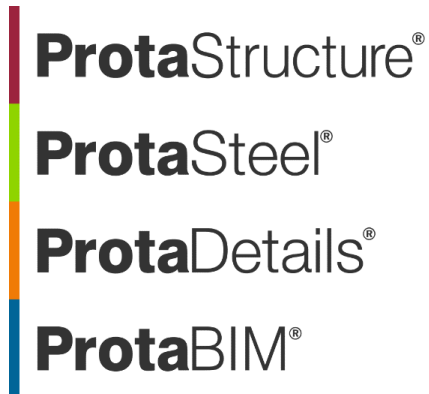




ProtaStructure Design Guide

Rebar Anchorage and Lap Lengths

Version 2.0

24th April 2025

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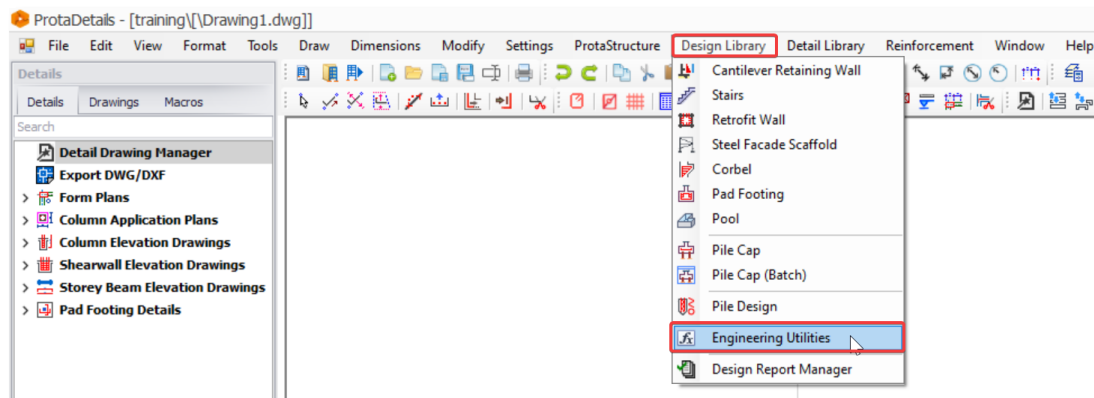
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Scope

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.

Engineering Utils

Steel Bars

Cover and Anchorage

Hook Length

Rebar Area Calculator

Others

Unit Conversion

Simple Beam Analysis

Hydraulics

Uniform Flow Depth

Gradually Varied Flow

General

Element Type : Column

Rebar Position : Top

Concrete Design Code : TS500

Rebar Diameter (From Available Rebars) : ø14

Concrete Material	C25	
Rebar Material	S420	Rebar Diameters
Link Material	S420	Link Diameters

Concrete Cover

Exposure Condition : Exterior ☐ At Foundation Level

Concrete Cover : 2.5 cm

Lap and Anchorage Length

Lapped Rebar Ratio : 1

Section Depth : 40.0 cm

Concrete Cover : 4.0 cm

Concrete Type : Normalweight Concrete

Reinforcement Coating : Uncoated

Anchorage Length : 52.59 cm ☐ Bar is Under Compression

Lap Length : 78.89 cm ☐ All Section Under Tension

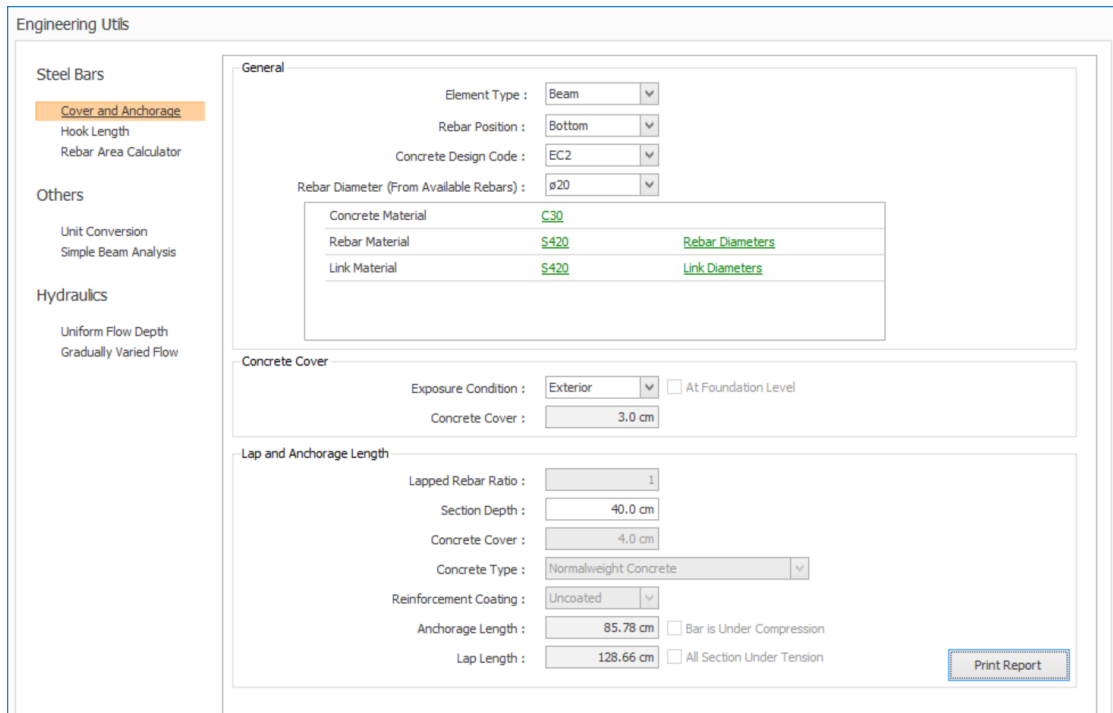
Print Report

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} ;

$$f_{ctm} = 0.3 f_{ck}^{2/3} \text{ for } f_{ck} \leq C50/60$$

$$f_{ctm} = 0.3 30^{2/3} = 2.90 \text{ MPa}$$

$$f_{ctk,0.005} = 0.7 f_{ctm} = 0.7 * 2.90 = 2.03 \text{ MPa}$$

$$f_{ctd} = \frac{\alpha_{ct} f_{ctk,0.005}}{\gamma_c}$$

$$\gamma_c = 1.5 \text{ from EC2 Table 2.1N}$$

$$\alpha_{ct} = 1.0 \text{ (recommended value)}$$

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

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

$$f_{bd} = 2.25\eta_1\eta_2f_{ctd}$$

Selection of η_1 and η_2 coefficients can be seen below;

$$\eta_1 = 0.7 \quad (\text{assumed to be on the safe side})$$

$$\eta_2 = 1.0 \quad \text{for } \phi \leq 32 \text{ mm}$$

$$f_{bd} = 2.25 * 0.7 * 1.0 * 1.35 = 2.13 \text{ MPa}$$

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

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

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

$$\sigma_{sd} = f_{yk} = \frac{f_y}{1.15} = \frac{420}{1.15} = 365.22 \text{ MPa}$$

$$l_{b,rqd} = \left(\frac{20}{4}\right) \left(\frac{365.22}{2.13}\right) = 857.76 \text{ mm}$$

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

$$l_{bd} = \alpha_1\alpha_2\alpha_3\alpha_4\alpha_5l_{b,rqd} \geq l_{b,min}$$

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

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

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

$$\text{for anchorages in tension } l_{b,min} = \max\{0.3l_{b,rqd}; 10\phi; 100 \text{ mm}\} = 257.2 \text{ mm} \leq 857.76 \text{ mm}$$

$$\text{for anchorages in compression } l_{b,min} = \max\{0.6l_{b,rqd}; 10\phi; 100 \text{ mm}\} = 514.39 \text{ mm} \leq 857.76 \text{ mm}$$

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

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

Check l_0 against the minimum values as follows;

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

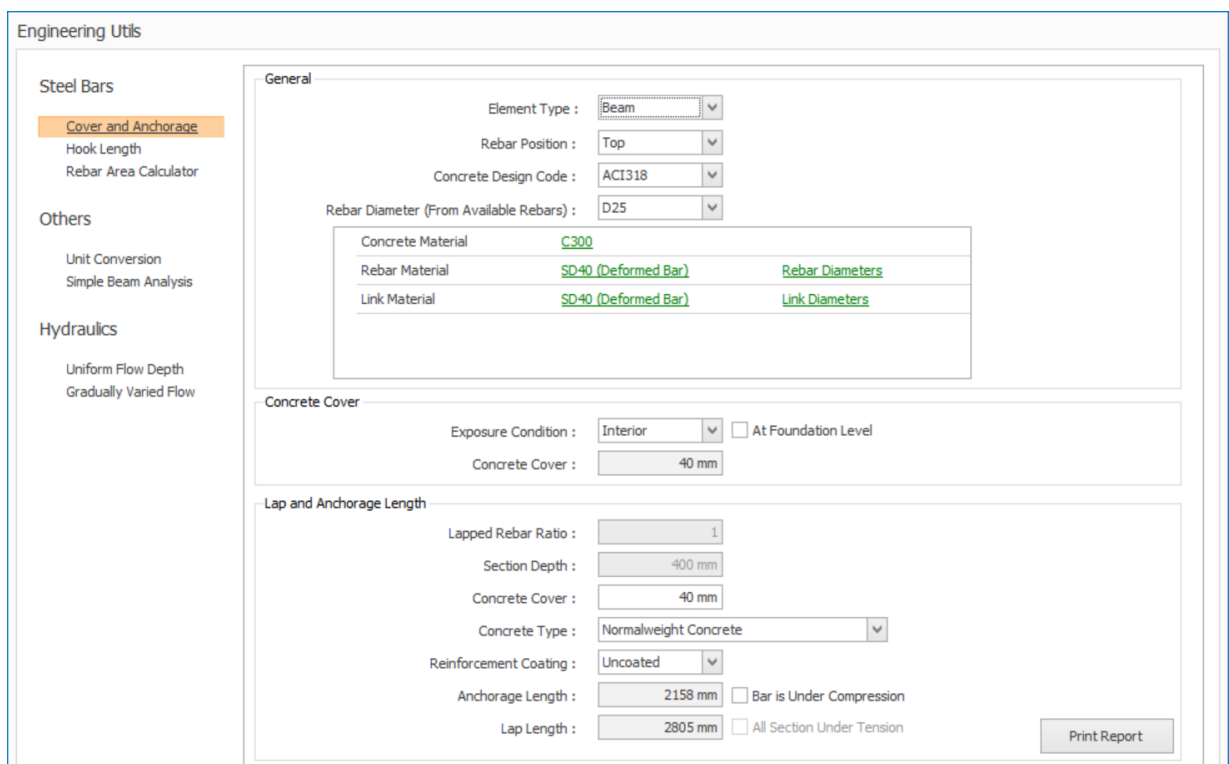
Case Studies for ACI318

i 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, λ , Ψ_t , Ψ_e , and Ψ_g are the modification factors that are given in ACI318 Table 25.4.2.5 and selected as follows

$\lambda = 1.0 \rightarrow \text{Normal weight concrete}$

$\Psi_t = 1.3 \rightarrow \text{Assumed to be on the safe side}$

$\Psi_e = 1.0 \rightarrow \text{No epoxy coating is considered}$

$\Psi_g = 1.0 \rightarrow \text{Due to the rebar grade}$

$$l_d = \left(\frac{400 * 1.3 * 1.0 * 1.0}{1.1 * 1.0 * \sqrt{30}} \right) 25 = 2157.69 \text{ mm}$$

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

$$l_{st} = 1.3l_d \geq 300 \text{ mm}$$

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

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.

Mühendislik Araçları

Donatılar

Pas Payı ve Ankraj

Kanca Boyu

Donatı Alanı Hesabı

Diğer

Birim Çevirme

Basit Kiriş Hesabı

Hidrolik

Üniform Akım Derinliği

Tedrici Değişen Akım

Genel

Eleman Tipi : Kiriş

Donatı Pozisyonu : Üst

Betonarme Tasarım Kodu : ACI318

Donatı Çapı (Mevcut Donatılardan) : D25

Beton Malzemesi	C300
Donatı Malzemesi	SD40 (Deformed Bar)
Etriye Malzemesi	SD40 (Deformed Bar)

Pas Payı

Maruziyet Koşulları : İç ☐ Temel Katında

Pas Payı : 40 mm

Bindirme ve Ankraj Boyu

Bindirme Oranı : 1

Kesit Derinliği : 400 mm

Pas Payı : 40 mm

Beton Tipi : Normal Beton

Donatı Kaplaması : Kaplanmamış

Ankraj Boyu : 438 mm ☒ Basınç Donatısı

Bindirme Boyu : 710 mm ☐ Tüm Kesit Çekme Altında

Rapor Hazırla

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, λ and ψ_r are the modification factors that are given in ACI318 Table 25.4.9.3 and selected as follows;

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

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

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

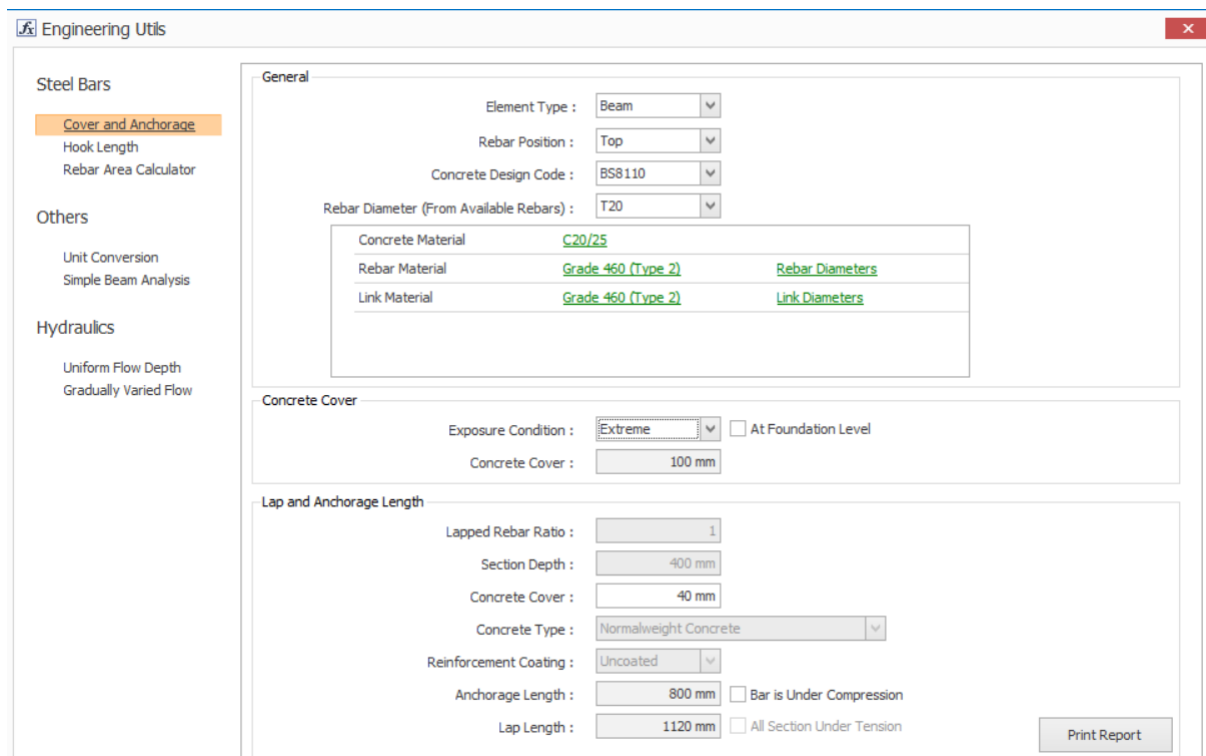
Case Studies for BS8110

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 *Grade 460 (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 Table 3.26, since in our case, Type-2 deformed bar is considered, and the bar is under tension, $\beta = 0.5$.

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

Then anchorage length can be calculated as follows;

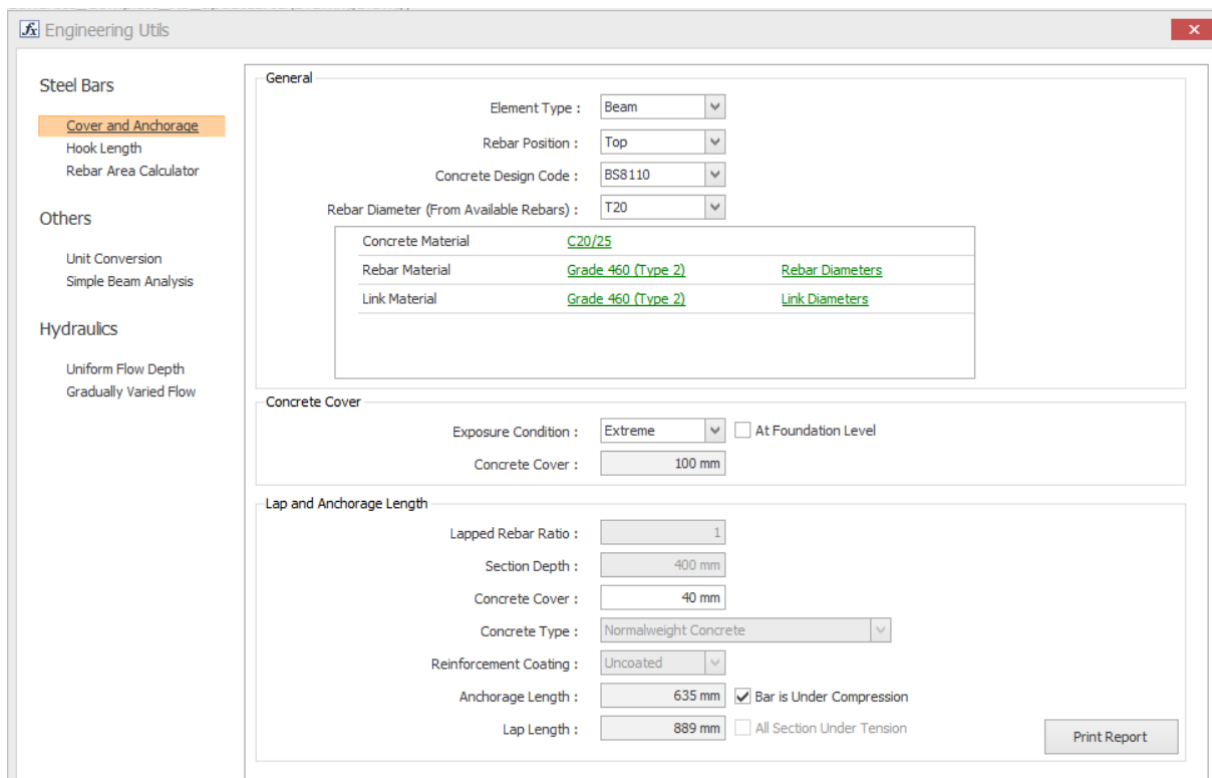
$$l_b = \frac{f_{yd}}{4f_{bu}} \phi = \frac{400}{4 * 2.5} 20 = 800 \text{ mm}$$

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

$$l_0 = 1.4 * l_b = 1.4 * 800 = 1120 \text{ mm}$$

Case Study 2

In this study, lap and anchorage lengths of a beam made of *C20/25* concrete and having *T20* rebars with *Grade 460 (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, $\beta = 0.63$.

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

Then anchorage length can be calculated as follows;

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

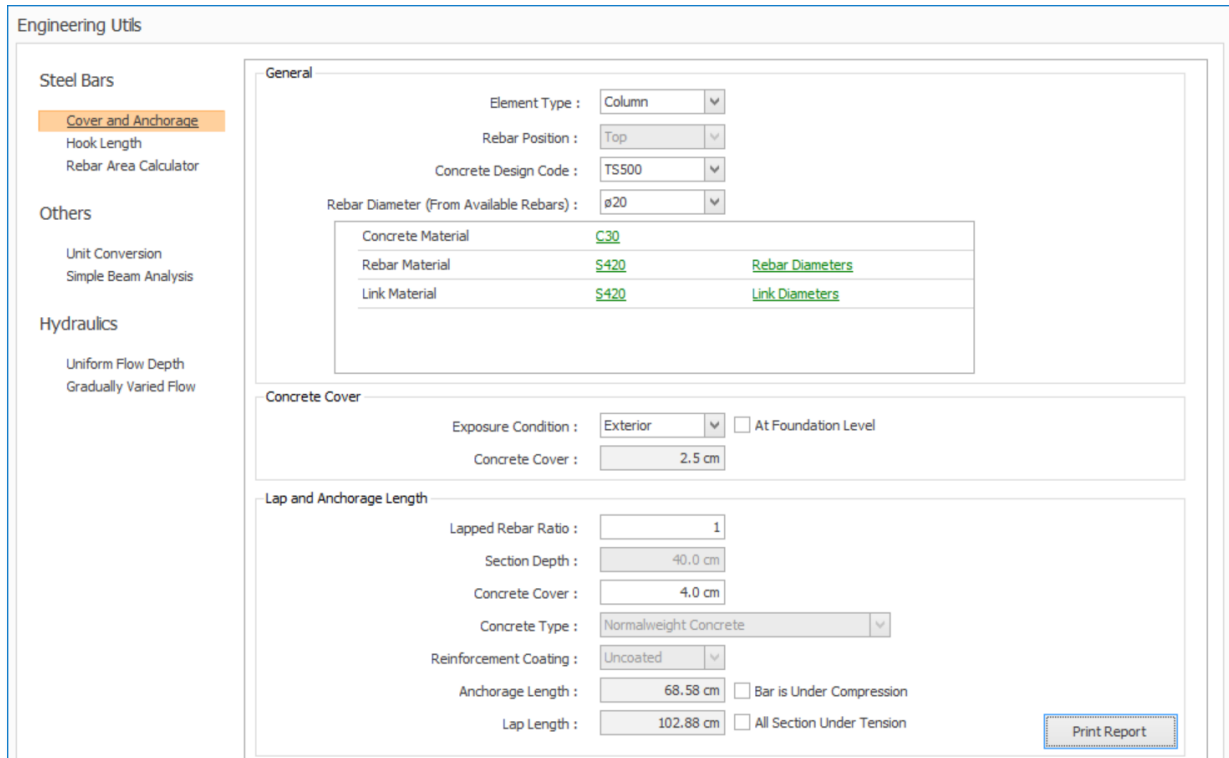
According to BS8110 Section 3.12.8.12 design length of laps should be at least 1.4 times the anchorage length;

$$l_0 = 1.4 * l_b = 1.4 * 634.92 = 888.89 \text{ mm}$$

Case Studies for TS500

Case Study 1

In this study, lap and anchorage lengths of a column made of C30 concrete and having Ø20 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.

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

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

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

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

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

$$l_b = 684.79 \geq 400 = 684.79 \text{ mm}$$

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

$$l_0 = \alpha_1 l_b$$

Where, $\alpha_1 = 1 + 0.5r$

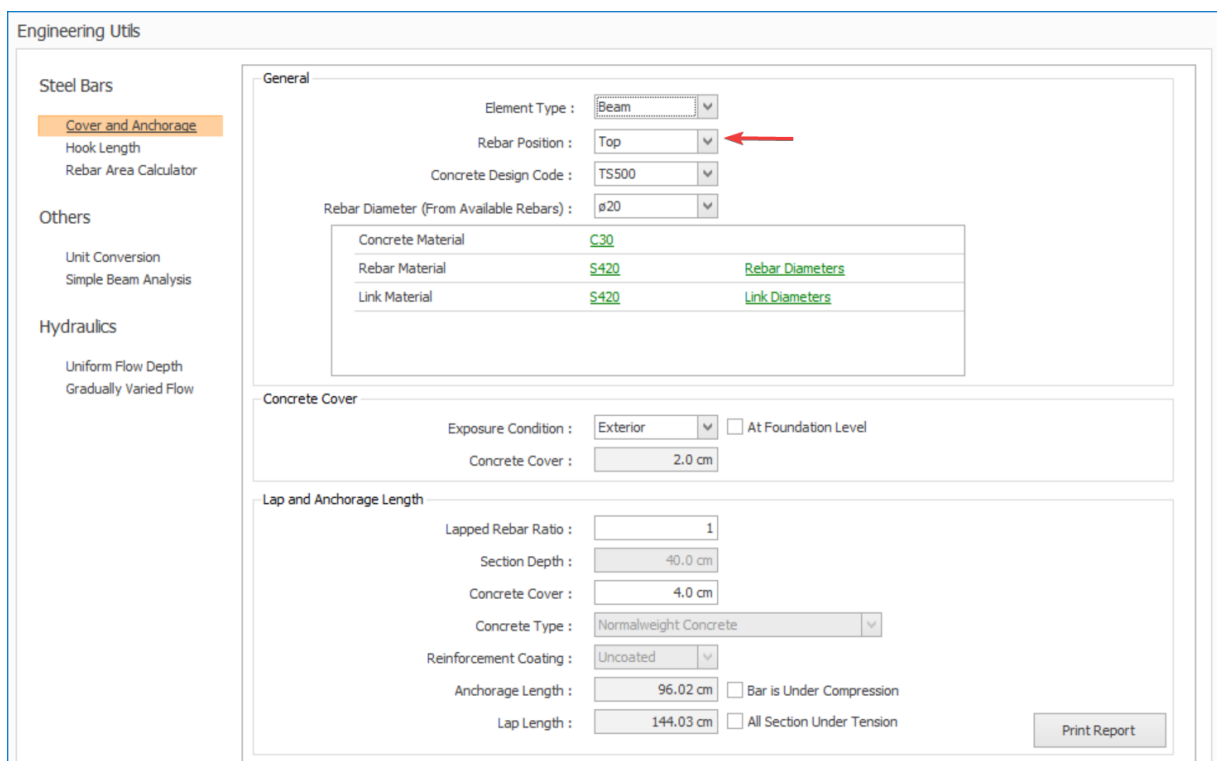
Let's assume that the ratio of spliced reinforcement to the total reinforcement is 1 for this case. Then $r = 1$.

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

$$l_0 = 1.5 * 684.79 = 1028.77 \text{ mm}$$

Case Study 2

In this study, lap and anchorage lengths of a beam made of C30 concrete and having Ø20 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.



Engineering Utils

Steel Bars

- Cover and Anchorage**
- Hook Length
- Rebar Area Calculator

Others

- Unit Conversion
- Simple Beam Analysis

Hydraulics

- Uniform Flow Depth
- Gradually Varied Flow

General

Element Type : **Beam**

Rebar Position : **Top**

Concrete Design Code : **TS500**

Rebar Diameter (From Available Rebars) : **Ø20**

Concrete Material	C30
Rebar Material	S420 Rebar Diameters
Link Material	S420 Link Diameters

Concrete Cover

Exposure Condition : **Exterior** ☐ At Foundation Level

Concrete Cover : **2.0 cm**

Lap and Anchorage Length

Lapped Rebar Ratio : **1**

Section Depth : **40.0 cm**

Concrete Cover : **4.0 cm**

Concrete Type : **Normalweight Concrete**

Reinforcement Coating : **Uncoated**

Anchorage Length : **96.02 cm** ☐ Bar is Under Compression

Lap Length : **144.03 cm** ☐ All Section Under Tension

Print Report

Engineering Utils

Steel Bars

Cover and Anchorage

Hook Length

Rebar Area Calculator

Others

Unit Conversion

Simple Beam Analysis

Hydraulics

Uniform Flow Depth

Gradually Varied Flow

General

Element Type : Beam

Rebar Position : Bottom

Concrete Design Code : TS500

Rebar Diameter (From Available Rebars) : ϕ20

Concrete Material	C30	
Rebar Material	S420	Rebar Diameters
Link Material	S420	Link Diameters

Concrete Cover

Exposure Condition : Exterior ☐ At Foundation Level

Concrete Cover : 2.0 cm

Lap and Anchorage Length

Lapped Rebar Ratio : 1

Section Depth : 40.0 cm

Concrete Cover : 4.0 cm

Concrete Type : Normalweight Concrete

Reinforcement Coating : Uncoated

Anchorage Length : 68.58 cm ☐ Bar is Under Compression

Lap Length : 102.88 cm ☐ All Section Under Tension

Print Report

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.

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

$$f_{cta} = \frac{0.35\sqrt{f_c}}{\psi_c} = \frac{0.35\sqrt{30}}{1.5} = 1.28 \text{ MPa}$$

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

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

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.

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

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

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

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

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

$$l_0 = \alpha_1 l_b$$

$$\text{Where, } \alpha_1 = 1 + 0.5r$$

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

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

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

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

Thank You...

Thank you for choosing the ProtaStructure Suite product family.

Our top priority is to make your experience excellent with our software technology solutions.

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