Task a)

Step1 : Determining maximum aggregate size (D_{max}).

D_{max} must be consistent with the dimensions of the structural element.

D_{max} can be determined from Table 3.

Table 3. Maximum size of aggregate recommended for various types of structural element (TS 802 / March 2016)

Minimum dimension of cross-section of structural element (cm)	Maximum Aggregate Size (mm)			
	Shearwalls, beams and columns	Heavily reinforced slabs	Lightly reinforced and unreinforced slabs	Unreinforced walls
6-14	16	16	32	16
15-29	32	32	63	32
30-74	63	63	63	63

D_{max}= 32 mm

Step 2: The Strength Class

Desired strength class C25/30; but we must select C30/37 strength class with respect to the exposure class XF3 (Table 1) in TS EN 206

Table 1. Recommended limiting values for composition and properties of concrete (TS EN 206 / January 2017)

XF3	Minimum Strength Class	Maximum Water/Cement	Minimum Cement Content (kg/m^3)	Minimum Air Content (%)
	C30/37	0.50	320	4.0

Step 3: Target Compressive strength (fcm)

Determine it from Table 4 considering standard deviation is known or not.

Table 4. Target compressive strengths (f_{cm}) determination (TS 802 / March 2016)

If standard deviation is unknown	$f_{cm} = f_{ck} + \Delta$	$f_{ck} < 20/25$ MPa → Δ =4 MPa
		$20/25 \leq f_{ck} \leq 30/37$ MPa → Δ =6 MPa
		$f_{ck} > 30/37$ MPa → Δ =8 MPa

Since standard deviation is unknown → $f_{cm}=f_{ck}+\Delta$ = 30 + 6 =36 MPa

Step 4: W/C ratio

Determine W/C ratio from Table 5 with respect to target compressive strength (f_{cu}) and type of concrete

Table 5. Water/Cement ratio for target compressive strength (TS 802 / March 2016)

Compressive strength at 28-day (150x300 mm cylinder) (MPa)	Water / Cement Ratio	
	Non-air entrained concrete	Air entrained concrete
45	0.38	0.30
40	0.42	0.34
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

For f_{cm}=36 MPa, W/C is now given in Table 5.

Therefore, Interpolation should be done to calculate w/c ratio for 36 MPa

f_{cm} **W/C**

35 → 40 (5 MPa increment) 0.39 → 0.34 (0.05 reduction)

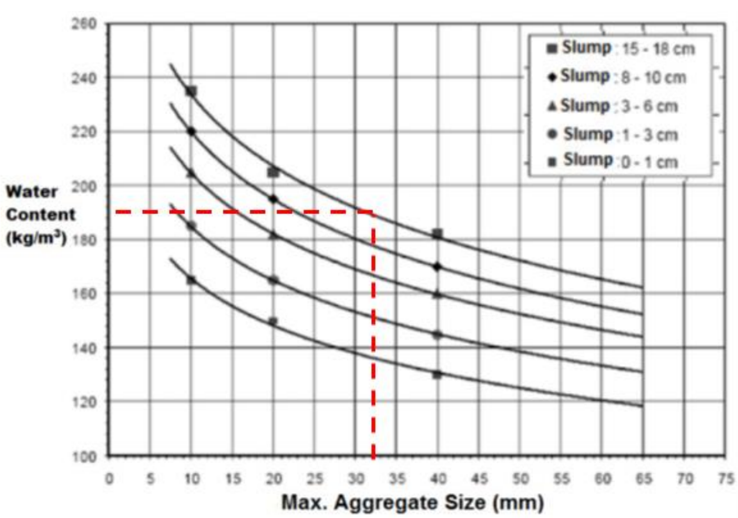
35 → 36 (1 MPa increment) 0.39 → x reduction

x = (0.05/5)*1 = 0.01 → W/C = 0.39 – 0.01 = 0.38

⁎ Checking W/C (Table 1) : W/C = 0.38 < max W/C =0.50 √ OK

Step 5: Water content

Determine it from Figure 1:



Then, W = 190 kg

Assuming that super plasticizer reduces water content by 15% → W= 190*(1-0.15)=161.5 kg

Step 6: Cement content

W/C = 0.38 → C = 161.5 / 0.38 = 425 kg/m³

⁎ Checking C (Table 1) C = 425 kg/m³ > C_{min} = 320 kg/m³ √ OK

Step 7 : Admixture Content

S.P. = 425 * 0.015 = 6.38 kg → V_{SP} = 6.38 / 1.15 = 5.53 dm³ > 3 dm³

So, the water content of S.P. must be taken into account

⁎ 70% of S.P. is water then, water coming from S.P. = 6.38 * 0.7 = 4.47 kg

A.E.A. = 425 * 0.0005 = 0.21 kg → V_{AEA} = 0.21 / 1.01 = 0.21 dm³

Water content of A.E.A can be ignored.

Water adjustment : W' = 161.5 – 4.47 = 157.03 kg

Step 8 : Amount of Aggregates:

1 m³ concrete = 1000 dm³ = $V_{agr} + V_c + V_w + V_{SP} + V_{AEA} + V_{air}$

$$V_{agr} = 1000 - \left[\frac{425}{3.15} + 157.03 + \frac{6.38}{1.15} + \frac{0.21}{1.01} + 50\right] = 652.29\ dm^3$$

Equivalent density of mix → $\delta_{mix} = \frac{1}{\left(\frac{0.47}{2.65} + \frac{0.25}{2.80} + \frac{0.28}{2.80}\right)} = 2.73\ kg/dm^3$

Natural Sand = $A_1 = (V_{agr} * \delta_{mix}) * a_1$=652.29*2.73*0.47=836.95 kg

Crushed Stone #1 = $A_2 = (V_{agr} * \delta_{mix}) * a_2$=652.29*2.73*0.25=445.19 kg

Crushed Stone #2 = $A_3 = (V_{agr} * \delta_{mix}) * a_3$=652.29*2.73*0.28=498.61 kg

Step 9: Moisture Adjustment for aggregates & mix water

$$(A_w - M)\% = \begin{cases} (+) : \text{Dry Agg} \\ (0) : \text{SSD} \\ (-) : \text{Moist Agg} \end{cases}$$

Natural Sand : $A_w - M = 1.5\% - 3.5\% = -2.0\%$ Moist

Crushed Stone #1 : $A_w - M = 0.8\% - 0.6\% = 0.2\%$ Dry

Crushed Stone #2 : $A_w - M = 0.5\% - 0.5\% = 0.0\%$ SSD

Water adjustment due to the moisture content of the aggregates

$$W_{adj} = W' + \sum A_i(A_{Wi} - M_i)$$
$$W_{adj} = 157.03 + [836.95(-0.02) + 445.19(0.002)] = 141.18\ kg$$

Aggregate content adjustment due to moisture content of aggregates

$$A_{i,adj} = A_i - A_i(A_{Wi} - M_i)$$
$$A_{1,adj} = A_1 - A_1(A_{W1} - M_1) = 836.95 - 836.95(-0.02) = 853.69\ kg$$
$$A_{2,adj} = A_2 - A_2(A_{W2} - M_2) = 445.19 - 445.19(0.002) = 444.30\ kg$$

Amount of the constituents for 1 m³ of concrete		
Material	**Mix Design (kg)**	**Adjusted Mixing Amount (kg)**
Cement (C)	425	425
Water (W)	157.03	141.18
Natural Sand (A_1)	836.95	853.69
Crushed Stone #1 (A_2)	445.19	444.30
Crushed Stone #2 (A_3)	498.61	498.61
Super Plasticizer (S.P.)	6.38	6.38
Air Entraining Admixture (A.E.A)	0.21	0.21
	B_{theo}=2369.37 kg/m³	B_{theo}=2369.37 kg/m³

Task b)

$$W_2 = 161.5 + \frac{0.3 * 1000}{25} = 173.5\ kg$$

W/C = W_2/C_2 =0.38 → C_2 = 173.5 / 0.38 = 456.58 kg > C_{min} = 320 kg √ OK

S.P.$_2$ = 456.58*0.015=6.85 kg → V_{SP2} = 6.85 / 1.15 = 5.96 dm³ > 3 dm³

So, the water content of S.P. must be taken into account

∗ 70% of S.P. is water then, water coming from S.P. = 6.85 * 0.7 = 4.8 kg

A.E.A.$_2$ = 456.58 * 0.0005 = 0.23 kg → V_{AEA2} = 0.23 / 1.01 = 0.23 dm³

Water content of A.E.A can be ignored.

Water adjustment : W_2' = 173.5 – 4.8 = 168.70 kg

$$V_{agr2} = 1000 - \left[\frac{456.58}{3.15} + 168.70 + \frac{6.85}{1.15} + \frac{0.23}{1.01} + 60\right] = 620.17\ dm^3$$

Natural Sand = $(A_1)_2$ = (V_{agr2}*δmix)*a_1=620.17*2.73*0.47 = 795.74 kg

Crushed Stone #1 = $(A_2)_2$ = (V_{agr2}*δmix)*a_2=620.17*2.73*0.25 = 423.27 kg

Crushed Stone #2 = $(A_3)_2$ = (V_{agr2}*δmix)*a_3=620.17*2.73*0.28 = 474.06 kg

Mixing water adjustment (due to moisture content of the aggregates)

$$W_{2,adj} = W_2' + \sum (A_i)_2 (A_{Wi} - M_i)$$
$$W_{2,adj} = 168.70 + [795.74(-0.02) + 423.27(0.002)] = 153.64\ kg$$

Aggregate content adjustment due to moisture content of aggregates

$$A_{1,2\ adj} = 795.74 - 795.74(-0.02) = 811.65\ kg$$
$$A_{2,2\ adj} = 423.27 - 423.27(0.002) = 422.42\ kg$$

Amount of the constituents for 1 m³ of concrete		
Material	**Mix Design (kg)**	**Adjusted Mixing Amount (kg)**
Cement (C)	456.58	456.58
Water (W)	168.70	153.64
Natural Sand (A_1)	795.74	811.65
Crushed Stone #1 (A_2)	423.27	422.42
Crushed Stone #2 (A_3)	474.06	474.06
Super Plasticizer (S.P.)	6.85	6.85
Air Entraining Admixture (A.E.A)	0.23	0.23
	B_{theo}=2325.43 kg/m³	B_{theo}=2325.43 kg/m³

Task c)

Specimen	Max Load P (kN)	Comp. Str. fc (MPa)
1	1015	45.1
2	925	41.1
3	990	44.0
	$f_{c,avg}$	**43.4 MPa**
	$f_{c,min}$	**41.1 MPa**

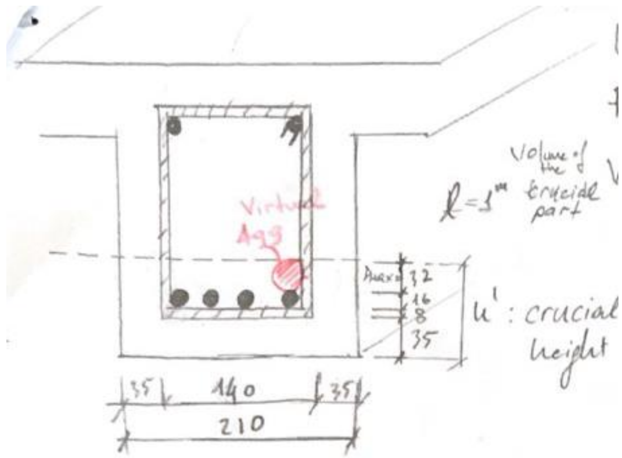
Evaluation for the Class : C30/37

$f_{c,avg} \geq f_{ck} + 4.0\ (MPa)$ → $43.4 \geq 37 + 4.0 = 41\ MPa$ √ OK

$f_{c,min} \geq f_{ck} - 4.0\ (MPa)$ → $41.1 \geq 37 - 4.0 = 33\ MPa$ √ OK

Tested concrete specimens conform to the requirements for the strength class of C30/37.

Task d)



h' = 35 + 8 + 16 + 32 = 91 mm

F = b_w * h' = 210*91 = 19110 mm²

V = F * L = 19110 * 1000 = 191.1x10⁵ mm³

S : The sum of areas of the surfaces which are in contact with concrete in volume (V).

$$S = S_{mould} + S_{reinforcing\_bar} = S_{mould} + S_{longitudinal} + S_{stirrup}$$

S_{mould} = (91*2 + 210) * 1000 = 392000 mm²

$S_{longitudinal}$ = (π*16*1000) * 4 = 201061.93 mm²

$S_{stirrup}$ = π*8*[(91-35)*2 + (210 – 35.2)] * 5 = 31667.25 mm²

Then S = 392000 + 201061.93 + 31667.25 = 624729.18 mm²

Diameter : L = V/S = 191.1x10⁵ / 624729.18 = 30.59 mm

Evaluation :

$D_{max}/L < 0.8$ → No wall effect

$0.8 < D_{max}/L < 1.0$ → Concrete must be carefully placed

$D_{max}/L > 1$ → Concrete cannot be placed, D_{max} must be decreased!

D_{max}/L = 32 / 30.59 = 1.05 > 1 → Concrete cannot be placed, D_{max} must be decreased!