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ProtaStructure Design Guide

Rebar Anchorage and Lap Lengths

Version 2.0 | 24th April 2025

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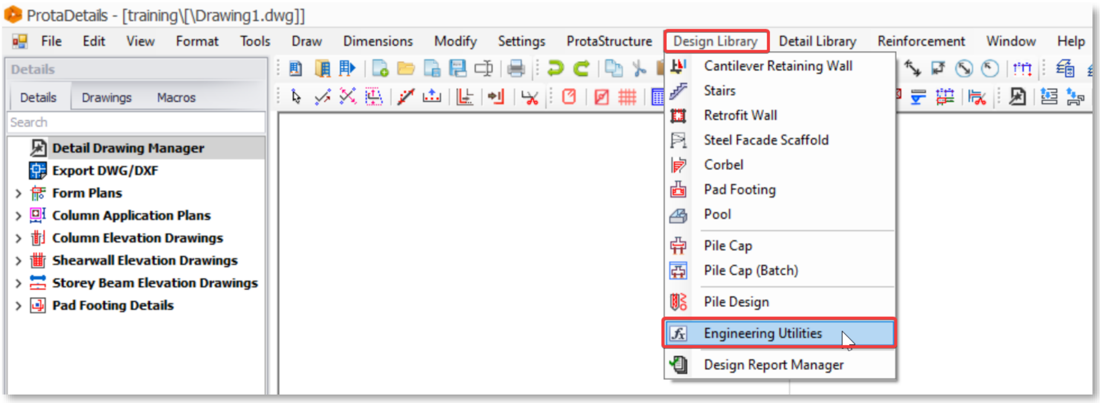
Scope

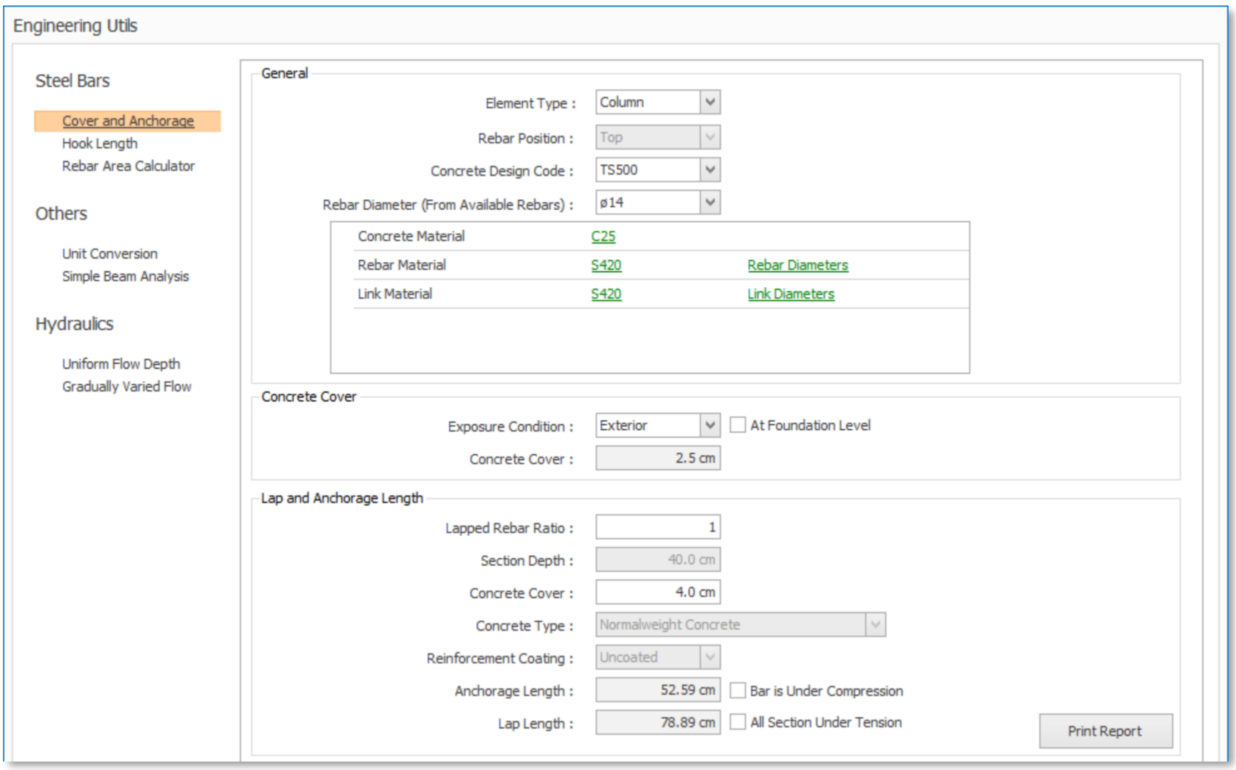
ProtaDetails is capable of calculating lap and anchorage lengths according to several building codes around the world. This document presents detailed lap and anchorage length calculations for different building codes with case studies.

User Interface

In ProtaDetails, the lap and anchorage length calculator can be accessed from the “Engineering Utilities” window. The “Engineering Utilities” window can be accessed under “Design Library”.



In the “Engineering Utilities” window, the user can enter the parameters such as element type, rebar diameter, material properties, etc. ProtaDetails will simultaneously calculate, and present lap and anchorage length as the input parameters are entered.

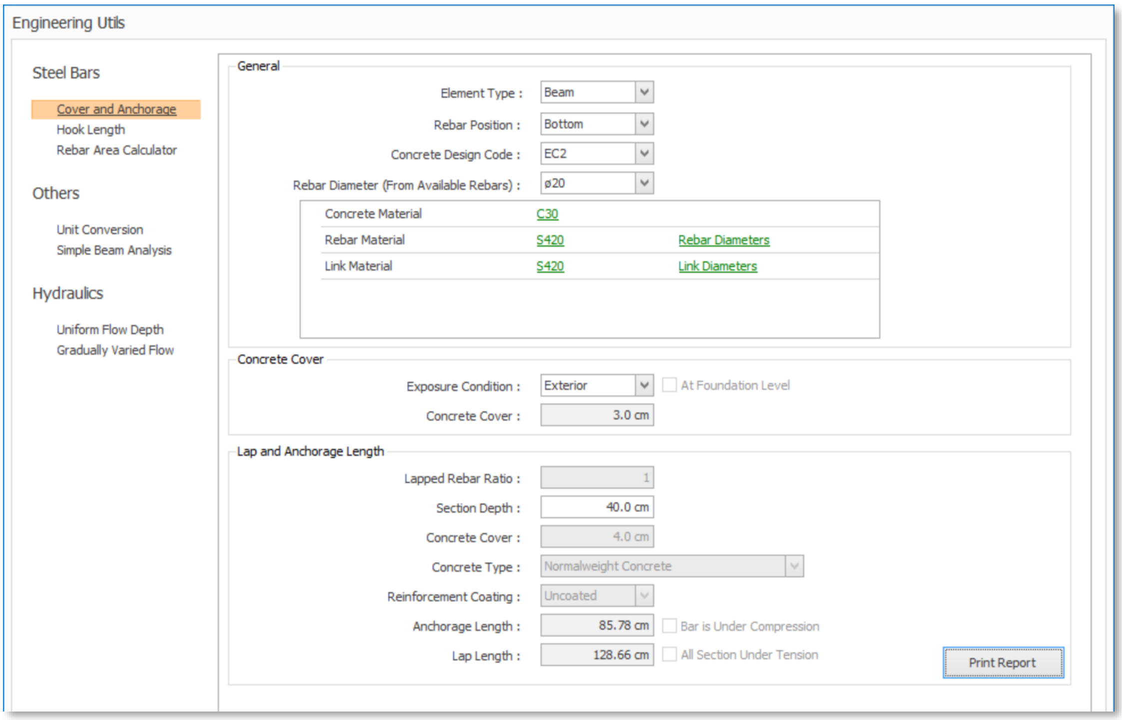


Case Study for Eurocode 2

i Similarity Between Different Building Codes

The Norm of Brazil (NBR 6118:2003) is similar to the EC2 building code. Therefore, no particular case study regarding the NBR code is included in this document.

In this study, lap and anchorage lengths of a beam made of $C30$ concrete and having $Ø20$ rebars with $S420$ steel are calculated. ProtaDetails "Engineering Utilities" windows can be seen below.



Firstly, f_{ctd} must be determined according to EC2 Section 3.1.6. The following steps must be conducted to obtain f_{ctd} ;

$f_{ctm} = 0.3\, f_{ck}^{2/3} for\ f_{ck} \leq C50/60$
$f_{ctm} = 0.3\ 30^{2/3} = 2.90\ MPa$
$f_{ctk,0.005} = 0.7 f_{ctm} = 0.7 * 2.90 = 2.03\ MPa$
$f_{ctd} = \dfrac{\alpha_{ct} f_{ctk,0.005}}{\gamma_C}$
$\gamma_C = 1.5 \quad from\ EC2\ Table\ 2.1N$
$\alpha_{ct} = 1.0 \quad (recommended\ value)$

$$f_{ctd} = \frac{1 * 2.03}{1.5} = 1.35\ MPa$$

Then, design bonding stress f_{bd} can be determined according to EC2 Section 8.4.2 as follows;

$$f_{bd} = 2.25\eta_1\eta_2 f_{ctd}$$

Selection of η_1 *and* η_2 coefficients can be seen below;

$\eta_1 = 0.7 \quad (assumed\ to\ be\ on\ the\ safe\ side)$
$\eta_2 = 1.0 \quad for\ \emptyset \leq 32\ mm$
$f_{bd} = 2.25 * 0.7 * 1.0 * 1.35 = 2.13\ MPa$

After that, the basic required bonding length, $l_{b,rqd}$, can be calculated according to EC2 Section 8.4.3 as follows;

$$l_{b,rqd} = \left(\frac{\emptyset}{4}\right)\left(\frac{\sigma_{sd}}{f_{bd}}\right)$$

Where σ_{sd} is assumed to be equal to f_{yk}

$\sigma_{sd} = f_{yk} = \frac{f_y}{1.15} = \frac{420}{1.15} = 365.22\ MPa$
$l_{b,rqd} = \left(\frac{20}{4}\right)\left(\frac{365.22}{2.13}\right) = 857.76\ mm$

Then, the design anchorage length, l_{bd} , can be calculated as;

$$l_{bd} = \alpha_1\alpha_2\alpha_3\alpha_4\alpha_5 l_{b,rqd} \geq l_{b,min}$$

Where, $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and α_5 coefficients are taken as 1.0 as per EC2 Table 8.2

$$l_{bd} = 1.0 * 857.76 = 857.76\ mm \geq l_{b,min}$$

Calculated l_{bd} length must be checked against $l_{b,min}$ lengths which are shown below;

$for\ anchorages\ in\ tension$	$l_{b,min} = \max\{0.3 l_{b,rqd}; 10\emptyset; 100\ mm\} = 257.2\ mm \leq 857.76\ mm$
$for\ anchorages\ in\ compression$	$l_{b,min} = \max\{0.6 l_{b,rqd}; 10\emptyset; 100\ mm\} = 514.39\ mm \leq 857.76\ mm$

Design lap length, l_0, can be calculated using the below expression;

$$l_0 = \alpha_1 \alpha_2 \alpha_3 \alpha_5 \alpha_6 l_{b,rqd} \geq l_{0,min}$$

$Where,\quad \alpha_6 = 1.5 \rightarrow\ assumed\ to\ be\ on\ the\ safe\ side$

$$l_0 = 1.0 * 1.5 * 857.76 = 1286.64\ mm \geq l_{0,min}$$

Check l_0 aginst the minimum values as follows;

$$l_{0,min} = \max\{0.3 \alpha_6 l_{b,rqd}; 15\emptyset; 200\ mm\} = 385.79\ mm \leq 1286.64\ mm$$

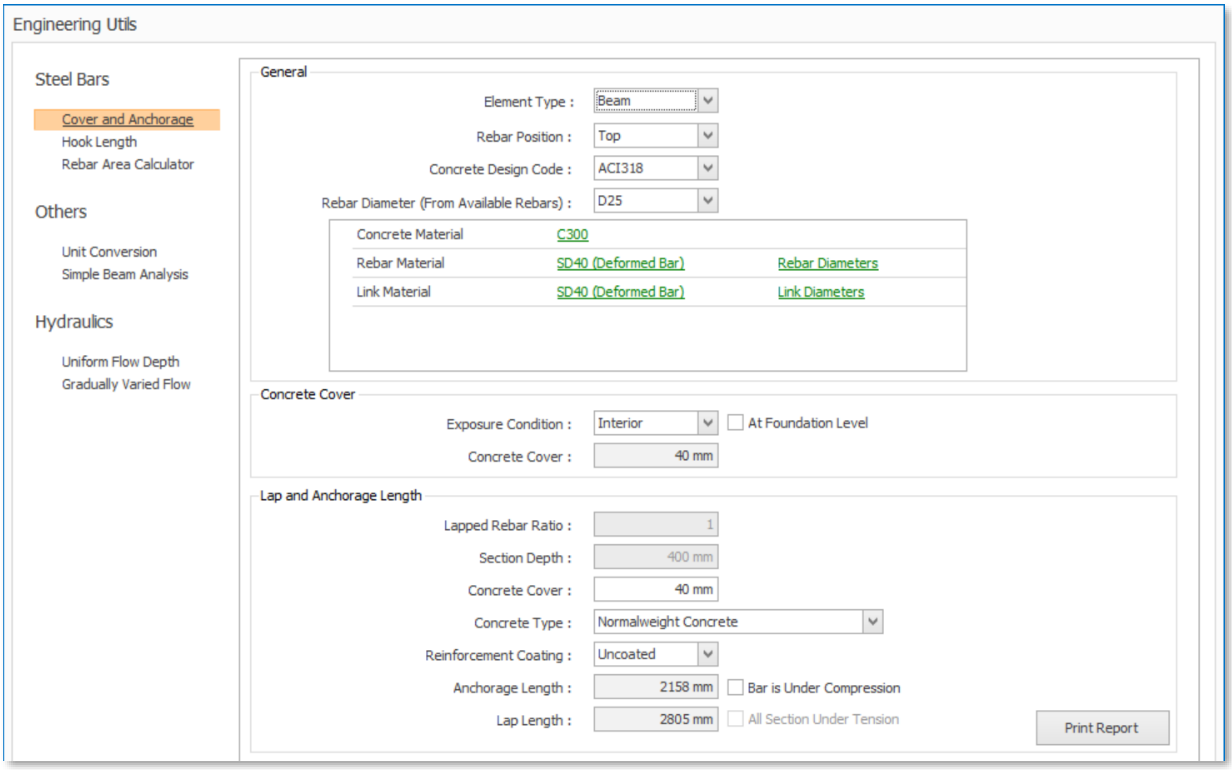
Case Studies for ACI318

Similarity Between Different Building Codes

National Structural Code of Phillippines (NCSP 2015) and Indonesian National Standard 2847 (SNI-2847-2019) are similar to the ACI318 building code. Therefore, no particular case study regarding those codes is included in this document.

Case Study 1

In this study, lap and anchorage lengths of a beam made of $C300$ concrete and having $D25$ rebars with $SD40$ steel are calculated. ProtaDetails “Engineering Utilities” window can be seen below.



Assume the section is under tension. According to ACI318 Table 25.4.2.3 development length of bars that are larger than No.22 under tension can be calculated as;

$$l_d = \left(\frac{f_y \Psi_t \Psi_e \Psi_g}{1.1\lambda\sqrt{f_c'}}\right) d_b$$

Where, $\lambda, \Psi_t, \Psi_e, and\ \Psi_g$ are the modification factors that are given in ACI318 Table 25.4.2.5 and selected as follows

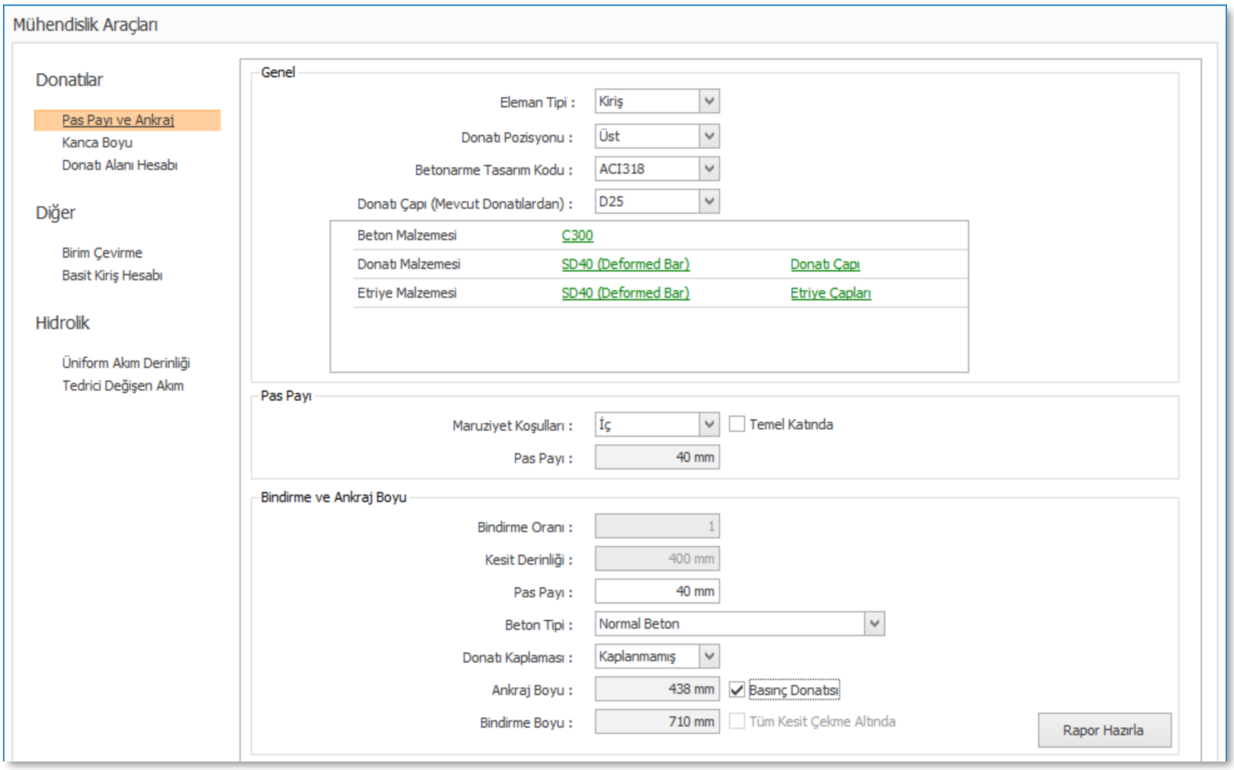
$\lambda = 1.0 \rightarrow Normal\ weight\ concrete$
$\Psi_t = 1.3 \rightarrow Assumed\ to\ be\ on\ the\ safe\ side$
$\Psi_e = 1.0 \rightarrow No\ epoxy\ coating\ is\ considered$
$\Psi_g = 1.0 \rightarrow Due\ to\ the\ rebar\ grade$
$l_d = \left(\frac{400 * 1.3 * 1.0 * 1.0}{1.1 * 1.0 * \sqrt{30}}\right) 25 = 2157.69\ mm$

According to ACI318 table 25.5.2.1 lap splice length of rebars under tension can be calculated as;

$l_{st} = 1.3 l_d \geq 300\ mm$
$l_{st} = 1.3 * 2157.69 = 2805 \geq 300 = 2805\ mm$

Case Study 2

In this study, lap and anchorage lengths of a beam made of $C300$ concrete and having $D25$ rebars with $SD40$ steel are calculated. ProtaDetails "Engineering Utilities" window can be seen below.



This time, let's assume that the section is under compression. According to ACI318 Section 25.4.9 development length of bars under compression can be calculated as;

$$l_d = \left(\frac{0.24 f_y \psi_r}{\lambda \sqrt{f_c{}'}}\right) d_b$$

Where, $\lambda\ and\ \Psi_r$ are the modification factors that are given in ACI318 Table 25.4.9.3 and selected as follows;

$\lambda = 1.0 \rightarrow Normal\ weight\ concrete$
$\Psi_r = 1.0 \rightarrow Assumed\ to\ be\ on\ the\ safe\ side$
$l_d = \left(\frac{0.24 * 400 * 1.0}{1.0 * \sqrt{30}}\right) 25 = 438.18\ mm$

According to ACI318 Table 25.5.5 lap splice length of rebars under compression can be calculated as;

$$l_{sc} = 0.071 f_y d_b \geq 30\ mm = 0.071 * 400 * 25 = 710\ mm \geq 30mm = 710\ mm$$

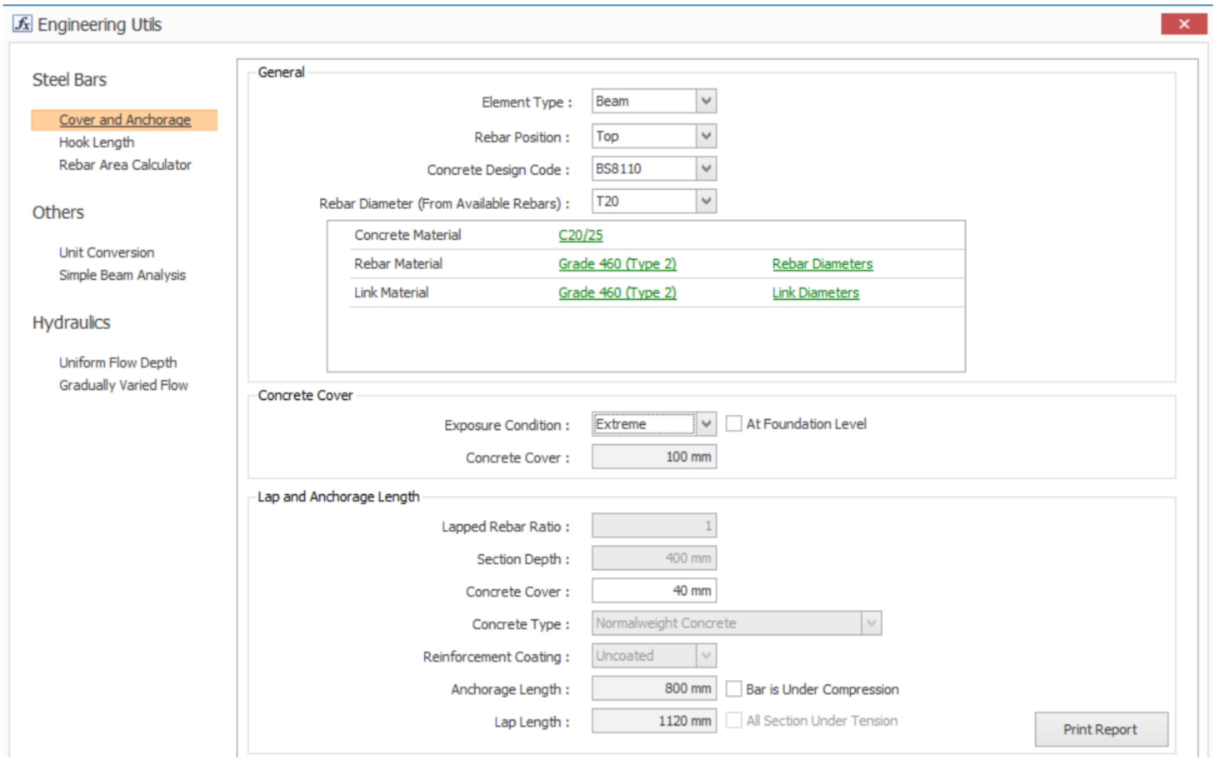
Case Studies for BS8110

i Similarity Between Different Building Codes

The National Building Code of India (NBCI2016) is similar to the BS8110 building code. Therefore, no particular case study regarding the NBCI code is included in this document.

Case Study 1

In this study, lap and anchorage lengths of a beam made of $C20/25$concrete and having $T20$ rebars with $Grade460\ (Type\ 2)$ steel is calculated. ProtaDetails "Engineering Utilities" window can be seen below.



For this case, let's assume that the rebar is under tension. Then, the design ultimate bond stress, f_{bu}, can be calculated according to BS8110 Section 3.12.8.4 as follows;

$$f_{bu} = \beta\sqrt{f_{cu}}$$

Where β is a coefficient given in BS8110 Table3.26, since in our case, Type-2 deformed bar is considered, and the bar is under tension, $\beta = 0.5$.

$$f_{bu} = 0.5\sqrt{25} = 2.5\ MPa$$

Then anchorage length can be calculated as follows;

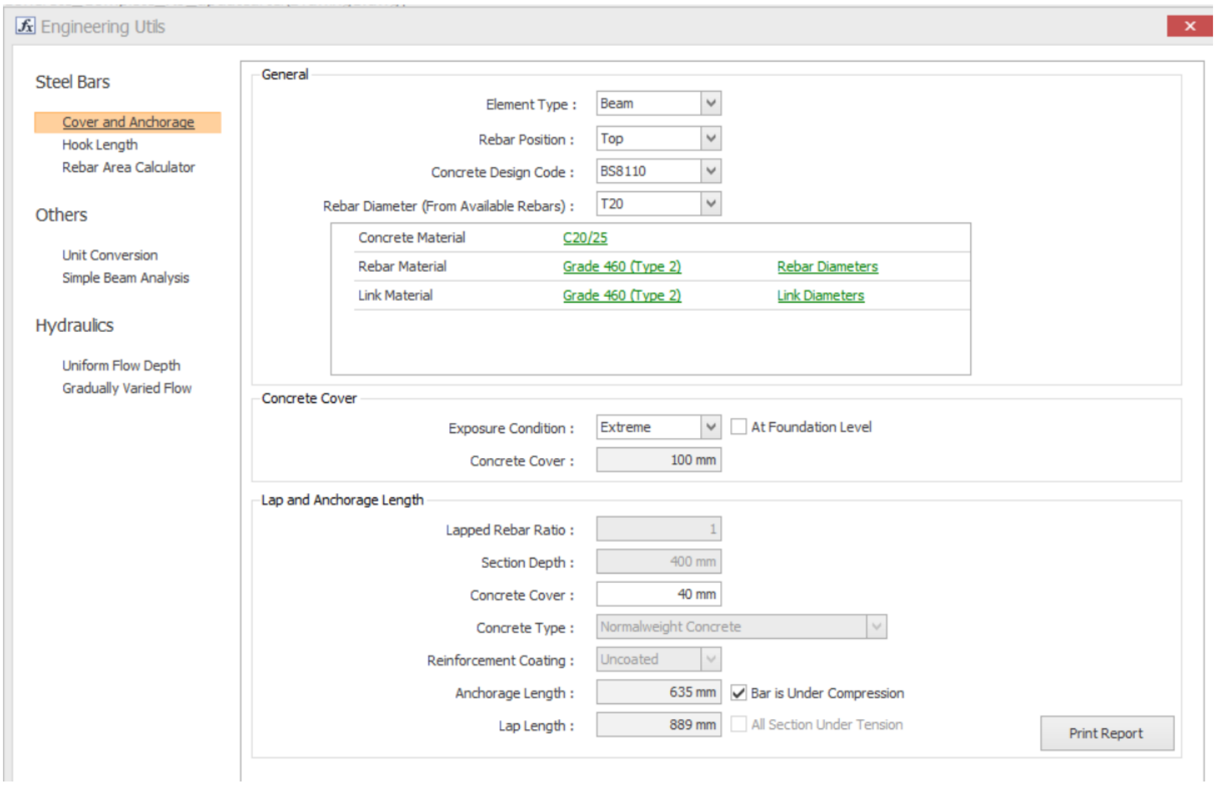
$$l_b = \frac{f_{yd}}{4 f_{bu}} \phi = \frac{400}{4 * 2.5} 20 = 800\ mm$$

According to BS8110 Section 3.12.8.12 design length of tension laps should be at least 1.4 times the anchorage length;

$$l_0 = 1.4 * l_b = 1.4 * 800 = 1120\ mm$$

Case Study 2

In this study, lap and anchorage lengths of a beam made of $C20/25$concrete and having $T20$ rebars with $Grade460\ (Type\ 2)$ steel is calculated. ProtaDetails "Engineering Utilities" window can be seen below.



For this case, let's assume that the rebar is under compression. Then, the design ultimate bond stress, f_{bu}, can be calculated according to BS8110 Section 3.12.8.4 as follows;

$$f_{bu} = \beta \sqrt{f_{cu}}$$

Where β is a coefficient given in BS8110 Table3.26, since in our case, Type-2 deformed bar is considered, and the bar is under compression, $\beta = 0.63$.

$$f_{bu} = 0.63\sqrt{25} = 3.15\ MPa$$

Then anchorage length can be calculated as follows;

$$l_b = \frac{f_{yd}}{4 f_{bu}} \phi = \frac{400}{4 * 3.15} 20 = 634.92\ mm$$

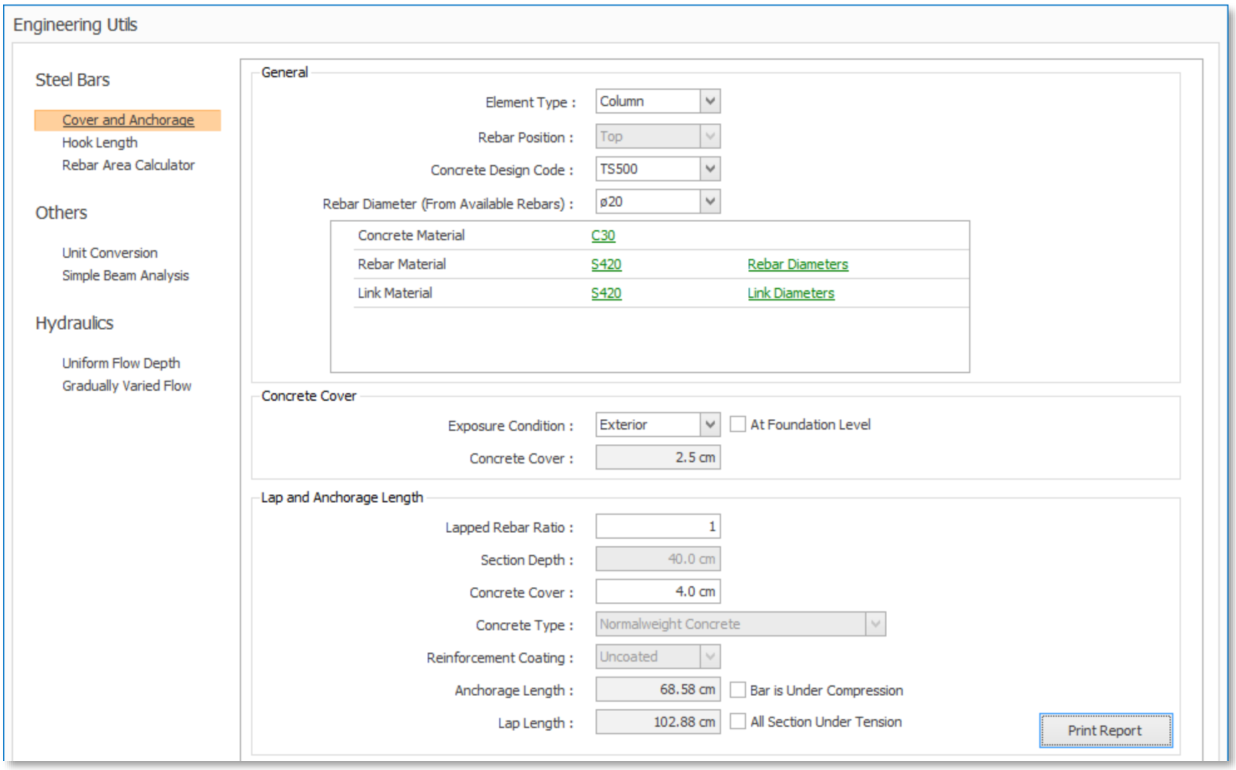
According to BS8110 Section 3.12.8.12 design length of laps should be at least 1.4 times the anchorage length;

$$l_0 = 1.4 * l_b = 1.4 * 634.92 = 888.89\ mm$$

Case Studies for TS500

Case Study 1

In this study, lap and anchorage lengths of a column made of $C30$ concrete and having $\emptyset 20$ rebars with $S420$ steel are calculated. ProtaDetails "Engineering Utilities" window can be seen below.



Note that columns can be classified as CASE 2 according to TS500 9.1.1.

$$f_{yd} = \frac{f_y}{\Psi_s} = \frac{420}{1.15} = 366.22\ MPa$$

$$f_{ctd} = \frac{0.35\sqrt{f_c}}{\Psi_c} = \frac{0.35\sqrt{30}}{1.5} = 1.28\ MPa$$

Anchorage length can be calculated using TS500 Equation 9.1 as follows;

$$l_b = \left(0.12\frac{f_{yd}}{f_{ctd}}\emptyset\right) \geq 20\emptyset$$

$$l_b = \left(0.12\frac{366.22}{1.28}20\right) \geq 20 \times 20$$

$$l_b = 684.79 \geq 400 = 684.79\ mm$$

Lap length can be calculated using TS500 Equation 9.2 as follows;

$$l_0 = \alpha_1 l_b$$

$$Where, \quad \alpha_1 = 1 + 0.5r$$

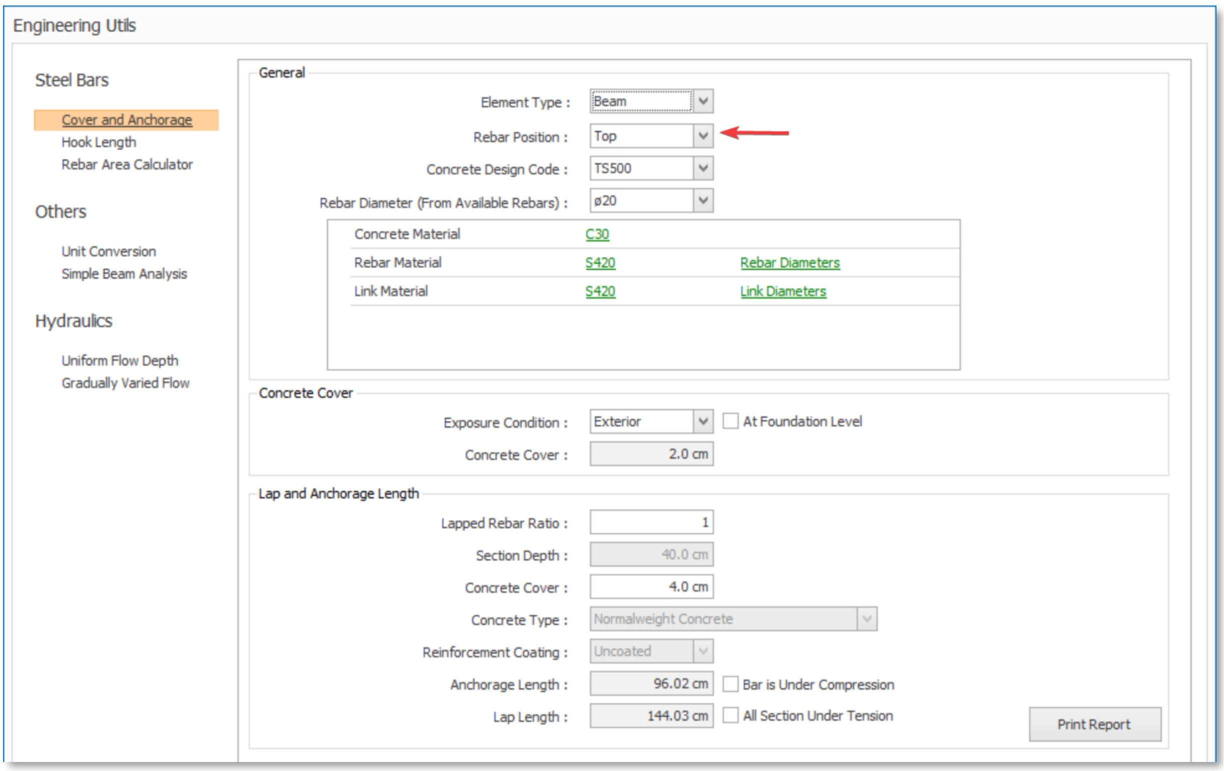
Let's assume that the ratio of spliced reinforcement to the total reinforcement is 1 for this case. Then $r = 1$.

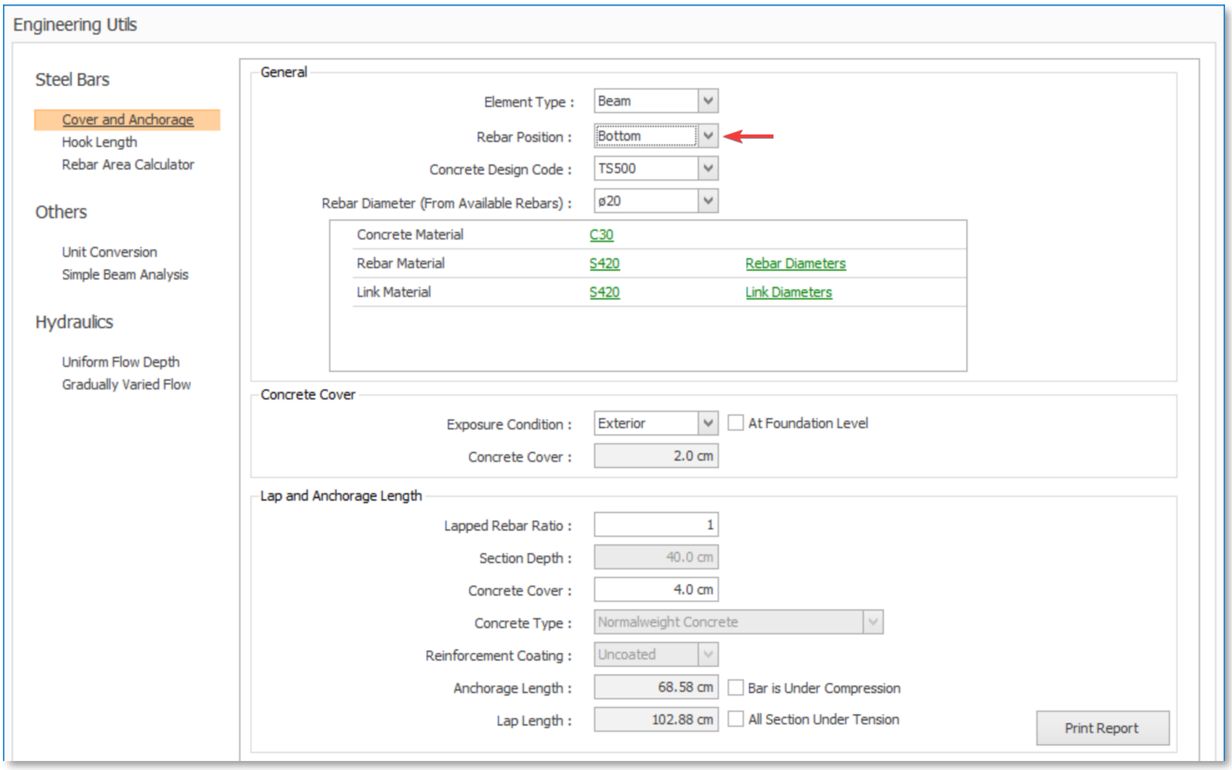
$$\alpha_1 = 1 + 0.5 * 1 = 1.5$$

$$l_0 = 1.5 * 684.79 = 1028.77\ mm$$

Case Study 2

In this study, lap and anchorage lengths of a beam made of $C30$ concrete and having $\emptyset 20$ rebars with $S420$ steel are calculated. Calculations for both the top and bottom rebar positions are made and presented. ProtaDetails "Engineering Utilities" windows can be seen below.





Note that the top reinforcements of beams can be classified as CASE 1, and the bottom reinforcements of beams can be classified as CASE 2 according to TS500 9.1.1.

$$f_{yd} = \frac{f_y}{\Psi_s} = \frac{420}{1.15} = 366.22\ MPa$$

$$f_{ctd} = \frac{0.35\sqrt{f_c}}{\Psi_c} = \frac{0.35\sqrt{30}}{1.5} = 1.28\ MPa$$

Anchorage length can be calculated using TS500 Equation 9.1 as follows;

$$l_b = \left(0.12\frac{f_{yd}}{f_{ctd}}\emptyset\right) \geq 20\emptyset$$

According to TS500 9.1.2.1, development length values obtained from Eq. 9.1 should be multiplied by 1.4 when bars conform to CASE 1. In this case, development length should be multiplied by 1.4 for top reinforcements.

$$l_{b,top} = \left(0.12\frac{366.22}{1.28}20\right)1.4 \geq 20 * 20$$

$$l_{b,top} = 958.70 \geq 400 = 958.70\ mm$$

$$l_{b,bot} = \left(0.12\frac{366.22}{1.28}20\right) \geq 20 * 20$$

$$l_{b,bot} = 685.84 \geq 400 = 685.84\ mm$$

Lap length can be calculated using TS500 Equation 9.2 as follows;

$$l_0 = \alpha_1 l_b$$

$$Where, \qquad \alpha_1 = 1 + 0.5r$$

Let's assume that the ratio of spliced reinforcement to the total reinforcement is 1 for this case. Then $r = 1$.

$$\alpha_1 = 1 + 0.5 * 1 = 1.5$$

$$l_{0,top} = 1.5 * 958.70 = 1438.05\ mm$$

$$l_{0,bot} = 1.5 * 684.79 = 1028.77\ mm$$

Thank You...

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