

Exercise 3: Concrete recipe study

We're looking at some concretes to be used for the curbs of a road bridge in the Alps. In the tender, the engineer specified the concrete as follows, according to SN EN 206:

C 30/37
XC4, XD3, XF4
 $D_{\max} = 32 \text{ mm}$
Cl 0.10
S3

The company plans to produce this concrete using the following recipe: 350 kg/m³ of CEM I 42.5 N, W/C = 0.45, with superplasticizer, but without air entrainer, placed by crane.

To ensure resistance to frost and de-icing salts, however, the client requires the addition of entrained air by means of an air entrainer in this concrete.

1. What is the total quantity of entrained air recommended to ensure frost resistance with $D_{\max} = 32 \text{ mm}$?
2. Are strength requirements always met with entrained air? (We'll assume an aggregate factor K_g of 0.7 in Bolomey's formula). If not, how should the concrete composition be modified to meet them?
3. Are durability requirements met?
4. What else should be checked if the concrete were to be pumped?
5. How would the composition of the concrete have to be modified if the $D_{\max}$ had to be lowered to 16 mm due to very dense reinforcement (concrete placed by crane)? - Propose a modified recipe and check that it meets the original requirements. How would you modify this recipe if the concrete had to be pumped into place?
6. How should the composition of the concrete be modified if the heat of hydration were to be limited to limit the risk of thermal cracking during the pouring of the curb (assuming $D_{\max} = 16 \text{ mm}$ and pump-applied concrete)?

Propose a modified recipe, and check that it meets the original requirements.

7. More generally, discuss the advantages/disadvantages of the concrete composition and placement variants dealt with in the exercise in relation to the durability requirements (exposure classes) of the structural element under consideration.

Appendix 1:

Recommended air content values for freeze/thaw resistance with de-icing salts.

DIN 1045 values, according to Bulletin du Ciment n°11, November 1994, TFB, Wildegg.

Diamètre de grain maximal du mélange de granulats [mm]	Teneur en air moyenne [part de volume en %]
8	≥ 5,5
16	≥ 4,5
32	≥ 4,0
63	≥ 3,5

NB: "Diamètre de grain maximal" = $D_{\max}$, "Teneur en air moyenne" = average air content [%]

!!! CAUTION - this is not the air content of all ordinary concrete; only that required to make concrete freeze/thaw resistant with de-icing salts!!!

These values are significantly higher than those obtained in ordinary concretes without air entrainers (for which we would typically have between 1 and 2% air for a $D_{\max}$ of 32 mm). For self-compacting concrete, a natural air content of around 1% is often obtained without entrained air.

2. The entrained air content required for freeze/thaw-resistant concrete with de-icing salts increases as the maximum grain diameter decreases. This is because, as the $D_{\max}$ decreases, the quantity of fines and therefore of cement paste (which is the phase vulnerable to freezing) increases in the mix. More air must therefore be added as a % of the total mix to "protect" more paste.

Appendix 2:

Indicative heat of hydration for binders:

CEM I 42.5 N: 380 J/g

Fly ash: 150 J/g

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