Concrete Construction Fundamentals

An Online Continuing Education Course for Engineers

Course Number: C-5017

Credit: 5 Hours / 5 PDH / 5 CPD

Concrete Fundamentals

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Introduction

A professional engineer working with concrete will provide expertise about its properties, the principles of its design, and the mechanics of its construction. For example, a professional engineer acting as a forensics engineer may be hired by a building owner to examine building system discrepancies such as concrete structural damage, which are also called distresses. The professional engineer will write a report that identifies root causes and will recommend short- and long-term solutions. The engineer may collaborate with a licensed contractor specializing in concrete construction as part of the inspection and documentation process. The generation of the report requires inspecting the concrete structure and reviewing the maintenance and repair records, as well as verifying compliance with applicable local building code and industry standards. For example, American Concrete Institute (ACI) 562 provides the code requirements for the assessment, repair, and rehabilitation of existing concrete structures. ACI 562 references ACI 318 (Building Code Requirements for Structural Concrete) which specifies the amount of concrete cover over the reinforcement steel bars to ensure the bars are not exposed to the environment. A visual inspection documented with plenty of photos and video would verify if there is an adequate amount of concrete cover. There are more elaborate inspection steps, such as using ground-penetrating radars to verify the concrete steel reinforcement against existing plans or documents like the as-built drawings.

This course is intended to provide training on the common fundamentals of concrete beneficial to engineers without a civil or structural engineer background. This course is also intended for civil engineers who want a refresher on concrete principles. Some of the fundamentals to be presented are the following:

a) application of American Concrete Institute (ACI) and American Society for Testing and Materials (ASTM) standards for concrete

b) the properties and composition of concrete

c) the concrete process starting with estimating the amount of concrete needed and including how to mix, pour and finish concrete; the concrete process is called concreting

d) preliminary design calculations for a concrete beam and a column

e) calculation of the amount of each ingredient needed for a concrete slab

f) concrete reinforcement principles such as ACI code on the minimum and maximum amount of concrete area to be occupied by steel reinforcement bars, also known as rebar

g) identification of common distresses of concrete such as cracking and how to remediate concrete distresses; this includes reference to Florida's Champlain Towers South collapse

h) quality assurance and testing of concrete this includes inspection of existing concrete structures such as testing the concrete's pH and verifying its compressive strength

Concrete is a manufactured construction material that can be classified as a composite material as it is a mixture of different components. The three main components or ingredients are aggregate, cement, and water. When they are mixed, the final product is called concrete, and sometimes it is mistakenly referred to as cement, which is just one of concrete's ingredients. If admixtures are used as another ingredient, then they typically make up less than 5% of concrete's volume.

Concrete may be cast into bricks, blocks, and other relatively small building units which are used in concrete construction. It is also commonly poured or placed within forms such as for a foundation slab of a building. Concrete properties or characteristics include compressive strength, durability, and workability. It also can be made watertight by using high-strength concrete and utilizing water-resisting admixtures and densifier sealers. Since concrete has advantages in meeting structural requirements, it has many applications like building foundations, columns, walls, and slabs. Larger-scale concrete applications include multistory or high-rise buildings, roads, bridges, dams, and airplane runways.

Acronym and Standards List

American Concrete Institute (ACI)
American Society for Testing and Material (ASTM)
American Society of Civil Engineers (ASCE)
ASCE 7: Minimum Design Loads for Buildings and Other Structures
ACI 201.1: Guide for Conducting a Visual Inspection of Concrete in Service
ACI 301: Specifications for Structural Concrete
ACI 305: Specification for Hot Weather Concreting
ACI 318: Building Code Requirements for Structural Concrete
ACI 332: Residential Code Requirements for Structural Concrete
ACI 506R: Guide to Shotcrete
ACI 546: Guide for Concrete Repair
ACI 562: Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures
ASTM C94: Ready Mix Concrete Specifications
ASTM C150: Standard Specification for Portland Cement
ASTM C172: Standard Practice for Sampling Freshly Mixed Concrete
ASTM C293: Standard Test Method for Flexural Strength of Concrete Using Simple Beam With Center-Point Loading
ASTM A615: Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM C805: Standard Test Method for Rebound Number of Hardened Concrete
ASTM C1064: Temperature of Freshly Mixed Hydraulic-Cement Concrete
ϵ : strain, which is equal to ΔL divided by L_O
ΔL : change of length
L_O : original length
f_R : modulus of rupture
ksi : thousands pounds per square inch (1 ksi = 1,000 pounds per square inch)
kips : thousands pounds (1 kip = 1,000 pounds)
M: bending moment
T: tensile force
P: load applied to concrete structure
w: weight per foot (pounds per foot) of concrete structure
b: width of concrete structure
h: thickness or depth of concrete structure
A_g: overall or gross cross-section area of concrete structure
A_s: cross-section area of steel rebar
U: required strength (in force) for a concrete structure based on ASCE 7 (and ACI 318)

Concrete Characteristic #1: Compressive Strength

The compressive strength of concrete is its ability to resist compression. Concrete can support very high compressive loads. Consider the compressive force of a vehicle on a concrete driveway. Concrete's tensile strength is conservatively only about 8% of compressive strength. Concrete also has relatively low strength as far as bending and twisting or torsion. Adding reinforcing bars, known as rebar, to concrete will increase the strength or resistance to failure, especially from tension, bending, and twisting. Essentially the concrete material becomes a composite material that includes the extra strong rebar.

Concrete slabs, which are laid on properly prepared ground and are less than 5 inches thick, generally will not need rebar. A concrete slab is a common structural element of modern buildings, consisting of a flat, horizontal surface made of concrete. Unreinforced (or non-reinforced) slabs may be used for exterior paving, such as four-inch-thick residential walkways. Any concrete structure without reinforcement like rebar is called plain, unreinforced, or non-reinforced concrete. Steel is the most common reinforcement; other types of reinforcement are glass and plastic fibers. Highways are generally 11 to 12 inches thick of concrete, and airport runways are typically up to 20 inches thick of concrete.

With a slab for residential driveways, wire mesh is typically used instead of steel reinforcing bars. The wire mesh is not as strong as rebar but it reinforces concrete, and like rebar, it reduces the risk of concrete cracking due to excessive tensile stress. Figure 1 shows the wood frame or form where the concrete will be laid or poured as well as the wire mesh and plastic-made water vapor barrier.

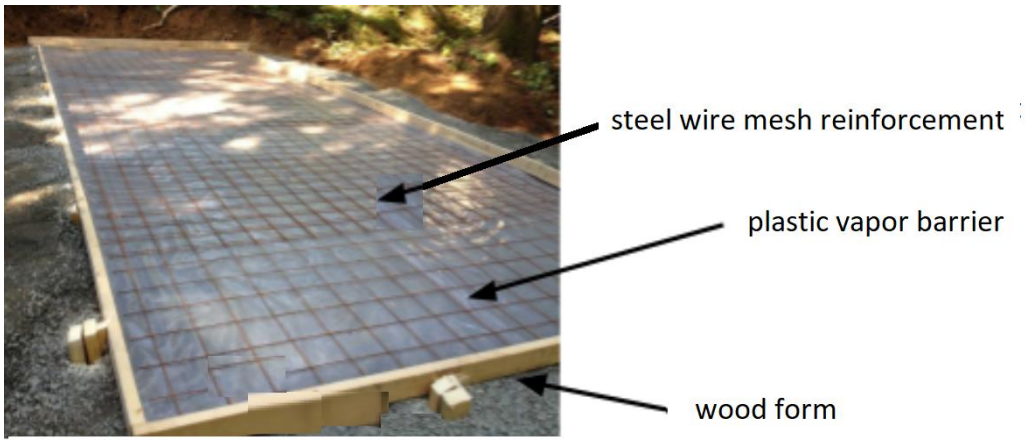

Figure 1. Wire mesh reinforcement prior to concrete being poured within the wood forms

Converse to reinforced concrete, there is plain concrete. Plain concrete still has the standard ingredients of cement, water, and aggregates, but it has no reinforcement. It is ordinary concrete without any kind of reinforcement like wire mesh or matrix of rebar. Reinforced concrete is just

plain concrete with reinforcement. Plain concrete is generally less expensive than reinforced concrete and can be used for pavements, footpaths, building floors, and other applications that do not require high tensile strength due to lack of reinforcement. Plain concrete can be made strong by decreasing the water to cement ratio to 0.40 or less. A water to cement ratio of 0.4 means there are 0.4 pounds of water to 1 pound of cement.

The water to cement ratio is the ratio of the weight of water to the weight of cement used in concrete. A lower ratio leads to higher compressive strength and durability, but it may make the concrete mix difficult to work with and form. More water in the mix will improve workability but will reduc

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Exposure		te gth
F0		
F1	Freezing and thawing with limited exposure to water	0.55	3,500
F2	Freezing and thawing with frequent exposure to water	0.45	4,500