Technology in Practice

What, Why & How?

TIP 21 - Concrete Mixtures for High Strength and Modulus of Elasticity

This TIP outlines the process of proportioning and producing concrete mixtures for high strength and high modulus of elasticity.

WHAT is High Strength and High Modulus of Elasticity?

The compressive strength at which high strength concrete is defined has changed over time. Currently, ACI Committee 363 defines a specified compressive strength greater than 8000 psi [55 MPa] as high strength.

Modulus of Elasticity (MOE) is material property characterizing the stiffness of a material to applied load. MOE is defined as the ratio of normal stress to corresponding strain for tensile or compressive stress less than the proportional limit of the material. For concrete it is the slope of the stress-strain curve within the typical working stress range of 0 to 40% of the ultimate strength of a test cylinder. It is also referred to as stiffness, elastic modulus, Young's modulus, and static modulus of elasticity; and is often represented by the using notations E_c or MOE. E_c is used in design to determine column shortening, deflection of beams, and estimating the load at which concrete cracks in bending.

Designers typically use an empirical relationship (Equation 1) to estimate E_c based on the specified compressive strength of concrete. For most purposes, this estimate is adequate. With higher strength concrete, other empirical relationships are suggested based on research. If, however, the value of E_c is critical to design of the structure, the specification may require the measurement of E_c of the proposed mixture. ACI 318-19 includes a provision for the engineer to specify testing for E_c of the proposed mixture in the submittal. General values of MOE for concrete vary between 3 to 5 million psi [20 to 35 GPa]. What level E_c is "high" is not defined. Using the empirical ACI 318 relationship, E_c corresponding to a compressive strength of 8000 psi [55 MPa] is around 5 million psi [35 GPa]. While E_c is not as commonly specified as high strength, the two are often correlated since achieving high E_c often requires proportioning concrete mixtures for higher compressive strength.

WHY is High Strength and High Modulus Important?

High strength concrete is often used in columns and shear walls in high rise structures where the higher strength helps reduce member cross-section and reinforcement required. This can reduce dead load on the structure. Using structural members of smaller dimensions also increases functional floor space. High strength prestressed concrete girders and cast-in-place beams can span greater lengths, permit wider girder or grid spacing, or sections with less depth.

Two of the most common reasons for using concrete with a higher E_c is to reduce deflections and to reduce the change in dimensions of vertical and horizontal structural members when loaded. Typical applications where high E_c is specified are for vertical members bearing higher loads, such as in the lower columns of high-rise buildings, to minimize deflection and sway to wind and other lateral forces, and to reduce deflection of horizontal members with long spans between supports.

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