Design Principles and Calculations - Interface Shear

Shear

Composite action between the section and the concrete slab exists because of the unique shear resistance developed along the interface between the two materials. This shear resistance, which has been called "bond" or "interface shear" is primarily the result of a "locking" or "clamping" action in the longitudinal direction between the concrete and the section when the composite joist is deflected under load. Another contributing factor to the shear resistance is the lateral compression stress or "poisson's effect" which results from slab continuity in the lateral direction. This continuity prevents lateral expansion from occuring as a result of longitudinal compression stresses and thus lateral compression stress results. However, this effect has been ignored in determining interface shear capacity which has been based on full scale testing of spandrel joists having only a 6 inch slab overhang on one side for its entire span length. A cross-section of a test specimen is illustrated in fig. 8.

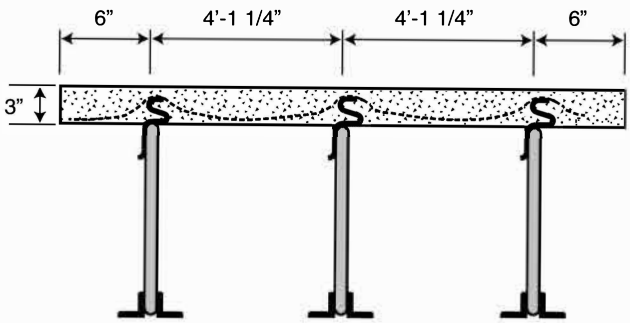


Fig. 8

It was decided to base the limiting interface shear value on this most critical condition as this could often occur in practice with large duct openings. Also, one would expect some additional shear resistance to occur due to some form of friction (or plain "bond") mechanism, however, **full scale tests have not shown any significant differences in results among specimens whose section were clean or painted.**

Shear Force

Shear resistance of the steel-concrete interface can be evaluated by either elastic or ultimate strength procedures; both methods have shown good correlation with the test results. The interface shear force resulting from superimposed loads on the composite joist may be computed, using the "elastic approach", by the well known equation:

$$q = \frac{VQ}{I_C} \quad \text{...} \quad (12)$$

Where q = *horizontal shear flow per mm of length (lb./in.)*

V = *vertical shear force at the section (lb.) due to superimposed loads*

Q = *statical moment of the effective concrete in compression (hatched area) about the elastic N.A. of the composite section (in.^{3})*

I_C = *moment of inertia of the composite joist (in.^{4})*

And $Q = \frac{b}{n}(Y_c - y/2)$ *and* $y = y_c$ *but* $\not> t$

Where b = *effective concrete flange width (in.) = lesser of L / 4 or joist spacing*

n = *modular ratio* $= E_s / E_c = 9.2$ *for* $f'_c = 3$ *ksi*

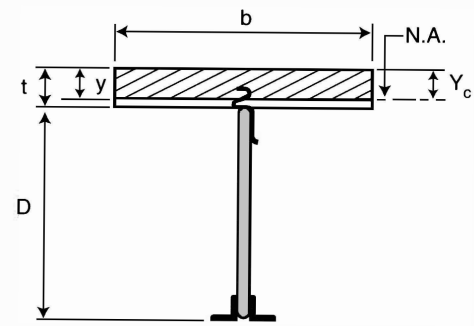
t = *slab thickness (in.)*

Y_c = *depth of N.A. from top of concrete slab*

y = Y_c *when N.A. lies within slab*

= *t when N.A. lies outside slab*

case 1: N.A. within slab ($y = Y_c$)



case 2: N.A. outside slab ($y = t$)

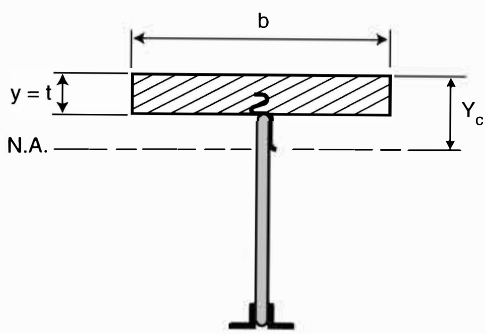


Fig. 9

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For a uniformly loaded joist, the average interface shear s, at ultimate load when calculated by ultimate strength principles, would be:

$$s = \frac{2T_u}{L} \quad \text{...} \quad (13)$$

and would represent the average shear force, per unit length, between the points of zero and maximum moment. Some modification to this formula would occur when the strain neutral axis at failure would be located within the section. As this modification is slight and would only occur with bottom chord areas greater that 1.84 sq. in., it is neglected.

Compare the elastic and ultimate approaches:

Since $M_u = T_u d_u$ equation (13) can be rewritten:

$$S = \frac{2M_u}{d_u L} \quad \text{...} \quad (14)$$

Also, for a uniformly distributed load,

$$M_u = \frac{V_u L}{4} \quad \text{...} \quad \mathbf{(15)}$$

Subscipts u, are added to equation (12) to **represent the** arbitrary "q" force at failure:

$$q_u = \frac{V_u Q}{I_c} \quad \text{...} \quad (16)$$

Combining (14) and (16) results in:

$$\frac{q_u}{s} = \frac{D_u L}{2M_u} \times \frac{V_u Q}{I_c} \quad \text{..} \quad (17)$$

and, substituting (15) into equation (17)

$$\frac{q_u}{s} = \frac{2QD_u}{I_c} \quad \text{..} \quad (18)$$

The value I_c/Qd_u has been calculated for the various Hambro composite joist sizes, is a constant, and = 1.1. Substituting this in (18),

$$\frac{q_u}{s} = 1.82$$

This verifies that q and s are closely related and that the interface shear force does, in fact, vary from a maximum at zero moment (maximum vertical shear) to a minimum at maximum moment (zero vertical shear). The more recent full scale testings programs have consistently established a failure value for $q_u = 1{,}300\ lb./in.$ and using a safety factor of 1.85, the safe limiting interface shear, $q = 700\ lb./in.$ This is sometimes converted to "bond stress" $u = q$ / *embedded* perimeter $= q / 7.0$. Hence, the safe limiting "bond stress" $u = 700 / 7 = 100\ psi$.

As a further safety factor, the bond stresses are usually limited to a value less than $90\ psi$.