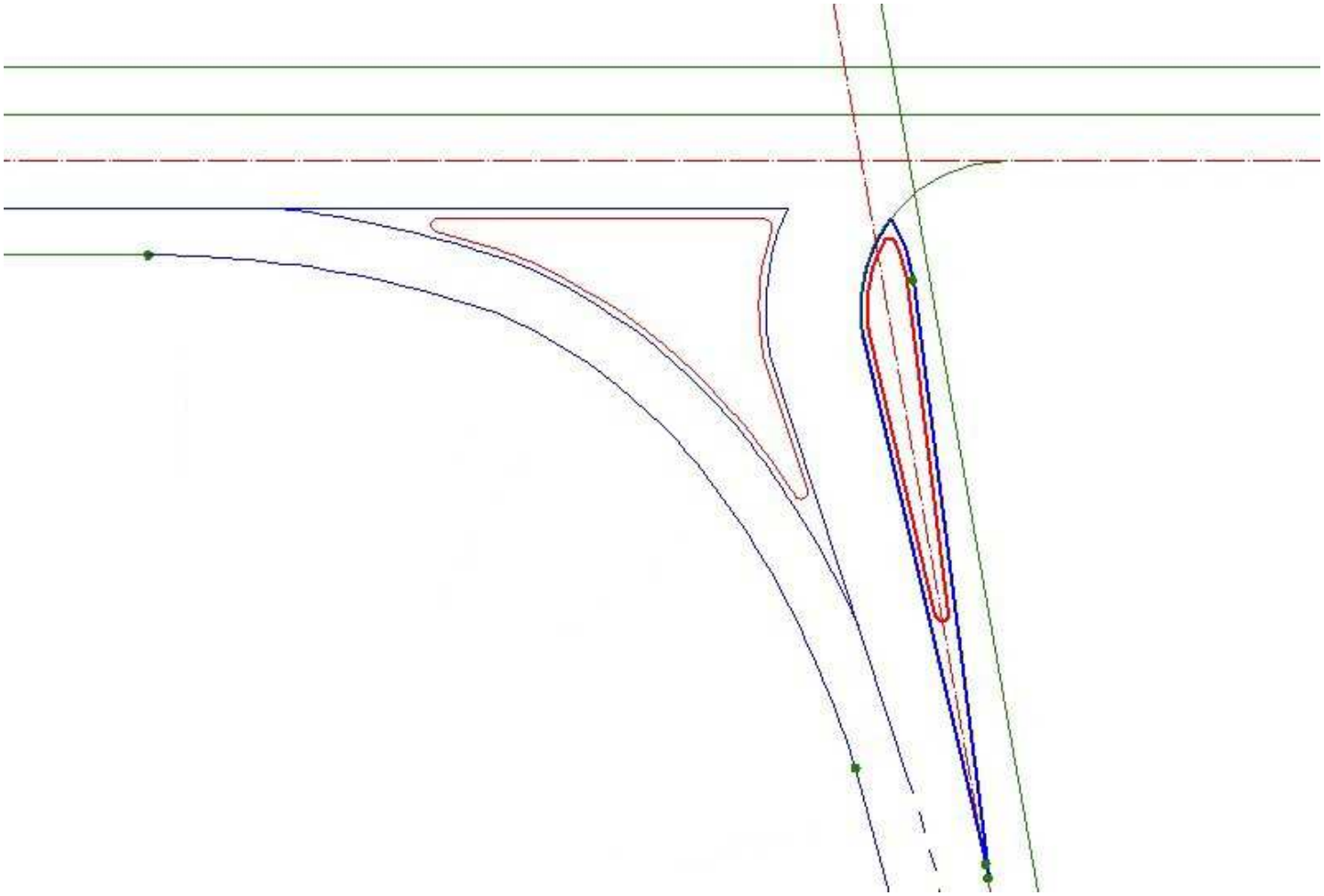


fig. 1040 (construction of directing island including road marking)

- *SÚK **III** + SÚK **V** ....**left** channelising **islands***
- *SÚK IV .....the procedure is not used*
- *SÚK **VI** .....**both** channelising **islands***

- construction of **physical edges of channelising island** according to *fig. 1040* (if the **area** bounded by road marking **≥ 7 m²** or **the length** of all **edges ≥ 3 m**) – round corners according to *fig. 0930*
  - *SÚK **III** + SÚK **V** ....**left** channelising **island***
  - *SÚK IV .....the procedure is not used*
  - *SÚK **VI** .....**both** channelising **islands***