Université d'Ottawa
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Canada's university

University of Ottawa
Faculty of Engineering

Department of
Civil Engineering

CVG 2141
Civil Engineering Materials

Final Exam

Professor: Dr. Leandro F. M. Sanchez **December 15th, 2020**

Name: _____

Student Nº: _____

Signature: _____

- **TIME: 3 H**
- **OPEN BOOK**
- **TOTAL 100 POINTS**
  - **PART I QUESTION = 50 POINTS**
  - **PART II QUESTION = 25 POINTS**
  - **PART III QUESTION = 25 POINTS**

- Programmable calculators are not allowed

PART I - CONCRETE (50 POINTS)

1ST QUESTION (**34 PTS**)

You work for a consulting engineering company. You will participate in the construction of a 3 km tunnel line in Ottawa composed of reinforced concrete members (i.e., tunnel line and foundation blocks – Figure 1) that can be considered a) exposed to the environment (i.e., subjected to freeze-thaw cycles and de-icing salts) and b) in contact with a soil containing a very high amount of sulfates. Your role as an engineer is to ensure that the concrete mixture selected for the construction is suitable to enable the short and long-term performance and durability of the structure.

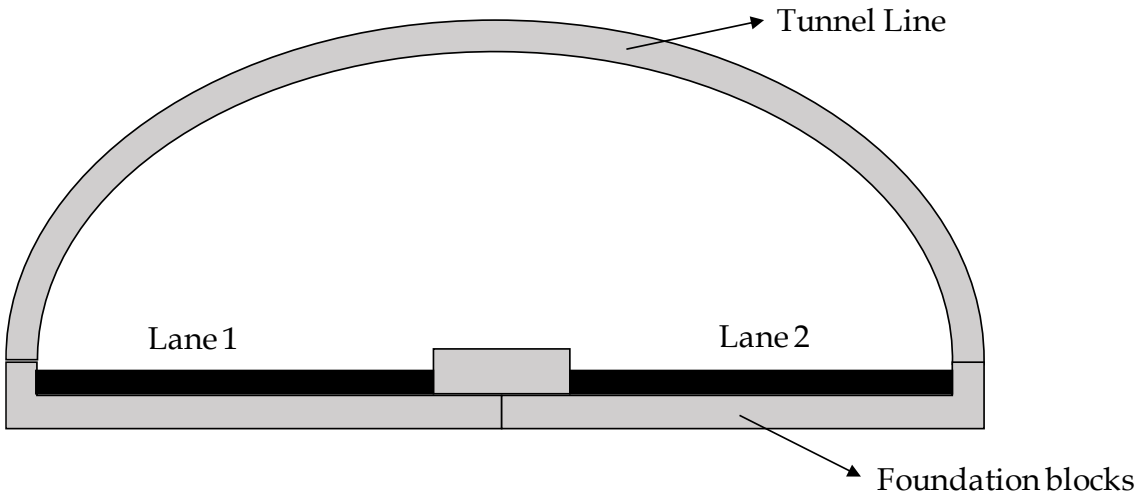

Figure 1: Tunnel line members.

In this context, please, answer the following questions: (**note:** there is not only one good answer for the following questions, yet your answers must be justified!):

a. The concrete strength and the required water-to-cement ratio for the concrete mixtures used in the tunnel line members (i.e., tunnel line and foundation blocks) in order to ensure proper long-term behaviour and durability. (**5 POINTS**)

b. Knowing that the concrete supplier participating in this construction needs to supply a mixture that meets CSA strength criterion (i.e., strength is higher than the targeted value in 99% of the time), and the standard deviation of the company for similar mixtures is 5 MPa, what's the compressive strength that the company should aim for ? (**5 POINTS**)

c. Explain the potential durability-related problems that may arise in the tunnel members (i.e., tunnel line and foundation blocks). (**6 POINTS**)

d. The cement/binder type, aggregates types and features (i.e. coarse and fine), and chemical admixtures of interest in the construction of the tunnel line members. It should be taken into consideration that the tunnel line must be built fairly quickly! Moreover, the thickness of the members (i.e., tunnel line and foundation blocks) is 40 cm and the concrete cover is 10 cm. Finally, the service life of the structure is aimed for 75 years. **(10 POINTS)**

e. Describe your choices in terms of a) concrete placement (manual cart, crane, pump, etc.), b) fresh state features (slump), c) consolidation (manual or mechanical) and d) cure type (i.e. type & number of days) in order to guarantee a good quality of the concrete. (**8 POINTS**)

2ND QUESTION (16 points)

You have worked closely to the concrete supplier to design the best concrete mixture possible for the tunnel line illustrated in Figure 1. After some preliminary selections and calculations, you have adopted the use of 180 kg/m3 of water, 1128 kg/m3 of coarse aggregates, a water-to-binder ratio of 0.45 (i.e., binder is equal to cement + SCMs) and an air content of 6%. In addition, it was specified the use of fly ash. The ingredients have the following properties:

- Cement: SG = 3.15
- Fly ash: SG = 2.6, used as a cement replacement (30% of the total binder)
- Coarse aggregate: SG_{OD} = 2.65, AC = 0.6%, MC = 2%
- Sand: SG_{OD} = 2.7, AC = 0.7%, MC = 3%

Determine the final mix-design in kg/m3 **of all components of the concrete mix** (i.e. cement, fly ash, sand, coarse aggregates, water). Do not forget to make adjustments (i.e. moisture) if needed! **(Note: This mixture has nothing to do with the particular selections previously made in the 1st Question! Please, simply mix-proportion 2ND question concrete mixture as per the provided data).**

PART II – ASPHALT & CONCRETE (25 points)

3RD QUESTION (**25 points**)

In the construction of the tunnel line illustrated in Figure 1, your company is also requested to design the pavement (i.e., two lanes) inside the tunnel. After initial discussions, your boss was still unsure on the use of asphalt or concrete for the pavement and asked you to study the best solution for this project. In this context, please, answer the following questions: (**note:** there is not only one good answer for the following questions, yet your answers must be justified!):

a. Describe the advantages and disadvantages of each material. (**5 POINTS**)

b. Select the type of material more suitable for this construction. Explain and sketch how the structural behaviour of the pavement will be as per the material's selection. **Justify your answer**! (**10 POINTS**)

c. Which durability related problems make take place in the pavement as per the material's selection? Which types of treatment are needed to ensure the durability and long-term performance of the pavement made of the material selected in question "b"? (**10 POINTS**)

PART III – WOOD, MASONRY AND STEEL (25 points)

4TH QUESTION (**25 points**)

You work for a consulting engineering company. You will participate in the construction of a touristic building in downtown Ottawa composed of the following structural/non-structural members: arches, slabs, columns, beams, and walls. After a number of meetings and discussions, due to many reasons (including aesthetics), the material choices for the construction of this structure **were restricted to: a) timber (wood) members b), masonry and; c) steel members.** In this context, please, answer the following questions: (**note:** there is not only one good answer for the following questions, yet your answers must be justified! Moreover, you may select more than one material for the structure):

a. Describe the advantages and disadvantages of each material; (**5 POINTS**)

b. Select the material (s) most suitable for this construction. **Justify your answer**! (**10 POINTS**)

c. Which durability related problems make take place in this building as per the materials selection previously made? Which types of treatment are needed to ensure the durability and long-term performance of the building? (**10 POINTS**)