Reinforcement Anchorage Length Calculation in Beam and Columns according to Various Country Regulations

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Abstract: ***There is international consensus on many design models for structural concreteelements. However, the harmonization of code provisions reveals that the structuralanalysis of some details was conducted very differently in single national codes in thepast. The omnipresent anchorage of reinforcing bars is one of the issues still unsolved.Due to the different weather conditions between Turkey and neighboring countries such as Russia and Europe, the reinforcement conditions in the standards of these countries were different from what is in the Turkish standard. Accordingly, this research was written to show the details of the anchorage of the beam reinforcement to the column and the overlapping of the reinforcement in the middle of the column to show the anchorage detail differences between Turkish, Russian and European regulations. This paper compares important provisions and parameters related to anchorage and lap of bars in reinforced concrete.***

Keywords: Anchorage length; Lap length; Hookanchorage;Colon; Beam

1. Introductıon

The main purpose of providing reinforcement bars is to transfer the load from one member to another. It may be either to another rebar or to concrete. In order to successfully transfer the load from one member to another, reinforcement bars must be tied tightly at both ends so that they do not slip. The reinforcing bars shall be so anchored with sufficient anchor so that the internal forces to which they are subjected are transmitted to the concrete and to avoid longitudinal cracking or spalling of the concrete. Lap length is provided for overlapping two rebars in order to safely transfer the load from one bar to another bar. The length of the anchor and the length of the lap varies according to the areas of tension and stress and depends on the grade of concrete, the size of the rebar, the concrete cover, etc. If necessary, transverse reinforcement should be provided.

2. Literature Survey

Many literture investigate anchorage length as follows:

Investigates on bond strength corresponding to various welded plate mechanical anchorages on 8mm diameter HYSD bars of different characteristics strengths, which are bonded inside concrete. The results appears when mechanical anchorages are used the development length requirement gets reduced to about half and one-fourth for the plate sizes[5]. investigates the parameters which have influences on the bond and anchorage as there are some of them have not been considered by all of them and found their significance in obtaining more accurate bond resistance like transverse pressure, transverse reinforcement, the yield strength of the transverse reinforcement, bar geometry, anchorage length, concrete cover and transverse pressure[2].

3. Methods

In this research, the anchorage length of the upper reinforcement of the beam support attached to a column and the overlapping length of the reinforcement in the middle of the column were calculated according to Turkish, Russian and European standards. The equations and conditions required for these calculations have been tabulated to facilitate understanding of the differences. Also, examples are solved to compare calculation methods between standards.

Accordıng to TS500-2000
Anchorage of Rebar
Straight Anchorage

The required anchorage length connects the reinforcement in the section to its position during concrete pouring. Here the reinforcement bars are divided into two groups, position I and position II. At the time of pouring the concrete, position II includes those that are inclined between 45 and 90 degrees from the horizontal, or less inclined or horizontal, but located in the lower half of the section or more than 300 mm from the free upper surface of the section. When it comes to position I, it includes all other bars except these (Figure 1).

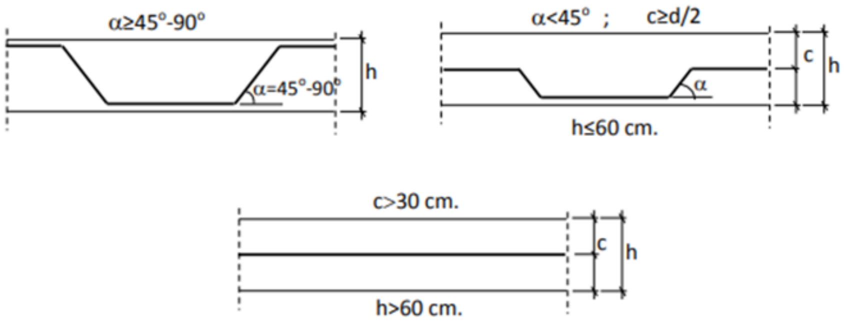

Figure 1: Reinforcement Bars in Position II [3]

Anchorage Tensile Rebar

The anchorage should be extended by the anchorage length (ℓb) without cutting the reinforcement from the unnecessary point. As basic anchorage, this length is shown in Equation 1 for ribbed bars in Position II.

$$\ell_b = 0{,}12 \frac{f_{yd}}{f_{ctd}} \text{Ø} \geq 20\,\text{Ø} \quad (1)$$

fyd : Longitudinal reinforcement design yield strength
fctd : Concrete design axial tensile strength

Straight anchorage is not allowed in TS 500 on flat surface bars.

Straight anchorage occurs if the tensile bar is extended by the anchorage length (ℓb) on either side of the highest stress point.

Anchorage pressure Rebar

Hook is not applied to the pressure point because the hook is in the same direction as the force (Figure 3). See table 4 four more details.

Hook Anchorage

Sometimes it is not possible to extend the reinforcement long enough to form a straight anchorage. In such cases, the end of the reinforcement can be bent and hooked or bowed, and the anchorage length can be taken up to 3/4. The equation is as below and in Figure 7. That is, the flat reinforcement piece required for anchorage can be reduced by Δℓb. Δℓb is the attached hook or bow. In the case of hook or hairpin, the length of the straight part of the reinforcement should be ℓb-Δℓb, and the hook curvature angle can vary between 90°-180°.

If the angle between the reinforcement axis and the hook is 90°, there must be a flat piece with a distance of not less than 12Ø at the independent end of the hook. Hook inner diameter, dm, cannot be less than 6Ø (Figure 2).

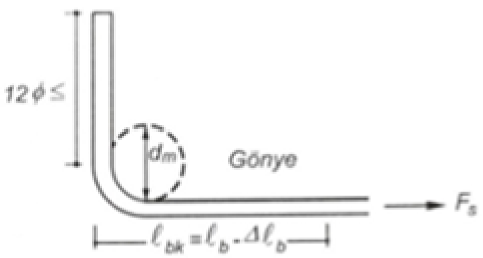

Figure 2: Details of 900 hooks foreseen in TS-500-2000[9]

Add rebar

Additions to the reinforcement should be made at the place and as shown on the construction site. Therefore, splicing should be done in areas where bending moments are minimum. This type of addition should be decided by the project engineer.

Laps couplers

It is preferred that the reinforcement bars are adjacent in lap joints. If it is necessary to leave a gap between two placed bars, this gap should not be more than 1/6 of the overlap length and 100 mm (Figure 3).

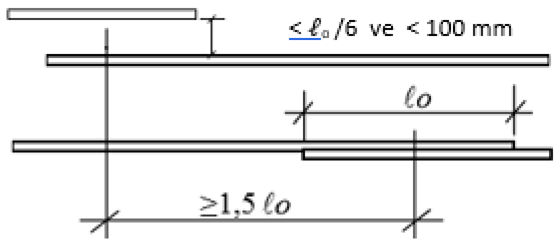

Figure 3: Overlap joints [3]

Lap Addition of Tensile Rebar

Below, figure 4, shows lap joints in hooked and unhooked tension reinforcement.

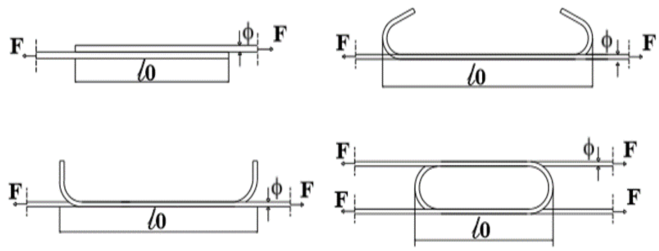

Figure 4: Laps couplers [3]

The overlap length formed without hooking can be taken from the equation below.

$\ell_o = a_1 \ell_b$ (2)

In here, $a_1 = 1 + 0{,}5r$

$$r = \frac{Reinforcement\ added\ in\ the\ same\ section}{Total\ reinforcement}$$

Table 1: Overlay length (ℓo) in lap joints [1]

Kancasız	Kancalı
Konum I	
$\ell_o = 1{,}4(1+0{,}5r)\ell_b$	$\ell_o = 1{,}05(1+0{,}5r)\ell_b$
Konum II	
$\ell_o = (1+0{,}5r)\ell_b$	$\ell_o = 0{,}75(1+0{,}5r)\ell_b$

Lap Addition of Pressure Reinforcement

As mentioned earlier, the overlap length can be smaller than the tensile reinforcement, since the presence of some of the stress in the end region of the compression reinforcement does not cause shrinkage and cracking. According to the experiments, that tightly placed winding reinforcement along the lap joint is very beneficial. While the wrap reinforcement makes the end recline more effective, it also prevents the surrounding concrete from bursting due to the curvatures in the reinforcement. Table 4 below shows some details.

Columns

Usually reinforcements on each floor have a lap joint. The addition should be made as far as possible in the middle part of the column where the moment is small. However, for ease of application, additions can be made at the lower end of the column. At the same time, if tension occurs in the column longitudinal reinforcement at any load combination, the lap joints to be formed at the lower end of the column in the longitudinal reinforcement shall comply with the following conditions. Overlap joints are made at floor level. However, in terms of earthquake, it is inconvenient that the thrust is made in the articulation zone.

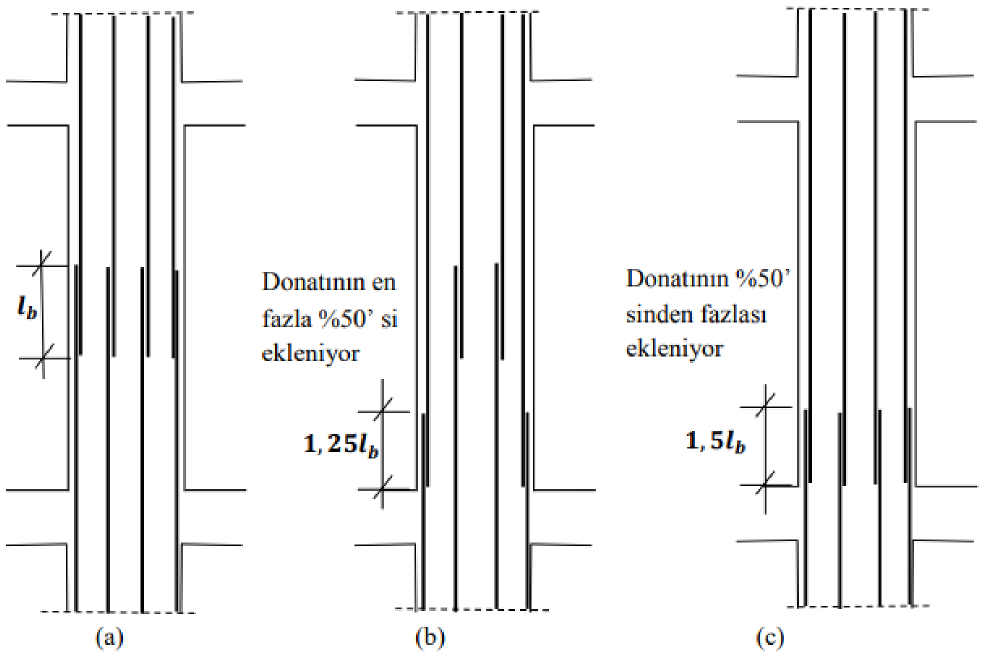

Figure 5: Column Longitudinal Reinforcement Overlap Attachment Shapes According to TS500 a) Adding the reinforcement in the middle of the column b) Adding 50% of the reinforcement in the lower end of the column c) Adding more than 50% of the reinforcement in the lower end of the column [3]

İf column longitudinal reinforcement is added in the area in the middle of the column, it must be $\ell_{\circ} \geq \ell b$.

If no shrinkage occurs in the column longitudinal reinforcement at the load combination, the rules given for adding compression reinforcement in lap joints are used.

If half or less of the longitudinal reinforcement is added in the same section, the overlap length should not be less than (1.25ℓb) and wrap reinforcement should be used along the overlap. If more than half of the longitudinal reinforcement is added, the overlap length should not be less than (1.5ℓb). These increments result from the large value of the moment at the lower end of the column (Figure 5).

Accordıng To SNIP 2.03.01-84 and SP 52-101-2003

Rebar anchorage

The reinforcement anchorage in the Russian reinforced concrete regulations is given below;

Straight anchorage

In straight anchorage, flat reinforcement is not allowed. But ribbed reinforcement is allowed.

$$l_{0,an} = \frac{R_s A_s}{R_{bond} u_s}$$

$l_{0,an}$: Longitudinal reinforcement rated anchorage (anchorage) length

A_s: The area of the docking reinforcement.

u_s: It is the perimeter of the anchorage reinforcement.

R_s: Design tensile strength of longitudinal reinforcement

R_{bond} : It is the anchorage strength that is assumed to be uniformly distributed throughout the reinforcement and should be calculated according to equation 4.

$$R_{bond} = \eta_1 \eta_2 R_{bt} \quad (4)$$

R_{bt}: Concrete Tensile Strength (rated or in use)

η_1: It is the reinforcement surface coefficient

η_2: The reinforcement diameter is the coefficient of influence:

Equation 5 is valid when structural effects are taken into account.

$$\boldsymbol{l_{an} = \alpha \, . \, l_{0,an} \cdot \frac{A_{s,cal}}{A_{s,ef}}} \quad (5)$$

l_{an} **:** Longitudinal reinforcement anchor length

α : Concrete quality coefficient

In Russian reinforced concrete regulations, basically, regardless of the method used to reduce the anchorage length of the reinforcement, the calculated anchorage length shall not be less than 30% of the value of the direct anchorage length.

Hook Anchorage

When determining the diameter of the hook at the end of the hooked reinforcement in a reinforced concrete element, attention should be paid to the points of crushing the concrete inside the hook or removing the hook. If the rebar hook diameter frost is defined, the minimum hook diameter is shown in Table 4.

Add rebar

According to Russian reinforced concrete regulation SP 52-101-2003, reinforcement additions are two types.

1. Weldless Joins (adds thrusts)

a. Direct termination of ribbed reinforcement.
b. Direct termination welded to shear reinforcements.
c. Placing plate or giving ring shape on reinforcement ends

2. Welded and mechanical end joints:

Table 4 shows the details of adding an overlay.

Accordıng to EUROCODE 2; BS EN 1992-1-1 VE 2004 VE EN 1992-1-1:2004 (E)

Anchorage of longitudinal reinforcement

Reinforcing bars, wires or welded mesh fabrics shall be so anchored that the bond forces are safely transmitted to the concrete avoiding longitudinal cracking or spalling. Transverse reinforcement shall be provided if necessary [4].

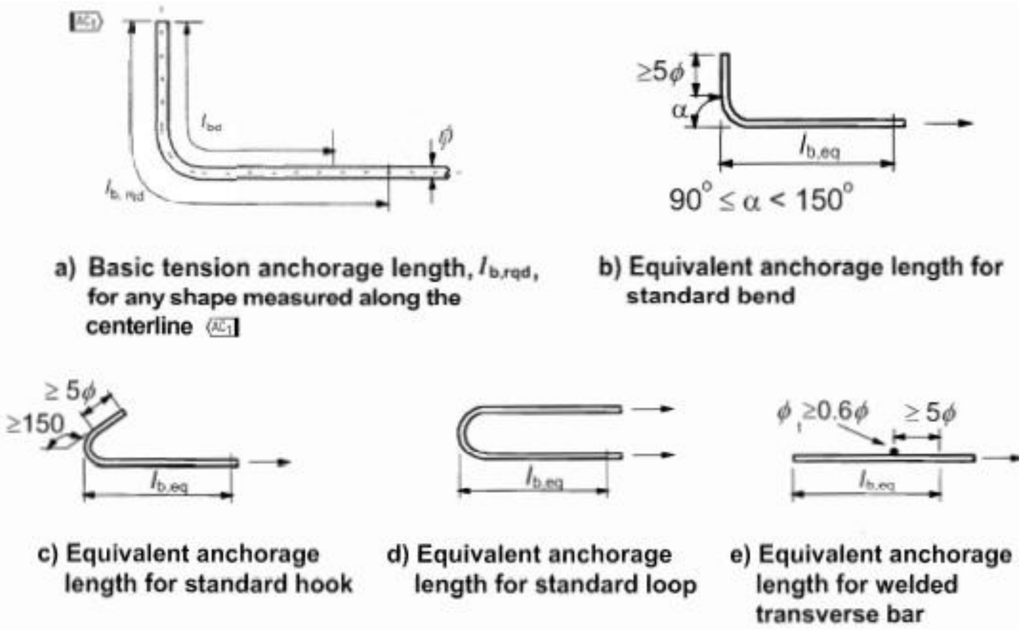

Figure 6: Methods of anchorage other than by a straight bar[4]

Splitting forces are higher and dowel action is greater with the use of large diameter bars. Such bars should be anchored with mechanical devices. As an alternative they may be anchored as straight bars, but links should be provided as confining reinforcement[4].

Bends and hooks do not contribute to compression anchorages [4].

Concrete failure inside bends should be prevented by complying with ♦ that will come later[4].

Basic anchorage length

The calculation of the required anchorage length shall take into consideration the type of steel and bond properties of the bars[4].

The basic required anchorage length, $l_{b,rqd}$, for anchoring the force As,σ_{sd} in a straight bar assuming constant bond stress equal to f_{bd} follows from[4]:

$$l_{b,rqd} = (\text{Ø}/4)\ (\sigma_{sd}\ /\ f_{bd}) \qquad (6)$$

For bent bars the basic required anchorage length, $l_{b,rqd}$, and the design length, l_{bd}, should be measured along the centre-line of the bar (see Figure 6a)[4].

Design anchorage length

The design anchorage length, I_{bd}, is:

$$l_{bd} = a_1 a_2 a_3 a_4 a_5 l_{b,rqd} \geq l_{b,min} \qquad (7)$$

where a_1, a_2, a_3, a_4 and $a_5$are coefficients given in Table 4) [4]:

a_1 : is for the effect of the form of the bars assuming adequate cover (see Figure 6))[4].

a_2 : is for the effect of concrete minimum cover (see Figure 7))[4].

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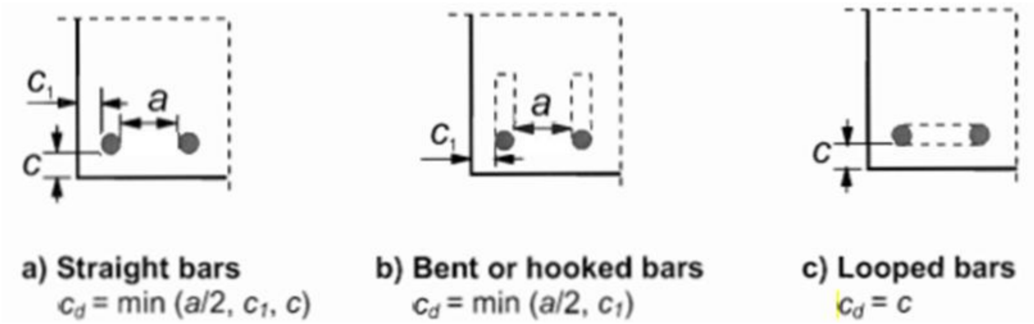


Figure 7: Values of Cd for beams and slabs [4]

a3 : is for the effect of confinement by transverse reinforcement [4].
a4 : is for the influence of one or more welded transverse bars ($Ø_t$> 0,6Ø) along the design anchorage length l_{bd}[4].
a5 : is for the effect of the pressure transverse to the plane of splitting along the design anchorage length [4].
The product($a_2a_3a_5$) ≥ 0,7(8)
$l_{b,min}$: is the minimum anchorage length if no other limitation is applied as mentioned in Table 4[4] :
l_{bd} is shown in Table 4 as a simplified alternative.

Table 8.2: Values of a11 a2, a3, a4 and as coefficients [4]

Influencing factor	Type of anchorage	Reinforcement bar: In tension	Reinforcement bar: In compression
Shape of bars	Straight	α_1 = 1,0	α_1 = 1,0
	Other than straight (see Figure 8.1 (b), (c) and (d)	α_1 = 0,7 if c_d >3ϕ otherwise α_1 = 1,0 (see Figure 8.3 for values of c_d)	α_1 = 1,0
Concrete cover	Straight	α_2 = 1 – 0,15 (c_d – ϕ)/ϕ ≥ 0,7 ≤ 1,0	α_2 = 1,0
	Other than straight (see Figure 8.1 (b), (c) and (d))	α_2 = 1 – 0,15 (c_d – 3ϕ)/ϕ ≥ 0,7 ≤ 1,0 (see Figure 8.3 for values of c_d)	α_2 = 1,0
Confinement by transverse reinforcement not welded to main reinforcement	All types	α_3 = 1 – $K\lambda$ ≥ 0,7 ≤ 1,0	α_3 = 1,0
Confinement by welded transverse reinforcement*	All types, position and size as specified in Figure 8.1 (e)	α_4 = 0,7	α_4 = 0,7
Confinement by transverse pressure	All types	α_5 = 1 – 0,04p ≥ 0,7 ≤ 1,0	-

where:
λ = (ΣA_{st} - $\Sigma A_{st,min}$)/ A_s
ΣA_{st} cross-sectional area of the transverse reinforcement along the design anchorage length l_{bd}
$\Sigma A_{st,min}$ cross-sectional area of the minimum transverse reinforcement = 0,25 A_s for beams and 0 for slabs
A_s area of a single anchored bar with maximum bar diameter
K values shown in Figure 8.4
p transverse pressure [MPa] at ultimate limit state along l_{bd}

* See also 8.6: For direct supports l_{bd} may be taken less than $l_{b,min}$ provided that there is at least one transverse wire welded within the support. This should be at least 15 mm from the face of the support.

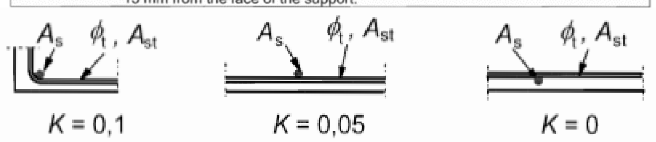


Figure 8: Values of K for beams and slabs [4]

Permissible mandrel diameters for bent bars

The minimum diameter to which a bar is bent shall be such as to avoid bending cracks in the bar, and to avoid failure of the concrete inside the bend of the bar[4].

In order to avoid damage to the reinforcement the diameter to which the bar is bent (Mandrel diameter) should not be less than $Ø_{m,min}$[4].

The mandrel diameter need not be checked to avoid concrete failure if the following conditions exist[4]:

- either the anchorage of the bar does not require a length more than 5Ø past the end of the bend or the bar is not positioned at the edge (plane of bend close to concrete face) and there is a cross bar diameter ≥ Ø inside the bend[4].
- the mandrel diameter is at least equal to the recommended values given in Table 4. Otherwise the mandrel diameter, $Ø_{m,min}$, should be increased in accordance with Expression (9)[4].

$$Ø_{m,min} \geq F_{bt}((1/a_b) + 1/(2Ø))/f_{cd} \quad (9)$$

Fbt : is the tensile force from ultimate loads in a bar (or group of bars in contact) at the start of a bend [4].
ab : for a given bar (or group of bars in contact) is half of the centre-to-centre distance between bars (or groups of bars) perpendicular to the plane of the bend. For a bar (or group of bars) adjacent to the face of the member, ab should be taken as the cover plus Ø/2[4].
The value of f_{cd} should not be taken greater than that for concrete class C55/67[3].

Laps couplers

(1) The detailing of laps between bars shall be such that[4]:

- the transmission of the forces from one bar to the next is assured[4];
- spalling of the concrete in the neighbourhood of the joints does not ocur [4];
- large cracks which affect the petiormance of the structure do not ocur[4].

(2) between bars should normally be staggered and not located in areas of high moments Iforces (e.g. plastic hinges). Exceptions are given in (4) below[4];

- at any section should normally be arranged symmetrically[4].

(3) The arrangement of lapped bars should comply with Figure 9[4]:

- the clear distance between lapped bars should not be greater than 4Ø or 50 mm, otherwise the lap length should be increased by a length equal to the clear space where it exceeds 4Ø or 50 mm[4].
- the longitudinal distance between two adjacent laps should not be less than 0,3 times the lap length, 10[4].
- In case of adjacent laps, the clear distance between adjacent bars should not be less than 2Øor 20 mm[4].

(4) When the provisions comply with (3) above, the permissible percentage of lapped bars in tension may be

100% where the bars are all in one layer. Where the bars are in several layers the percentage should be reduced to 50%[4].

All bars in compression and secondary (distribution) reinforcement may be lapped in one Asection[4].

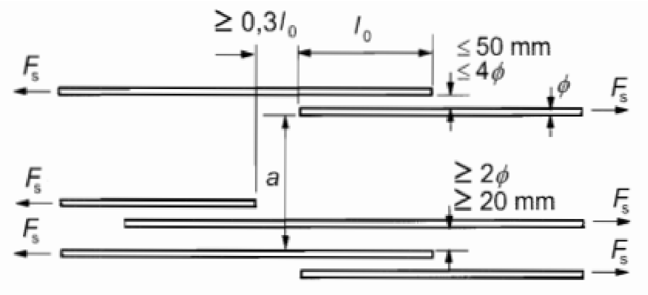


Figure 9: Adjacent laps [4]

Lap length

The design lap length is:

$$l_0 = a_1 a_2 a_3 a_5 a_6 l_{b,rqd} \geq l_{0,min} \quad (10)$$

The value of $l_{0,min}$ can be found with the equation in the Table[4].

Values of a_1, a_2, a_3 and a_5 may be taken from Table 8.2; however, for the calculation of a_3, $\sum A_{st,min}$ should be taken as $1{,}0A_s(\sigma_{sd} / f_{yd})$, with A_s = area of one lapped bar [4].

$a_6 = (\rho_1/25)^{0,5}$ but not exceeding 1,5 nor less than 1 ,0, where ρ_1 is the percentage of reinforcement lapped within 0,65 l_0 from the centre of the lap length considered (see Figure 10). Values of a_6 are given in Table 3 [4].

Table 3: Values of the coefficient a6 [3]

Percentage of lapped bars relative to the total cross-section area	< 25%	33%	50%	>50%
a_6	1	1,15	1,4	1,5
Note: Intermediate values may be determined by interpolation.				

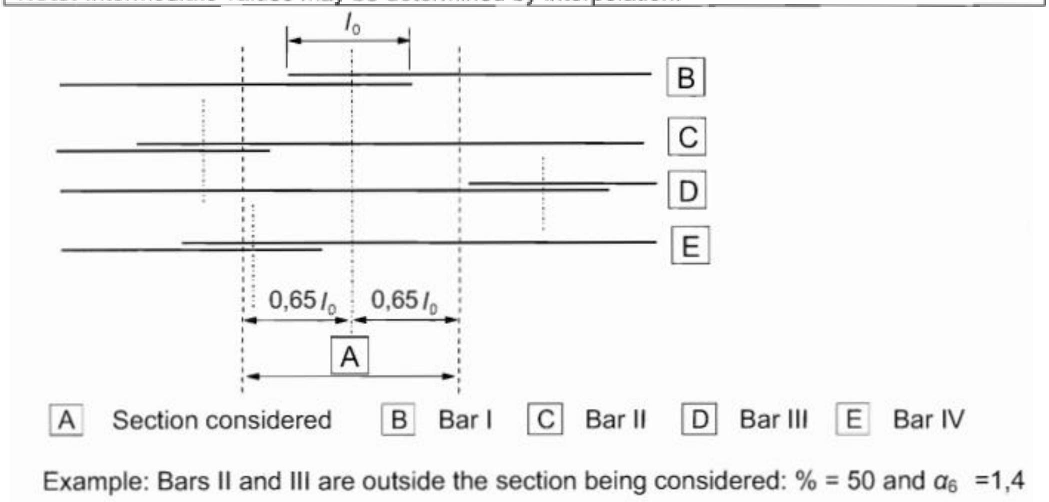


Figure 10: Percentage of lapped bars in one lapped section [4]

Transverse reinforcement in the lap zone

Transverse reinforcement for bars in tension

1) Transverse reinforcement is required in the lap zone to resist transverse tension forces[4].
2) Where the diameter, Ø, of the lapped bars is less than 20 mm, or the percentage of lapped bars in any section is less than 25%, then any transverse reinforcement or links necessary for other reasons may be assumed sufficient for the transverse tensile forces without further justification[4].
3) Where the diameter, Ø, of the lapped bars is greater than or equal to 20 mm, the transverse reinforcement should have a total area, $\sum A_{st}$ (sum of all legs parallel to the layer of the spliced.reinforcement) of not less than the area A_s of one lapped bar ($\sum A_{st} \geq 1{,}0A_s$). The transverse bar should be placed perpendicular to the direction of the lapped reinforcement[4].
4) If more than 50% of the reinforcement is lapped at one point and the distance, a, between adjacent laps at a section is ≤ 10Ø (see Figure 11) transverse reinforcement should be formed by links or U bars anchored into the body of the section[4].
5) The transverse reinforcement provided for (3) above should be positioned at the outer sections of the lap as shown in Figure 11a[4].

Transverse reinforcenlent for bars permanently in compression

In addition to the rules for bars in tension one bar of the transverse reinforcement should be placed outside each end of the lap length and within 4¢ of the ends of the lap length (Figure 11b)and (Table 4) [4].

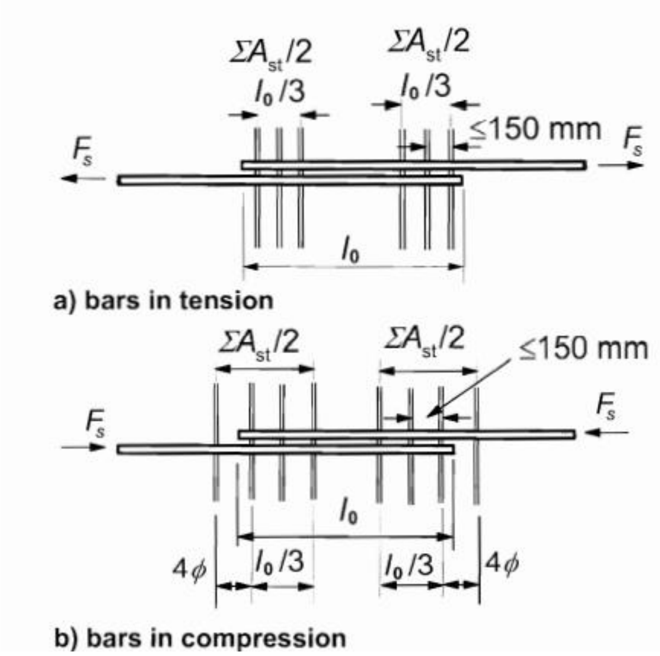


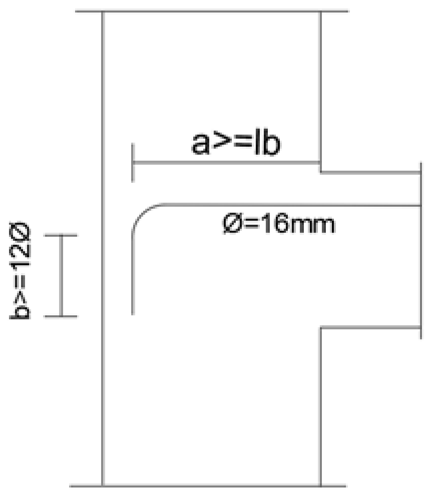
Figure 11: Transverse reinforcement for lapped splices [4]

Table 4: Comparison between code standard in Anchorage length and lap length estimation

TS500	*SNIP 2.03.0184 and SP 52-101-2003*	*EUROCODE 2; BS EN 1992-1-1 VE 2004 VE EN 1992-1-1:2004 (E)*
Anchorage length	**Anchorage length**	**Anchorage length**
$\ell_b = 0{,}12 \frac{f_{yd}}{f_{ctd}} Ø \geq 20 Ø$	Basic anchorage length $l_{0,an} = \frac{R_s A_s}{R_{bond} u_s}$	Basic required anchorage length constant bond tension = f_{bd} and in straight bar $l_{b,rqd} = (Ø/4)\ (\sigma_{sd} / f_{bd})$
$\ell_b\ (location\ \mathrm{I}) = \ell_b\ (location\ \mathrm{II})\ x\ 1{,}4$	$R_{bond} = \eta_1 \eta_2 R_{bt}$	Design anchorage length $l_{bd} = a_1 a_2 a_3 a_4 a_5 l_{b,rqd} \geq l_{b,min}$ for reinforcement under tension $l_{b,min} \geq max\{0{,}3\ l_{b,rqd};\ 10Ø;\ 100\ mm\}$ for reinforcement under pressure $l_{b,min} \geq max\{0{,}6\ l_{b,rqd};\ 10Ø;\ 100\ mm\}$ a_1, a_2, a_3, a_4, a_5 The coefficients are given in Table 8.2.
$32\ mm < Ø \ll 40\ mm \rightarrow$ $\ell_b' = (\frac{100}{32 - Ø})\ \ell_b$	η_1: hot rolled and for ribbed reinforcement =2.5 For flat reinforcement = 1.5 For cold drawn reinforcement = 2.0	
$\frac{A_{s\ necessary}}{A_{s\ available}} \longrightarrow$ $\ell_b' = \left(\frac{A_{s\ necessary}}{A_{s\ available}}\right) \ell_b \geq (\frac{\ell_b}{2})\ or\ 20Ø$	η_2: for ds (Ø) < 32 mm =1.0 ds (Ø) < 36 or 40 =0.9	l_{bd} as a simplified alternative $l_{bd} = a_1\ l_{b,rqd}$ Figure 8.1 b, c, d $l_{bd} = a_4\ l_{b,rqd}$ Figure 8.1 e
($d' < Ø$ Or the net distance between two reinforcements < 1.5Ø)⟶ $\ell_b' = \ell_b x\ 1{,}2$	Where structural effects are taken into account $\boldsymbol{l_{an} = \alpha\ .\ l_{0,an} \cdot \frac{A_{s,cal}}{A_{s,ef}}}$	On longitudinal reinforcement hooks Ø≤16mm ise mandrel = 4Ø Ø>16mm ise mandrel = 7Ø
For reinforcement under pure pressure $\ell_b' = \frac{3}{4} \ell_b$	The coefficient of α in hooked flat reinforcement is: α = 0.75 under pressure α = 1.0 under tension	**Adding an overlay**
For Hook $\ell_{bk} = \frac{3}{4} \ell_b$	hook anchorage (mendral=don; ds=Ø) in flat reinforcement If ds<20mm then frost= 2.5 ds If ds>20 mm don= 4 ds In ribbed reinforcement If ds<20 mm then don= 5 ds If ds>20 mm don= 8 ds	Laps length $l_0 = a_1 a_2 a_3 a_5 a_6 l_{b,rqd} \geq l_{0,min}$ $\mathbf{a_1}$, $\mathbf{a_2}$, $\mathbf{a_3}$ and $\mathbf{a_5}$ values can be taken from Table 2 for a_5; $(\mathbf{a_2 a_3 a_5}) \geq 0{,}7$ $1 \leq a_6 = (\rho_1/25)^{0,5} \leq 1{,}5$
For longitudinal reinforcement hooks (mendral) dm ≥ 6Ø	Calculated anchorage length l_an ≥ 30% basic anchorage length l_(0,an)	$l_{0,min} \geq max\{0{,}3\ a_6\ l_{b,req};\ 15Ø;\ 200\ mm\}$
$\ell_b\ (location\ \mathrm{I}) = \ell_b\ (location\ \mathrm{II})\ x\ 1{,}4$	**Adding an overlay**	**Transverse reinforcementalong the thrust**
90^0'hook $\ell_{bk} = \frac{3}{4} \ell_b$	In these calculations, the conditions related to the reinforcement anchor	**Bars in tension** Diameter of lap bars< **20mm** or percentage of lap bars

$a \geq \ell_b$, $b \geq 12Ø$	are valid.	in any section < %25
Adding an overlay	valid for ds<40mm Overlay length ≥ (0,4·α·$l_{0,an}$) or (20ds) or 260 mm	→any transverse reinforcement required for other reasons is sufficient Diameter of lapped bars ≥ 20mm → total area of transverse reinforcement≥ area of lapped bars (∑Ast ≥ 1,0As)
Overlap joint cannot be used for rebars with a diameter greater than 30 mm.	**Transverse reinforcement along the thrust** Winding reinforcement spacing along the lap ≤ 10 ds	**Bars in pressure state** In addition to the rules for drawbars, one bar of transverse reinforcement must be placed outside each end of the lap length and within 4Ø of the ends of the lap length (Figure 10b).
Overlay length $\ell_o = a_1 \ell_b$		Diameter of transverse reinforcement≥ max(6mm; diameter of longitudinal bars $Ø_{max}$/4)
For reinforcement under pure tension $\ell_o(Konum\ \text{I}) = 1{,}8\ \ell_b$		
For reinforcement under pure pressure $\ell_o \geq \ell_b\ ;\ 300\ mm$		Spacing of transverse reinforcement along the column ≤ $S_{cl,tmax}$ =min(20$Ø_{min}$, b_{min}, 400mm) Maximum range should be reduced to 0,6 $S_{cl,tmax}$
Transverse reinforcementalong the thrust		$Ø_{max}$>14mm→a minimum of 3 bars is required, evenly spaced along the overlap length.
Winding reinforcement spacing along the lap $s_c \geq d/4$		
Spacing of transverse reinforcement in the mid-thrust region of the column$\frac{d}{4} \leq s_c \leq 12\phi_{min}, 200\ mm$		

EXAMPLES



Accordıng To TS500
Column-beam (clock with 90^0 hooks)
The upper reinforcement of the beam in the junction area = 3Ø16
Colon =40x40, beam=25x60
f_{yd} =365 Mpa, f_{ctd}=1.1667
Ø = 16 mm
(Mandrel) dm ≥ 6Ø

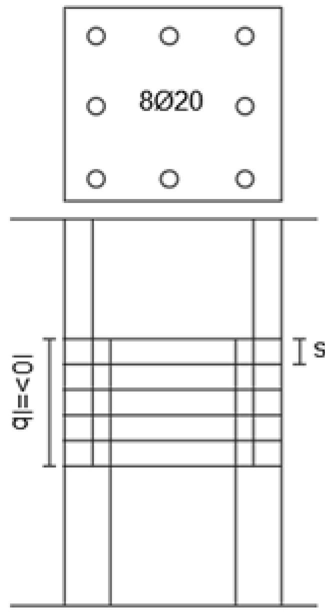
$$Anchorage\ length\ell_b = 0{,}12\ \frac{f_{yd}}{f_{ctd}} Ø \geq\ 20\ Ø$$

$$\ell_b = 0{,}12\ \frac{365}{1.1667}.16 = 600\ mm \geq\ 320\ mm\ \ ok$$

$$a \geq 0{,}4\ell_b = 0{,}4\,.\,600\ =\ 240\ mm, b \geq 12Ø = 12\,.\,16 = 192\ mm$$

$$a + b = 240 + 192 = 432\ mm$$

The bent rods stay in the transverse reinforcement of the column.



Adding an overlay in the middle of a column
Colon 40x40 ; 8Ø20
Concrete cover = 40 mm, d =400 – 40 = 360 mm

$$\ell_b = 0{,}12\ \frac{f_{yd}}{f_{ctd}} Ø \geq\ 20\ Ø$$

$$\ell_b = 0{,}12\ \frac{f_{yd}}{f_{ctd}} Ø \geq\ 20\ Ø$$

$$\ell_b = 0{,}12\frac{265}{1{,}1667}.20 = 750mm \geq 20x20 \geq 400mm$$

$$\ell_b = 0{,}12\ \frac{f_{yd}}{f_{ctd}} Ø \geq\ 20\ Ø$$

$$\ell_b = 0{,}12\ \frac{f_{yd}}{f_{ctd}} Ø \geq\ 20\ Ø$$

Laps length$\ell_0 \geq \ell_b = 750\ mm$

According to SNIP 2.03.01-84 ve SP 52-101-2003'E
Column-beam (clock with 90^0 hooks)

Colon=40x40, beam=25x60 , The upper reinforcement of the beam in the junction area= 3Ø16
For flat reinforcement $\eta_1 = 1{,}5$; $\eta_2 = 1$; under tension α =1
d_s = Ø =16 mm, don (mandrel)=2,5d_s = 40 mm
R_{bt} : Concrete Tensile strength = 1,1667 :Mpa
R_s : Design tensile strength of longitudinal reinforcement = 365 Mpa
R_{bond} : Rebar anchorage strength

$$R_{bond} = \eta_1\eta_2 R_{bt} = 1{,}5 . 1 . 1{,}1667 = 1{,}75\ Mpa$$

$$u_s = \emptyset.\pi = 3{,}14 . 16 = 50\ mm$$

$$A_s = \left(\frac{\emptyset}{2}\right)^2 .\pi = \left(\frac{16}{2}\right)^2 . 3{,}14 = 200{,}1\ mm^2$$

Anchoragelength $l_{0,an} = \frac{R_s A_s}{R_{bond} u_s} = \frac{365 . 200{,}1}{1{,}75 . 50} = 835\ mm$

$$Calculated\ transverse\ reinforcement\ area A_{s,cal} = 90\ mm^2$$

$$Arranged\ transverse\ reinforcement\ area\ A_{s,ef} = 100{,}53\ mm^2$$

$$\boldsymbol{l_{an} = \alpha . l_{0,an} . \frac{A_{s,cal}}{A_{s,ef}} = 1 . 835 . \frac{90}{100{,}53} = 748\ mm}$$

Calculated anchorage length $\boldsymbol{l_{an}}$ ≥ %30 direct anchorage length $l_{0,an}$
748 ≥ %30 . 835 = 250,5 ok

Adding an overlay in the middle of a column

Colon 40x40 ; 8Ø20
For flat reinforcement $\eta_1 = 1{,}5$; $\eta_2 = 1$; under pressure α =0,75

$$R_{bond} = \eta_1\eta_2 R_{bt} = 1{,}5 . 1 . 1{,}1667 = 1{,}75\ Mpa$$

$$u_s = \emptyset.\pi = 3{,}14 . 20 = 63\ mm$$

$$A_s = \left(\frac{\emptyset}{2}\right)^2 .\pi = \left(\frac{20}{2}\right)^2 . 3{,}14 = 314\ mm^2$$

Anchorage length $l_{0,an} = \frac{R_s A_s}{R_{bond} u_s} = \frac{365 . 314}{1{,}75 . 63}$ = 1040 mm

$$ECalculated\ transverse\ reinforcement\ area\ A_{s,cal} = 301\ mm^2$$

$$Arranged\ transverse\ reinforcement\ area\ A_{s,ef} = 314\ mm^2$$

$$\boldsymbol{l_{an} = \alpha . l_{0,an} . \frac{A_{s,cal}}{A_{s,ef}} = 0{,}75 . 1040 . \frac{301}{314} = 748\ mm} =$$

Lap length $\boldsymbol{l_{an}}$ ≥ (0,4·α·$l_{0,an}$) ya da (20ds) ya da 260 mm
(0,4·α·$l_{0,an}$) $= 0{,}4 . 0{,}75 . 1040 = 312\ mm$
Lap length $\boldsymbol{l_{an} = 748\ mm}$ ≥ 312 mm ; 400 mm ; 260 mm ok

EUROCODE 2; BS EN 1992-1-1 VE 2004 VE EN 1992-1-1:2004 (E)'E GÖRE

Column-beam (clock with 90^0 hooks)

Colon= 40 x 40, beam =25 x 6, The upper reinforcement of the beam in the junction area = 3Ø16

$$f_{bd} = 2{,}25\ \eta_1\eta_2 f_{ctd}$$

η_1 is a coefficient related to the quality of the bond condition and the position of the bar during concreting (see Figure 8.2): η_1 = 1,0 when 'good' conditions are obtained and
η_2 is related to the bar diameter: η_2 = 1,0
$f_{ctd} = 1{,}1667\ Mpa$
$f_{bd} = 2{,}25 . 1 . 1. 1{,}1667 = 2{,}625\ Mpa$
Under tension a_1 = 1 (Table 2)
d_s (Ø)=16 mm; Mandrel = 4Ø

$$\sigma_{sd} = f_{yd} = \frac{f_{yk}}{1{,}15} = \frac{420}{1{,}15} = 365\ Mpa$$

Anchorage length in flat bar $l_{b,rqd} = (\emptyset/4)\ (\sigma_{sd}\ /\ f_{bd})$
$l_{b,rqd} = (16/4)\ (365\ /\ 2{,}625) = 556\ mm$
l_{bd} as a simplified alternative
$a_1 = 1$
$l_{bd} = a_1 . l_{b,rqd}$ =1 . 556 = 556 mm

For reinforcement under tension $l_{b,min}$ ≥ max{0,3 $l_{b,rqd}$; 10Ø; 100 mm}
$l_{b,min}$ ≥ max{167; 160 mm ; 100 mm}=167 mm
$flat\ piece\ at\ the\ end\ of\ the\ hook\ \geq\ 5\emptyset$

$$l_{bd} + 5\emptyset = 556 + 5 . \frac{16^2 . 3{,}14}{4} = 1561\ mm$$

Adding an overlay in the middle of a column

Colon 40x40 ; 8Ø20
η_1 = 1,0, η_2 = 1,0, under tension: a_1 = 1 (Table 2)
d_s (Ø)=20 mm
$l_{b,rqd} = (\emptyset/4)\ (\sigma_{sd}\ /\ f_{bd})$
$l_{b,rqd} = (20/4)\ (365\ /\ 2{,}625) = 695\ mm$
Lap length $l_0 = a_1 a_2 a_3 a_5 a_6 l_{b,rqd} \geq l_{0,min}$
a_1, a_2, a_3 ve a_5 values can be taken from Table 2
a_1= a_2= a_3=1,0; for pressure a_5= -
(a_2 .a_3 .a_5) ≥ 0,7, 1 ≥ 0,7 ok
$1 \leq a_6 = (\rho_1/25)^{0{,}5} \leq 1{,}5$, (Table 2)
$\rho_1 = 1{,}5,\quad a_6 = \left(\frac{1{,}5}{25}\right)^{0{,}5} = 0{,}245$
$1 \leq a_6 = 0{,}245 \leq 1{,}5$ ok
$l_0 = 1 . 1 . 1 . 0{,}245 . 695 = 170\ mm$
$l_{0,min} \geq max\{0{,}3 . a_6 . l_{b,req};\ 15\emptyset;\ 200\ mm\}$
$l_{0,min} \geq max\{0{,}3 . 0{,}245 . 695;\ 300\ mm;\ 200\ mm\} = 300\ mm > l_0$
$l_0 = 300\ mm$

4. Results

According to the code methods, the following Table 5 is the results of anchorage and lap length between different standards adopted:

Table 5: Anchorage ve lap length results

Standard	Anchorage length mm	Lap length mm
TS500	432	750
SNIP	748	748
Eurocode 2	1561	300

5. Conclusion

The reinforcement calculation in the standards of Russia and Europe were different from what is in the Turkish standard. Accordingly, this research investigate the details of the anchorage of the beam reinforcement to the column and the overlapping of the reinforcement in the middle of the column to show the anchorage detail differences between Turkish, Russian and European regulations. According to the results of this study,there were significant differences between the regulations in the anchorage length of the upper reinforcement of the beam support attached to the column. As for the overlap length in the middle of the column, there is a convergence in the results of the Turkish and Russian regulations, which differ by less than half from them as a result of the European method.

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