3. Calculation sheet (TG1)

3. Check Composite Section > 3.3 Flexure Strength

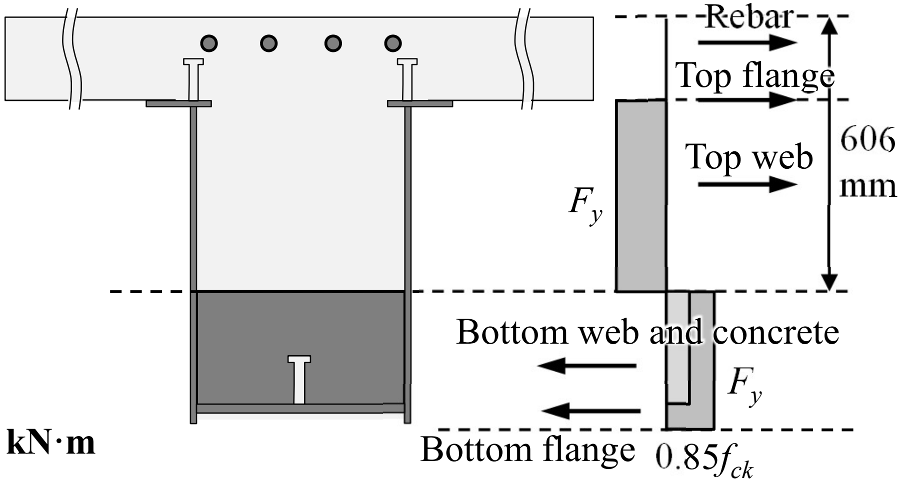
(2) Negative moment

Load transfer between steel beam and concrete slab

- **Tensile yielding of the slab reinforcement**

  $V_{sr} = F_{yr}A_{sr}$ **= 600 × 1962 = 1177 kN (minimum value)**
- Shear strength of steel headed stud $V_{stud} = V_{q,neg} = 1870$ kN
- Plastic neutral axis $C_{y,pl} = 623$ mm
- **The nominal plastic moment strength in negative bending** $M_{n,neg}$ **= 2015 kN·m**

  ➔ $\Phi M_{n,neg}$ **= 0.9×2015 = 1813 kN·m >** $M_{u,neg}$ **= 1425 kN·m … O.K.**



AISC 360-16 > I. Design of composite members > I3. Flexure > 2d. Load transfer between steel beam and concrete slab

(1. Load transfer for positive flexural strength) In continuous composite beams where longitudinal reinforcing steel in the negative moment regions is considered to act compositely with the steel beam, the total horizontal shear between the point of the maximum negative moment and the point of zero moment shall be determined as the lower value in accordance with the following limit states.

(comment) When and adequately braced compact steel section and adequately developed longitudinal reinforcing bars act compositely in the negative moment region, the nominal flexural strength is determined from the plastic stress distribution. Loads applied to a continuous composite beam with steel anchors throughout its length, after the slab is cracked in the negative moment region, are resisted in that region by the steel section and by properly anchored longitudinal slab reinforcement.

3. Calculation sheet (TG1)

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3. Check Composite Section > 3.4 Shear Strength

- The required shear strength $V_u = 610$ kN
- The nominal shear strength $\Phi V_n = 0.9 \times 0.6F_y\ (2ht_w) = 0.9\times0.6\times355\times10638 = 2039$ kN $> V_u = 610$ kN **… O.K.**

  where, A_w = the overall depth times the web thickness, (mm^2)

AISC 360-16 > I. Design of composite members > I4. Shear

(1. Filled and encased composite members) The design shear strength, $\Phi_v V_n$, shall be determined based on one of the following:

(a) The available shear strength of the steel section alone as specified in Chapter G.

(comment) ~ Though it would be logical to suggest provisions where both the contributions of the steel section and reinforced concrete are superimposed, there is insufficient research available to justify such a combination.

(2. Composite beams with formed steel deck) The available shear strength of composite beams with steel headed stud or steel channel anchors shall be determined based upon the properties of the steel section alone in accordance with chapter G.

(comment) A conservative approach to shear provisions for composite beams with steel headed stud or steel channel anchors is adopted by assigning all shear to the steel section in accordance with Chapter G. This method neglects any concrete contribution and serves to simplify design.

3. Calculation sheet (TG1)

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3. Check Composite Section > 3.5 Deflection (short-term)

- Boundary condition : Fix-Fix
- The equivalent moment of inertia, $I_{equiv} = I_s + \sqrt{\left(\sum Q_n / C_f\right)}\left(I_{tr} - I_s\right)$ = 335197 × 10^4 mm^4

  where,

  I_s = moment of inertia for the structural section (= I_x = 82808 × 10^4 mm^4)

  $\sum Q_n$ = sum of the nominal strengths of steel anchors between the point of maximum positive moment and the point of zero moment to either side (= $V_{q,pos}$ = 2550 kN)

  C_f = compression force in concrete slab for fully composite beam (= tensile yielding of the steel section $V_{steel} = F_y A_s$ = 6170 kN)

  I_{tr} = moment of inertia for the fully composite uncracked transformed section (= 475402 mm^4; the ratio of E_c/E_s is multiplied by the term elastic modulus of concrete)

  - In the term I_{equiv}, boundary condition is assumed as a pin-pin condition for a conservative estimation.

AISC 360-16 > I. Design of composite members > I3. Flexure > 2. Composite beams with steel headed stud

(comment) When a composite beam is controlled by deflection, the design should limit the behavior of the beam to the elastic range under serviceability load combinations. ~ More recent studies indicate that the use of the equivalent moment of inertia, I_{equiv}, for deflection calculation results in a prediction of short-term deflections roughly equivalent to the statistical average average of the experimental tests reviewed. Previous editions of the Specification recommended an additional reduction factor 0.75 be applied to I_{equiv} to form an effective moment of inertia; however, <u>this approach has been removed as its basis could not be substantiated</u>.

3. Calculation sheet (TG1)

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3. Check Composite Section > 3.5 Deflection (short-term)

- **Deflection** $\delta_{add} = \dfrac{(W_f + W_l) \times B_{ay}}{384 E_s I_{equiv}} \times L^4$ **= 2.3 mm**

  where,

  (Dead load) Superimposed load W_f = 5550 N/m^2

  Live load W_l = 15000 N/m^2

- **Total deflection δ_{comp}** with dead and live loads $W_d + W_s + W_f + W_l$,

  $\delta_{st} = \delta_{const} + \delta_{add}$ **= 3.1 + 2.3 = 5.4 mm < L/ 360 = 27.7 mm** **… O.K.**

Deflection δ_{const} during concrete curing (resisted by steel section)
⇩
Additional deflection δ_{add} after concrete curing (resisted by composite section)
⇩
Total deflection $\delta_{comp} = \delta_{const} + \delta_{add}$

AISC 360-16 > L. Design for serviceability > L2. Deflections

Deflections in structural members and structural systems shall be limited so as not to impair the serviceability of the structure.

(comment) ~ Historically, common deflection limits for horizontal members have been ***1/360 of the span for floors subjected to reduced live load*** *and 1/240 of the span for roof members.* ***Deflection of about 1/300 of the span (for cantilevers, 1/150 of the length) are visible and may lead to general architectural damage or cladding leakage****. Deflection greater than 1/200 of the span may impair operation of moveable components such as doors, windows and sliding partitions. ~ Load combinations for checking static deflections can be developed using first-order reliability analysis. Current static deflection guidelines for floor and roof systems are adequate for limiting superficial damage in most buildings. A combined load with an annual probability of being exceeded of 5% is appropriate in most instances. For* ***serviceability limit states*** *involving visually objectionable deformations, repairable cracking, or other damage to interior finishes, and* ***other short-term effects****, the suggested load combinations are:*

$$D + L$$

3. Calculation sheet (TG1)

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3. Check Composite Section > 3.5 Deflection (short-term)

IBC2015 > 16. Structural design > Section 1604 General design requirements > Table 1604.3 Deflection limits

CONSTRUCTION	L	S or W^{f}	$D + L^{d, g}$
Roof members:[e]			
Supporting plaster or stucco ceiling	$l/360$	$l/360$	$l/240$
Supporting nonplaster ceiling	$l/240$	$l/240$	$l/180$
Not supporting ceiling	$l/180$	$l/180$	$l/120$
Floor members	$l/360$	—	$l/240$

d. **The deflection limit for the *D* + *L* load combination only applies to the deflection due to the creep component of long-term dead load deflection plus the short-term live load deflection**.

3. Check Composite Section > 3.5 Deflection (long-term)

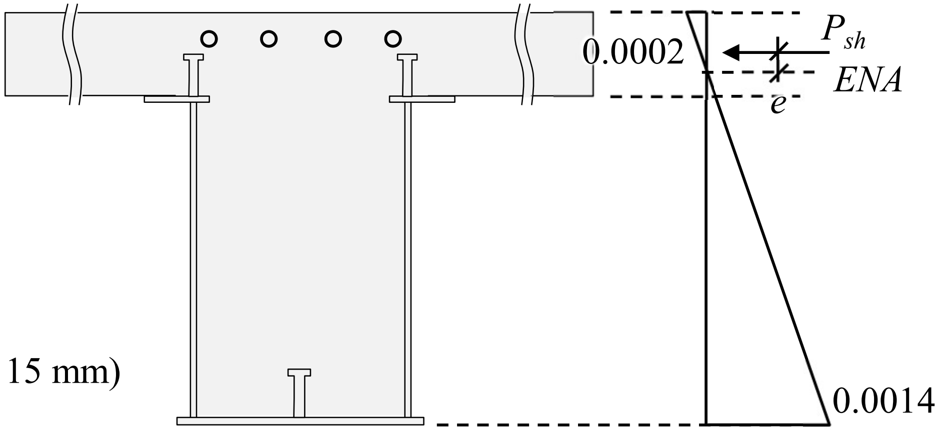
- The shrinkage strain, e_{sh}, may be taken as 0.0002.
- The shrinkage load $P_{sh} = e_{sh}E_cA_c = 0.0002 \times 27537 \times 600000 = 3304$ kN

AISC 360-16 > I. Design of composite members > I3. Flexure > 2. Composite beams with steel headed stud

(comment) ***Long-term deformations due to shrinkage and creep****: <u>There is no direct guidance</u> in the computation of long-tern deformations of composite beams due to creep and shrinkage. The long-term deformation due to shrinkage can be calculated with the simplified model, in which the effect of shrinkage is taken as an equivalent set of end moments given by the shrinkage force (long-term restrained shrinkage strain times modulus of concrete times effective area of concrete) times the eccentricity between the center of the slab and the elastic neutral axis. ~*

3. Calculation sheet (TG1)

3. Check Composite Section > 3.5 Deflection (long-term)



- The shrinkage strain, e_{sh}, may be taken as 0.0002.
- The shrinkage force $P_{sh} = e_{sh}E_cA_c = 0.0002 \times 27537 \times 600000 = 3304$ kN
- **The deflection due to shrinkage** $\delta_{lt} = \dfrac{P_{sh}eL^2}{8E_sI_x}$ **= 3.6 mm**

  where,

  e = eccentricity between the center of the slab and the elastic neutral axis (= 15 mm)

  I_x = moment of inertia of steel section (=82808×10^4 mm^4)
- $\boldsymbol{\delta_{st} + \delta_{lt}}$ **= 9.0 mm < $\boldsymbol{L}$/240 = 41 mm … O.K.**