2. Construction Materials Properties

2.1. Normal-Weight and Lightweight Concrete

2.1.1. Compressive Strength

The average compressive strength of the cylindrical samples (f_c') at age of 28-day for concrete, must be within:

- $f_c' \geq 2.4$ ksi [structural applications]
  ≥ 4.0 ksi [prestressed concrete and decks]
  ≤ 10.0 ksi [beyond, tests and allowance are essential]

2.1.2. Cement and Water Content

The sum of Portland cement and other cementitious materials (CM) as well as the water-cement ratio (W/CM) shall be specified as following:

- $CM \leq 29.6$ lb/ft^3 [ordinary concrete]
  ≤ 37 lb/ft^3 [high performance concrete (HPC)]
- $W/CM \leq 0.45$

2.1.3. Coefficient of Thermal Expansion

For more precise data, the coefficient of thermal expansion (α) should be determined by laboratory tests. Other else, it may be taken as:

- $\alpha = 10.8\text{x}10^{-6}/°\text{C}$ [normal-weight concrete]
  $= 9.0\text{x}10^{-6}/°\text{C}$ [lightweight concrete]

2.1.4. Modulus of Elasticity

In the absence of measured data, the modulus of elasticity (E_c) for normal-weight concrete with design compressive strengths (f_c') up to 15.0 ksi and lightweight concrete with up to 10.0 ksi, with unit weight (Υ_c) between 0.090 and 0.155 kip/ft^3, may be taken as:

- $E_c = 12000K_1.{\Upsilon_c}^{2.0}.{f_c'}^{0.33}$ [normal-weight and lightweight concrete]
  $= 2500{f_c'}^{0.33}$ [normal-weight concrete with Υ_c = 0.145 kip/ft^3]

For normal-weight concrete with (Υ_c) = 0.145 kip/ft^3 (f_c') up to 10.0 ksi, (E_c) can be taken as:

- $E_c = 33000K_1.{\Upsilon_c}^{1.5}.\sqrt{f_c'}$
  $= 1820\sqrt{f_c'}$

where:

K_1: correction factor for aggregate source; taken as 1.0 in absent of physical test.

Υ_c: unit weight of concrete (kip/ft^3).

f_c': compressive strength of concrete (ksi).

2.1.5. Poisson's Ratio

Unless determined by physical tests, Poisson's ratio (ν) may be assumed as 0.2 for normal-weight concrete with (f_c') up to 15.0 ksi and lightweight concrete with up to 10.0 ksi. While for components expected to be subject to cracking, the effect of (ν) may be neglected.

2.1.6. Modulus of Rupture

Unless determined by physical tests, the modulus of rupture (f_r) for normal-weight concrete with specified (f_c') up to 15.0 ksi and lightweight concrete with up to 10.0 ksi, may be taken as:

- $f_r = 0.24\lambda.\sqrt{f_c'}$

where:

λ: concrete density modification factor; taken as 1.0 for normal-weight concrete.

2.1.7. Tensile Strength

For normal-weight concrete with design (f_c') up to 10.0 ksi, the direct tensile strength (f_t) may be estimated as:

- $f_t = 0.23\sqrt{f_c'}$

2.1.8. Concrete Density Modification Factor

The concrete density modification factor (λ) shall be determined with respect to the concrete splitting tensile strength (f_{ct}) as:

- $\lambda \geq 0.75$ [lower limit]
  $= 4.7 f_{ct}/\sqrt{f_c'} \leq 1.0$ [f_{ct} is specified]
  $= 7.5\gamma_c \leq 1.0$ [f_{ct} is not specified]
  $= 1.0$ [normal-weight concrete]

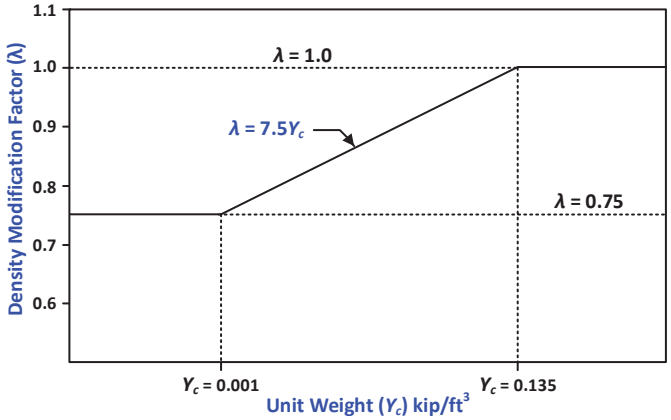

Figure 2.1: Illustration of Concrete Density Modification Factor as a Function of Unit Weight [AASHTO LRFD Figure C5.5.4.2-1]

2.2. Reinforcing Steel

2.2.1. Yield Strength

The reinforcing steel must be deformed and with yield strength (f_y):

- $75.0 \leq f_y \leq 100.0$ ksi [design purposes]

Plain steel bars or plain wire may be used for spirals, hoops and wire fabric. Bars with yield strengths (f_y) less than 60.0 ksi shall be used only with the approval of the owner.

2.2.2. Modulus of Elasticity

The modulus of elasticity (E_s) for reinforcing steel shall be assumed as:

- $E_s = 29000$ ksi [$f_y \leq 100.0$ ksi]

2.3. Prestressing Steel

The prestressing steel properties must follow one of the:

- Uncoated, stress-relieved or low-relaxation, seven-wire strand.
- Uncoated plain or deformed, high-strength bars.

2.3.1. Yield Strength

The yield strength of the prestressing steel (f_{py}) as related to its tensile strength (f_{pu}) is specified in Table below:

Table 2.1: Properties of Prestressing Strand and Bar [AASHTO LRFD Table 5.4.4.1-1]

Material	Grade or Type	Diameter $(\emptyset)$ in.	Tensile Strength (f_{pu}) ksi	Yield Strength (f_{py}) ksi
Strand	Grade 270 ksi	0.375 - 0.6	270	$0.90f_{pu}$
Bar	Type 1, Plain	0.75 - 1.375	150	$0.85f_{pu}$
	Type 2, Deformed	0.625 - 2.5	150	$0.80f_{pu}$

2.3.2. Modulus of Elasticity

If more precise data are not available, the modulus of elasticity for prestressing (E_{ps}) steels, may be taken as:

- $E_{ps} = 28500$ ksi [strands]
  $= 30000$ ksi [bars]