6.13 SECTION PROPERTIES OF STEEL-CONCRETE COMPOSITE GIRDER SECTIONS

6.13.1 GENERAL

This memo provides general calculation procedures for elastic section properties of steel-concrete composite girder sections. The elastic section properties are mainly used to calculate the stresses of steel girder sections in applicable limit states as specified in AASHTO-CA BDS-8 (AASHTO, 2017; Caltrans, 2019). The procedures for I-sections are illustrated and also applicable for other section shapes.

6.13.2 BASIC ASSUMPTIONS

The following assumptions should be used in the section property calculations for steel-concrete composite sections:

- For short-term composite sections, the concrete deck area shall be transformed by using the short-term modular ratio, n (Article 6.10.1.1.1b).

$$n = \frac{E}{E_c} \qquad \text{(AASHTO 6.10.1.1.1b-1)}$$

where:

E = modulus of elasticity of steel (ksi)

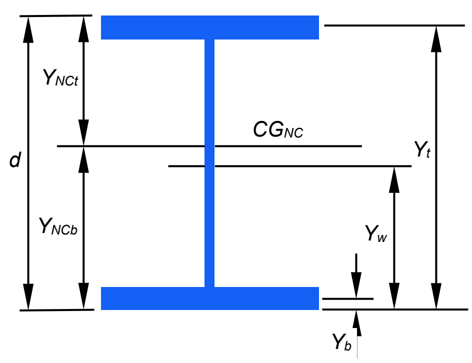
E_c = modulus of elasticity of concrete (ksi)

- For long-term composite sections, the concrete deck area shall be transformed by using the long-term modular ratio, $3n$ (Article 6.10.1.1.1b).
- For composite sections in negative flexure, both short-term and long-term section properties shall consist of the steel section and the longitudinal reinforcement within the effective width of the concrete deck, except as specified otherwise in Article 6.6.1.2.1, Article 6.10.1.1.1d, or Article 6.10.4.2.1.
- For composite sections, the concrete haunch area may be ignored.

6.13.3 NONCOMPOSITE SECTION

Table 6.13.3-1 Properties of Noncomposite Section

Component	A_i (in.^{2})	Y_i (in.)	A_iY_i (in.^{3})	Y_i - Y_{NCb} (in.)	$A_i(Y_i – Y_{NCb})^2$ (in.^{4})	I_i (in.^{4})
Top flange						
Web						
Bottom flange						
Σ						



$$Y_{NCb} = \frac{\sum A_i Y_i}{\sum A_i}$$

$$Y_{NCt} = d - Y_{NCb}$$

$$I_{NC} = \sum I_i + \sum A_i \left(Y_i - Y_{NCb}\right)^2$$

$$S_{NCb} = \frac{I_{NC}}{Y_{NCb}}$$

$$S_{NCt} = \frac{I_{NC}}{Y_{NCt}}$$

where:

A_i = area of component *i* (in.^{2})

CG = centroid of gravity

CG_{NC} = centroid of gravity axis of the noncomposite section

d = total depth of the steel section (in.)

I_{NC} = moment inertia of the noncomposite section (in.^{4})

I_i = moment inertia of component section *i* about its CG (in.^{4})

Y_b = distance between the bottom flange CG and the extreme fiber of the bottom flange (in.)

Y_i = distance between the CG of component *i* and the extreme fiber of the bottom flange (in.)

Y_{NCb} = distance between the extreme fiber of the bottom flange and the CG of noncomposite steel sections (in.)

Y_{NCt} = distance between the extreme fiber of the top flange and the CG of noncomposite steel sections (in.)

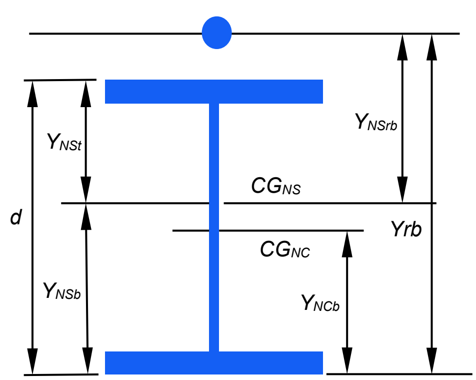
Y_t = distance between the top flange CG and the extreme fiber of the bottom flange (in.)

Y_w	=	distance between the bottom flange CG and the extreme fiber of the bottom flange (in.)
S_{NCb}	=	elastic section modulus for the bottom flange of the steel section alone (in.^{3})
S_{NCt}	=	elastic section modulus for the top flange of the steel section alone (in.^{3})

6.13.4 STEEL SECTION AND LONGITUDINAL REINFORCEMENT

Table 6.13.4-1 Properties of Steel Section and longitudinal Reinforcement

Component	A_i (in.^{2})	Y_i (in.)	A_iY_i (in.^{3})	Y_i - Y_{NSb} (in.)	$A_i(Y_i - Y_{NSb})^2$ (in.^{4})	I_i (in.^{4})
Top Reinforcement						
Steel section						
Σ						



$$Y_{NSb} = \frac{\sum A_i Y_i}{\sum A_i}$$

$$Y_{NSrb} = Y_{rb} - Y_{NSb}$$

$$Y_{NSt} = d - Y_{NSb}$$

$$I_{NS} = \sum I_i + \sum A_i \left(Y_i - Y_{NSb}\right)^2$$

$$S_{NSb} = \frac{I_{NS}}{Y_{NSb}}$$

$$S_{NSt} = \frac{I_{NS}}{Y_{NSt}}$$

$$S_{NSrb} = \frac{I_{NS}}{Y_{NSrb}}$$

where:

CG_{NS}	=	centroid of gravity axis of the combined steel section and the longitudinal reinforcement.
Y_{NSb}	=	distance between the extreme fiber of the bottom flange and the CG of the combined steel section and the longitudinal reinforcement (in.)
Y_{NSrb}	=	distance between the CG of the longitudinal reinforcement and the CG of the combined steel section and the longitudinal reinforcement (in.)
Y_{NSt}	=	distance between the extreme fiber of the top flange and the CG of

the combined steel section and the longitudinal reinforcement (in.)

Y_{rb} = distance between the CG of the longitudinal reinforcement and the extreme fiber of the bottom flange (in.)

I_{NS} = moment inertia of the combined steel section and the longitudinal reinforcement (in.^{4})

S_{NSb} = elastic section modulus for the bottom flange of the combined steel section and the longitudinal reinforcement (in.^{3})

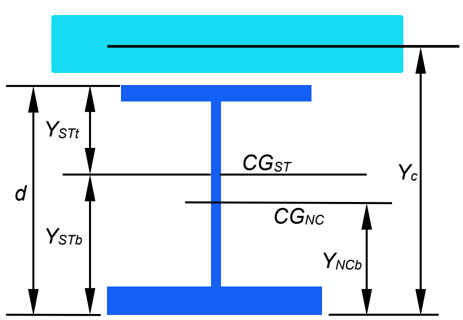
S_{NSrb} = elastic section modulus for the longitudinal reinforcement of the combined steel section and the longitudinal reinforcement (in.^{3})

S_{NSt} = elastic section modulus for the top flange of the combined steel section and the longitudinal reinforcement (in.^{3})

6.13.5 SHORT-TERM COMPOSITE SECTION

Table 6.13.5-1 Properties of Short-term Composite Section (*n*)

Component	A_i (in.^{2})	Y_i (in.)	A_iY_i (in.^{3})	Y_i - Y_{STb} (in.)	$A_i(Y_i - Y_{STb})^2$ (in.^{4})	I_i (in.^{4})
Steel section						
Concrete Slab $b_{eff}/n \times t_s$						
Σ						



$$Y_{STb} = \frac{\sum A_i Y_i}{\sum A_i}$$

$$Y_{STt} = d - Y_{STb}$$

$$I_{ST} = \sum I_i + \sum A_i \left(Y_i - Y_{STb}\right)^2$$

$$S_{STb} = \frac{I_{ST}}{Y_{STb}}$$

$$S_{STt} = \frac{I_{ST}}{Y_{STt}}$$

where:

CG_{ST} = centroid of gravity axis of the short-term composite section

b_{eff} = effective flange width (in.)

t_s = thickness of a concrete deck (in.)

Y_c = distance between the CG of the concrete deck slab and the extreme fiber of the bottom flange (in.)

Y_{STb} = distance between the extreme fiber of the bottom flange and the CG of the short-term composite section (in.)

Y_{STt} = distance between the extreme fiber of the top flange and the CG of the short-term composite section (in.)

I_{ST} = moment inertia of the short-term composite section (in.^{4})

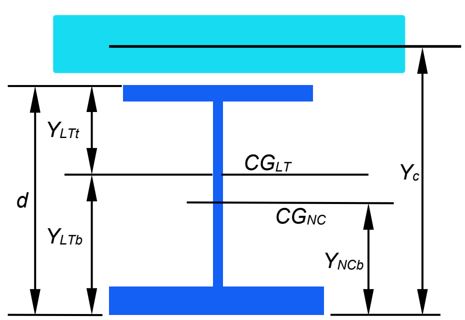
S_{STb} = elastic section modulus for the bottom flange of the short-term composite section (in.^{3})

S_{STt} = elastic section modulus for the top flange of the short-term composite section (in.^{3})

6.13.6 LONG-TERM COMPOSITE SECTION

Table 6.13.6-1 Properties of Long-term Composite Section (3*n*)

Component	A_i (in.^{2})	Y_i (in.)	A_iY_i (in.^{3})	Y_i - Y_{LTb} (in.)	$A_i(Y_i - Y_{LTb})^2$ (in.^{4})	I_i (in.^{4})
Steel section						
Concrete Slab $b_{eff}/3n \times t_s$						
Σ						



$$y_{LTb} = \frac{\sum A_i Y_i}{\sum A_i}$$

$$Y_{LTt} = d - Y_{LTb}$$

$$I_{LT} = \sum I_i + \sum A_i \left(Y_i - Y_{LTb}\right)^2$$

$$S_{LTb} = \frac{I_{LT}}{Y_{LTb}}$$

$$S_{LTt} = \frac{I_{LT}}{Y_{LTt}}$$

where:

CG_{LT} = centroid of gravity axis of the long-term composite section

Y_{LTb} = distance between the extreme fiber of the bottom flange and the CG of the long-term composite section (in.)

Y_{LTt} = distance between the extreme fiber of the top flange and the CG of the long-term composite section (in.)

I_{LT} = moment inertia of the long-term composite section (in.^{4})

S_{LTb} = elastic section modulus for the bottom flange of the long-term composite section (in.^{3})

S_{LTt} = elastic section modulus for the top flange of the long-term composite section (in.^{3})

6.13.7 REFERENCES

1. AASHTO. (2017). *AASHTO LRFD Bridge Design Specifications*, 8th Edition, American Association of State Highway and Transportation Officials, Washington DC.

2. Caltrans. (2019). *California Amendments to AASHTO LRFD Bridge Design Specifications, 8th Edition*, California Department of Transportation, Sacramento, CA.