TECH-LINE

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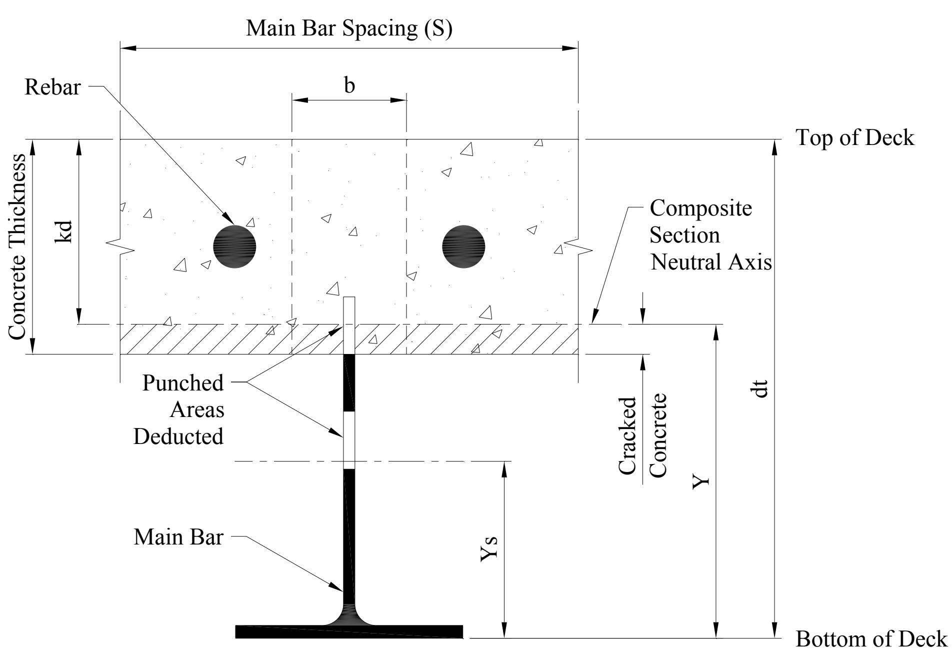
Computation of Composite Section Properties

Design of grid reinforced concrete decks (partially and fully filled) and Exodermic® decks in accordance with the provisions set forth in AASHTO LRFD Bridge Design Specifications, Section 4.6.2.1.8 begins with the determination of the flexural rigidity composite section properties in both the main bar (strong) direction, D_x, and perpendicular to the main bar (weak) direction, D_y, where $D_x = EI_x$ and $D_y = EI_y$. Converting an equivalent area of concrete to steel using the transformed area method, and assuming the concrete is cracked, the moment of inertia of the composite section (I) can be determined. Since concrete is converted to steel, the modulus of elasticity of steel (E = 29,000 ksi) is multiplied by the moment of inertia to determine D_x and D_y.

Using the figure below and the following variables, the effective depth of uncracked concrete in positive bending can be determined:

- kd = Effective depth of uncracked concrete = distance from top of deck to the composite section neutral axis
- S = Main bar spacing
- n = modular ratio = E_s/E_c (E_c in accordance with Section 5.4.2.4)
- b = S/n = The transformed width of the concrete section per main bar spacing
- dt = Total thickness of the composite section after a sacrificial element (usually 1/2") has been deducted
- As = Total area of all steel contributing to the analysis section (punched areas deducted) per main bar spacing
- Y_s = Centroid of all steel contributing to the analysis section
- Y = Location of the composite section neutral axis from the bottom of deck = (dt – kd)



Exodermic Deck Section

Since the area of steel and the steel neutral axis are known values, calculation of 'kd' can be derived by solving for the neutral axis of the composite section substituting the area of transformed concrete as (b)(kd) and its centroid as (kd)/2

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taken from the top of the deck section. Algebraic manipulation yields the following equation to find the neutral axis of the composite section in positive bending:

$$kd = \frac{-A_s + \sqrt{(A_s)^2 + 2bA_s(dt - Y_s)}}{b}$$

For fully filled grid reinforced concrete deck sections, this equation directly finds the positive bending neutral axis for the composite section by subtracting (dt – kd). For non-fully filled sections (Exodermic or partially filled grid reinforced concrete decks), 'kd' cannot exceed the total concrete thickness available. If the calculated value of 'kd' exceeds the actual concrete thickness, then the total thickness of concrete is considered uncracked and the neutral axis of the composite section is still found by subtracting the calculated value of 'kd' from the deck thickness 'dt.'

By redefining the location of the neutral axis of the concrete taken from the bottom of the deck, a similar equation can be derived to find the neutral axis of the composite section in negative bending for only fully filled grid reinforced concrete sections where the uncracked concrete is below the composite neutral axis yielding:

$$kd = \frac{-A_s + \sqrt{(A_s)^2 + 2bA_sY_s}}{b}$$

The complete derivation of these equations is available from the BGFMA upon request.

After the area of uncracked concrete has been determined, the composite section moment of inertia (I) can be found by summing the moment of inertia of the parts (steel and concrete) where 'd' is the distance from the composite section neutral axis to the centroid of the component (steel or concrete).

$$I = (A_s)(d_s^2) + I_s + (A_c)(d_c^2) + I_c$$

The moment of inertia obtained for the composite section is based on the main bar spacing in inches. To express the moment of inertia on a "per foot" basis, simply multiply the result by (12/S). Section moduli for selected locations can be found by dividing the moment of inertia (I) by the distance (c) from the composite neutral axis to the location of interest. The distance (c) is positive or negative and the established sign convention will determine which sign represents fibers in tension or compression. Section moduli for certain locations are calculated to verify capacity of the composite section or determination of fatigue resistance. Some of the most common locations are shown below, but some locations are not applicable to all grid types. Section moduli for concrete locations need to be multiplied by the modular ratio (n) to convert back from the transformed calculations and properly check capacity and stress for appropriate material properties.

Positive Bending Locations
- ✓ Top of Concrete
- ✓ Centroid of Rebar
- ✓ Top of Main Bar
- ✓ Top of Supplemental Bar
- ✓ Top of Cross Bar
- ✓ Top of Cross Bar Punch
- ✓ Bottom of Cross Bar
- ✓ Bottom of Main Bar

Negative Bending Locations
- ✓ Centroid of Rebar
- ✓ Top of Main Bar
- ✓ Top of Supplemental Bar
- ✓ Top of Cross Bar
- ✓ Top of Cross Bar Punch
- ✓ Bottom of Cross Bar
- ✓ Bottom of Main Bar
- ✓ Bottom of Concrete (Fully Filled Sections Only)