CIV-E2020 - Concrete Technology L	Course examination	22.02.2021

- Open book exam / Online exam
- Write on the answer document: your surname, first name and student number.
- You may use Excel or any other software for calculations, then copy/past as an image to your answer documents.
- Please justify your calculation with steps and equations used.

Question 1. (15p)

You task is to prepare a durability report about the reinforced concrete bridge shown in Figure 1.

a) Present three degradation mechanisms that may affect the durability of both concrete and reinforcement steel of the bridge.
b) for each mechanism:
   I. list the factors causing the degradation.
   II. explain shortly the principle of the degradation mechanism.
   III. list the damage caused by the degradation mechanism.
c) Determine the exposure classes for the bridge columns close to the Ring I road.

Figure 1. Laajalahti bridge on Ring I (kehä I)

Question 2. (15p)

Questions about the cement hydration process.

a) Point out the stages of hydration process and draw the heat development curve.
b) What causes the first peak in C3S and OPC hydration heat development (within minutes)?
c) What causes the induction period (dormant period) of the reaction within the first hours?
d) Describe the nucleation and growth theory of cement hydration.

Question 3. (15p)

Your task is to design concrete mixture using Nykänen-Monogram (appendix 1 or 01 - Nykänen Monogram (template).xlsx) for the following input:

- Minimum characteristic strength at 28 days = 37 MPa (C30/37)
- Slump = 90 mm,
- Air content = 4%, neglect the amount of AEA for the simplification of calculation.
- Portland cement with 28 days compressive strength = 55 MPa
- The aggregate size distribution index (H) of the combined aggregates = 450

Aggregates	Portion	Total moisture content	Absorbing water
Sand	25%	2.5%	0.5%
Gravel	35%	2.0%	0.5%
Crushed coarse aggregates	40%	1,0%	0.5%

a) Proportion a concrete mixture to be batched for 3.0 m^3 mixer (i.e. batch report).
b) Modify the mixture by adding superplasticizer dosage 2.0% by weight of cement. Assume that 1% of superplasticizer will decrease the water demand by 7% and increase the air content of fresh concrete by 10 dm^3/m^3.
(Hint: add the amount of superplasticizer for the batch report of 3.0 m^3)

Question 4. (15p)

4.1 The density of a concrete mix design was 2400 kg/m³ and the target air content was 2%. The results of the density test (Archimedian method[1] i.e., weigh in air, and then suspended in water) for hardened concrete specimen were:

- The weight of the specimen in air was 10,355 kg
- The weight of the specimen suspended in water was 5,822 kg

a) Calculate the actual air content of hardened concrete. Compare the result to the target air content and how does it affect the compressive strength of concrete?

4.2 A homogeneous sample of fresh concrete has been taken from a fresh concrete mixture.

- The aggregate to cement ration of the concrete mix weight is assumed to be 5 and the water to cement ration is 0.5 (i.e 1:5:0.5 Cem:Agg:Water).
- The specific gravities of the materials are cement = 3.10, aggregate = 2.67, AEA = 1.10
- Assume that the air content of the mixture is 4.0% and air-entraining agent is 0.1% of the cement weight.
- The water absorption of the aggregate is 0,8%.
- The fresh concrete sample weight is 600 g.
- The sample has been dried in microwave oven so that 97% of water has been evaporated.

	Microwave exposure time (minutes)	Weigh of sample + bowl (g)
Wet sample	0	900
Dry sample	20	845

a) What is the actual total water-cement ratio of concrete?

b) What is the actual effective water-cement ratio of concrete?

Question 5. (15p)

The maturity concept uses the principle that concrete strength is directly related to both age and its temperature history. Your task is to estimate the compressive strength of an existing structure based on the maturity age data given the excel sheet "02 - Temperature history.xlsx".

- Sheet 1: has the structure temperature for 7 days after casting, time interval 1 hour at the middle and under the surface of the concrete.
- Sheet 2: has the ambient air temperature until age of 91 days after casting, time interval 1 day.

- During first seven days the structure was insulated.
- At the age of 7 days, the insulation was removed, and the structure reached gradually the ambient temperature.
- Assume that the structure achieved the ambient temperature at the age of 10 days.
- Assume a linear transition of the temperature during the period between 7 and 10 days.
- Concrete strength class was C30/37 and the used cement was CEM II/B (S-LL) 42.5 N

a) Calculate the maturity age of the middle and surface of concrete at 91 days. Compare the maturity age to the real age. what does the difference mean and what are the measures to affect it?
b) At what time did the concrete reach its disassembly strength of the moulds?
c) How much is the predicted compressive strength of the concrete at the age of 91d?

[1] https://www.britannica.com/science/Archimedes-principle

Appendix 1. Nykänen Monogram