

Course: Concrete Technology

Week 16: Final examination

Mauricio Javier León Tejada

mjleon@ucsp.edu.pe

Objective

The objective of this final examination is to assess students' competency in the principal topics of Concrete Technology, including concrete materials, fresh and hardened concrete properties, concrete mix design methods, quality control procedures, special concretes, and durability-related deterioration mechanisms. Students are expected to demonstrate technical knowledge, analytical reasoning, and the ability to apply engineering principles to practical problems involving concrete production, construction, and long-term performance.

Instructions

- Section I: Multiple-Choice (20 pts): 20 questions, 1 point each; select the best answer.
- Section II: Integrative Questions (18 pts): 3 questions, 6 points each; provide clear and technically supported answers.
- Section III: Applied Case Study (12 pts): 1 case-based question applying concepts from Concrete Technology to a practical engineering scenario.



Section I: Multiple-Choice Questions

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Question 1

Which of the following statements best describes the main objective of the Total Fineness Modulus Method in concrete mix design?

- A. To determine the water-cement ratio exclusively from durability requirements.
- B. To optimize the proportion of fine and coarse aggregates by achieving a target combined fineness modulus that improves workability and compactness.
- C. To maximize cement content in order to increase compressive strength.
- D. To eliminate the need for aggregate gradation analysis during mix design.

Question 2

According to the Theoretical Curves Method, an aggregate combination is considered optimal when:

- A. The percentage of coarse aggregate is greater than the percentage of fine aggregate.
- B. The water-cement ratio is lower than 0.40.
- C. The deviations between the actual gradation curve and the theoretical curve are balanced, such that the areas above and below the ideal curve are approximately equal ($A_1 = A_2$).
- D. The maximum aggregate size is increased regardless of workability requirements.

Section I: Multiple-Choice Questions

Question 3

Why does the Theoretical Curves Method use the maximum aggregate size (TM) instead of the nominal maximum aggregate size (TMN)?

- A. Because the maximum aggregate size is always equal to the fineness modulus of the aggregate.
- B. Because the theoretical curve equations use the maximum aggregate size as the reference parameter for constructing the ideal gradation distribution.
- C. Because the nominal maximum size cannot be measured through sieve analysis.
- D. Because the maximum aggregate size produces the highest possible compressive strength regardless of other factors.

Question 4

What is the primary objective when adjusting the proportions of fine and coarse aggregates in the Theoretical Curves Method?

- A. To maximize the percentage of coarse aggregate and minimize cement consumption.
- B. To achieve a fixed water content regardless of aggregate characteristics.
- C. To make the combined gradation curve of the aggregates match the selected ideal theoretical curve as closely as possible.
- D. To ensure that the fineness modulus of the fine aggregate is always greater than 3.0.

Section I: Multiple-Choice Questions

Question 5

In the Theoretical Curves Method, the parameter **Z** represents:

- A. The water-cement ratio (w/c).
- B. The ratio between fine and coarse aggregate.
- C. The cement-water ratio (c/w), which is the inverse of the water-cement ratio.
- D. The percentage of air entrainment in the mixture.

Question 6

After determining the absolute volumes of cement, water, and air, the remaining volume in one cubic meter of concrete corresponds to:

- A. The total volume of cement paste.
- B. The total absolute volume of the combined aggregates.
- C. The volume occupied by entrained air only.
- D. The volume of excess water required for workability.

Section I: Multiple-Choice Questions

Question 7

Which statement best reflects the concept of quality in concrete technology and construction?

- A. Quality is determined exclusively by the compressive strength achieved by the concrete.
- B. Quality depends primarily on the client's perception of the finished project.
- C. Quality is the degree to which a product, process, or service complies with established requirements and expectations throughout the project life cycle.
- D. Quality is only evaluated after construction has been completed.

Question 8

What is the primary purpose of Quality Planning?

- A. To identify deviations after construction activities have been completed.
- B. To establish quality objectives, requirements, procedures, responsibilities, and resources necessary to achieve the expected quality level.
- C. To perform laboratory testing and inspections on finished products.
- D. To issue nonconformity reports and corrective actions.

Section I: Multiple-Choice Questions

Question 9

What is the principal purpose of quality records or protocols?

- A. To define how construction activities should be executed.
- B. To establish project specifications.
- C. To provide objective evidence that processes and products comply with requirements.
- D. To prepare project budgets.

Question 10

A nonconformity (NC) is best described as:

- A. A design change approved by the client.
- B. A record identifying that a product, process, or result does not meet established requirements.
- C. A calibration certificate for testing equipment.
- D. A procedure for executing a construction activity.

Section I: Multiple-Choice Questions

Question 11

According to ASTM C172, from which portion of the mixer truck discharge should a representative concrete sample be obtained?

- A. From the first portion discharged from the truck.
- B. From the last portion discharged from the truck.
- C. From the middle third of the mixer discharge.
- D. From any point during discharge, provided the volume is sufficient.

Question 12

During the slump test, the Abrams cone must be filled:

- A. In two equal-volume layers, each consolidated with 25 strokes.
- B. In three approximately equal-volume layers, each consolidated with 25 strokes.
- C. In four equal-height layers, each consolidated with 15 strokes.
- D. In a single layer consolidated with 75 strokes.

Section I: Multiple-Choice Questions

Question 13

After demolding, standard concrete specimens must be cured in water maintained at:

- A. 10 °C to 15 °C.
- B. 16 °C to 27 °C.
- C. 21 °C to 25 °C.
- D. 25 °C to 35 °C.

Question 14

Plastic shrinkage cracking occurs when:

- A. The rate of bleeding exceeds the rate of evaporation.
- B. The rate of evaporation exceeds the rate at which bleeding water reaches the surface.
- C. The concrete reaches its design compressive strength too quickly.
- D. Reinforcement corrosion generates expansive stresses.

Section I: Multiple-Choice Questions

Question 15

Why are mass concrete structures particularly susceptible to thermal cracking?

- A. Because they contain excessive amounts of entrained air.
- B. Because they have very low compressive strength.
- C. Because the interior retains heat generated by hydration, creating temperature gradients between the core and the surface.
- D. Because thermal expansion only occurs at the surface of the concrete.

Question 16

Which of the following is an example of acquired damage according to the Fernández Cánovas pathology model?

- E. Alkali–silica reaction present due to reactive aggregates within the concrete.
- F. Cracking caused by repeated freeze-thaw cycles during the service life of the structure.
- G. Structural damage caused by a vehicle collision with a bridge pier.
- H. Damage produced by an earthquake affecting the structure.

Section I: Multiple-Choice Questions

Question 17

What is the primary function of air-entraining admixtures in concrete exposed to freeze-thaw conditions?

- A. To increase compressive strength.
- B. To reduce cement consumption.
- C. To provide microscopic voids that relieve pressure generated by freezing water.
- D. To accelerate hydration during cold weather.

Question 18

A reinforced concrete pavement located in a cold climate develops surface cracks within a few hours after placement. Several years later, the pavement exhibits scaling, spalling, and reinforcement corrosion. Which of the following sequence best explains the likely progression of deterioration?

- A. Plastic shrinkage cracking → Increased permeability → Ingress of water and chlorides → Freeze-thaw damage and corrosion.
- B. Autogenous shrinkage → Reduced permeability → Corrosion → Thermal cracking.
- C. Plastic settlement → Alkali-silica reaction → Freeze-thaw damage → Reduced permeability.
- D. Thermal cracking → Reduced moisture penetration → Corrosion prevention → Surface scaling.

Section I: Multiple-Choice Questions

Question 19

Which material is considered one of the most important supplementary cementitious materials in high-strength concrete because it fills microscopic voids and densifies the microstructure?

- A. Limestone filler
- B. Fly ash
- C. Silica fume
- D. Air-entraining agent

Question 20

What is one of the main structural advantages of using high-strength concrete in high-rise buildings?

- A. Increased permeability of structural members
- B. Larger column dimensions are required
- C. Reduced structural member sizes, increasing usable floor space
- D. Elimination of reinforcement requirements



Section II: Integrative Questions

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Question 1

A construction project is experiencing a high number of nonconformities related to concrete placement. Several concrete elements have failed the first inspection and require rework, causing schedule delays and increased costs. The project team decides to review its Quality Management System.

Using the concepts of Quality Planning, Quality Assurance, and Quality Control, explain how each component of quality management could be applied to reduce nonconformities and improve project performance. In your answer, discuss the role of the following elements:

- Technical specifications
- Quality Plan
- Inspection and Test Plan (ITP)
- Procedures and work instructions
- Quality records/protocols
- Training of personnel
- Quality indicators

Additionally, explain why quality should be considered a shared responsibility across all project departments rather than the exclusive responsibility of the quality department.

Section II: Integrative Questions

Question 2

A 50-story office building is being constructed in a coastal city where structural elements will be exposed to chloride-rich environments. The design team wants to maximize usable floor space while ensuring long-term durability and high load-carrying capacity.

Explain why high-strength concrete would be an appropriate material for this project. In your answer, discuss:

- The material characteristics that make high-strength concrete suitable for this application.
- The benefits it provides to the structural design of the building.
- The durability advantages it offers in a coastal environment.
- At least three quality control measures that should be implemented during production and construction to ensure the desired performance.

Section II: Integrative Questions

Question 3

A reinforced concrete water-retaining structure located in a coastal environment has been in service for 15 years. During an inspection, engineers observe cracking, surface staining, localized spalling of the concrete cover, and evidence of reinforcement corrosion. Historical records indicate that the structure has been exposed to wetting–drying cycles, chloride-containing water, high temperatures during construction, and inadequate maintenance.

Using the concrete pathology model proposed by Fernández Cánovas, explain how you would evaluate this structure. In your answer:

1. Identify the possible type(s) of damage involved (congenital, acquired, and/or accidental) and justify your selection.
2. Describe the symptoms observed and explain what deterioration mechanisms may be responsible for them.
3. Outline the preliminary and detailed investigations that should be performed.
4. Propose a diagnosis and prognosis for the structure.
5. Recommend the most appropriate intervention strategy (preservation, restoration, repair, rehabilitation, strengthening, or demolition) and justify your recommendation.
6. Discuss the role of durability and permeability in the development of the observed deterioration.



Section III: Applied Case Study

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A 22-year-old reinforced concrete wastewater treatment facility is being evaluated due to signs of deterioration. During inspection, engineers observe:

- Map cracking with gel-like deposits on walls.
- Rust stains and areas of exposed reinforcement.
- Surface softening and material loss in wastewater channels.
- Excessive deflection in some floor slabs.
- Localized pitting in high-flow water channels.
- Moss and algae growth in moist areas.

Additional information:

- Siliceous aggregates were used during construction.
- Average temperatures range from 28–32°C.
- Relative humidity is frequently above 80%.
- Carbonation has reached the reinforcement depth in some members.
- High chloride concentrations are present near reinforcement.

The owner requests an engineering assessment and recommendations.

Section III: Applied Case Study

Part A – Identification of Deterioration Mechanisms

Identify the most probable deterioration mechanism responsible for each observation and briefly justify your answer.

Part B – Deterioration Analysis

Answer the following:

1. Why are the environmental conditions favorable for Alkali-Silica Reaction (ASR)?
2. Explain how carbonation can lead to reinforcement corrosion.
3. Describe how corrosion causes cracking and spalling of concrete cover.
4. Why is concrete permeability critical in durability performance?

Part C – Investigation Plan

Develop a diagnosis strategy by proposing:

Preliminary Investigation: List three activities that should be carried out before testing.

Detailed Investigation: Recommend four tests and explain what information each provides.

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