

CVG 2141 Quiz 6

1. Why does concrete require suitable mechanical properties?

Concrete requires suitable mechanical properties because it is used to construct many structural members and in order to ensure the safety of the structure, it must uphold the design standards for each property.

2. What are the main parameters that influence the compressive strength of concrete?

The compressive strength of concrete depends on the water to cement ratio, degree of hydration, portland cement type or pre-mixed cement, type and quality of SCMs, air content, quality of bond between the cement paste and aggregate, and aggregate strength.

3. What's the modulus of elasticity of concrete? How do we measure it?

The modulus of elasticity is the ratio between the stress and strain of a material and can be described as its stiffness or softness. Due to the fact that concrete exhibits nonlinear (nonelastic) behaviour, the secant method is used (when following CSA standards) to determine the modulus of elasticity. This involves a line being drawn from the origin to a desired point on the curve (typically 40% is used). As well, there are two formulas that can be used to determine the modulus of elasticity depending on the compression strength range.

$$\text{When } f_c = 20 - 40 \text{ MPa: } E(c) = 4500\sqrt{f'_c}$$
$$\text{General: } E(c) = (3300\sqrt{f'_c} + 6900) \left(\frac{\gamma(c)}{2300}\right)^{1.5}$$

4. Does concrete have a proper tensile strength? Why? What are the test procedures used to measure tensile strength of concrete in the laboratory? How do one use the tensile strength of concrete to design structures?

Concrete is known for its good compressive strength, however, it has poor tensile strength. This is because when in tension, the interfacial transition zone is responsible for holding the aggregates together as they are trying to move apart from each other. There are two types of tests that can occur, destructive and non destructive tests. For destructive tests, it includes the direct tension, bending flexure, and splitting test. For the non destructive tests, it includes the schmidt hammer, windsor hammer, pull off, ultrasound, maturity, cover meter tests. However, indirect tests are not that precise and are more beneficial when looked at from a qualitative rather than quantitative perspective. Moreover, when designing concrete structures, the tensile strength is considered zero. As well, steel reinforcements are added to balance the lack of tensile strength in concrete.

5. What's sulphate attack? What are the distinct types of sulphate attack? What should be done to avoid sulphate attack in concrete?

A sulfate attack is the deterioration of concrete due to the presence of sulfates causing swelling, the dissolution of the portlandite, and a C-S-H (calcium silicate hydrate) attack. It can be broken down into three distinct types including internal sulfate attack, external sulfate attack, and bacteriological sulfate attack. The internal sulfate attack (ISA) consists of three causes, aggregates in the presence of gypsum, delayed ettringite formation, and thaumasite sulfate attack. When gypsum dissolves in a sulfate solution, ettringite can precipitate. As a result, there is an increase in volume of approximately 280% which in turn causes cracking and degradation of the material. While delayed ettringite formation occurs when there are increased temperatures ($>65^{\circ}\text{C}$) causing it to transform to monosulfoaluminate. When temperatures cool again, it is converted back into ettringite and this change causes expansion and thus cracking in the concrete. Similarly, thaumasite sulfate attacks are due to the presence of SiO_2 and CO_2 causing volume expansion of the formed ettringite resulting in cracking. The second distinct type is the external sulfate attack describing when sulfate ions are introduced to the concrete from external sources including soil and seawater. A reaction between the sulfate ions, the portlandite, and C3A in the cement paste causes the formation of gypsum and ettringite. This results in the deterioration of the cement paste leading to increased porosity and permeability, as well, the expansion of the ettringite. Lastly, the bacteriological sulfate attack involves bacteria producing sulfuric acid leading to swelling, cracking, and strength loss. Sulfate attacks can be avoided by using petrographic and chemical analysis to understand the chemical composition of the aggregates, reducing the water to cement ratio, reducing the C3A content, checking the temperature, ensuring proper compaction and curing, or using moderate/high resistance sulfate cement.

6. What's Alkali-Aggregate Reaction (AAR)? Show the essential parameters for this chemical mechanism. How do one avoid and or mitigate AAR in concrete?

Alkali Aggregate Reaction (AAR) is a very common cause of degradation in concrete and results from the reaction between the alkali hydroxides (Na^+ , K^+ , OH^-) in the cement pores and the siliceous minerals in the aggregates. It results in the production of a silica gel that can absorb water which in turn expands causing deterioration from cracking. The essential conditions for AAR development include high alkali content, high moisture, and presence of reactive silica. Unfortunately, the only parameter that can be modified is the amount of reactive silica within the solution. Techniques for avoiding AAR include using reinforcements (to help restrain portions of concrete from expanding), as well as chemical admixtures like fly ash.

7. What's freezing and thawing in concrete? How can we avoid it?

Freezing and thawing describes the cycle in which the water absorbed into concrete is frozen and vice versa. This occurs since concrete is a porous material and the freezing and thawing cycle causes an expansion of about 9%. This change in volume results in degradation of

the concrete in forms like cracking and spalling. A mitigation technique used includes using air entrained admixtures. Air entrained admixtures help against freezing and thawing since they form reservoirs that provide enough space for the change in volume without damaging the concrete.

8. What's the corrosion process in reinforced concrete? What are the most common mechanisms that may trigger corrosion (describe them)? How can we avoid corrosion?

The corrosion process in reinforced concrete consists of two phases, the initiation and propagation phase. The initiation sets up the conditions required to break the passive film. This protective layer is created through a process called passivation and occurs naturally due to the high pH in concrete. The point where the aggressive agents break through the passive film is called the t_0 . Past this, there is the propagation phase where the material starts to corrode and the speed at which this occurs is dependent on the O₂ content, humidity, temperature, and potential difference. Often times, corrosion is caused by the penetration of aggressive agents like chloride ions and the carbonation of the concrete cover. Corrosion by chloride ions involves the chloride ions from de-icing and seawater being absorbed into concrete causing delamination which worsens over time. While corrosion by carbonation is caused by the reactions between hydrate products and CO₂ from the atmosphere. As a result, there is a dissolution of the portlandite. Corrosion can be avoided by the optimization of concrete cover properties, using corrosion inhibitors, using sealants on the concrete surface, using rebars as protection, having an epoxy coating and galvanized steel, and/or using cathodic protection.