Stay out of the Courthouse Zone

By **Wayne W. Walker, P.E. , F.ACI** and **Jerry A. Holland, P.E., F.ACI**

The transition from a slab-on-ground unreinforced/uncracked behavior to a reinforced/cracked behavior is not well discussed in the industry literature, and the absence of this information has caused confusion in the industry. This issue is further complicated if the slab surface is exposed to view and the owner is sensitive to cracking and/or crack widths greater than expected. This confusion between unreinforced/uncracked and reinforced/cracked slab behavior, with the associated expectations of no cracking or very narrow cracks, has caused a number of court cases for slab designers. We have seen these court cases often and have been calling the "zone" between unreinforced/uncracked and reinforced/cracked (see Fig. 1 below) slabs the **"Courthouse Zone"** because the owners often go to court to get judgments from the slab designers.

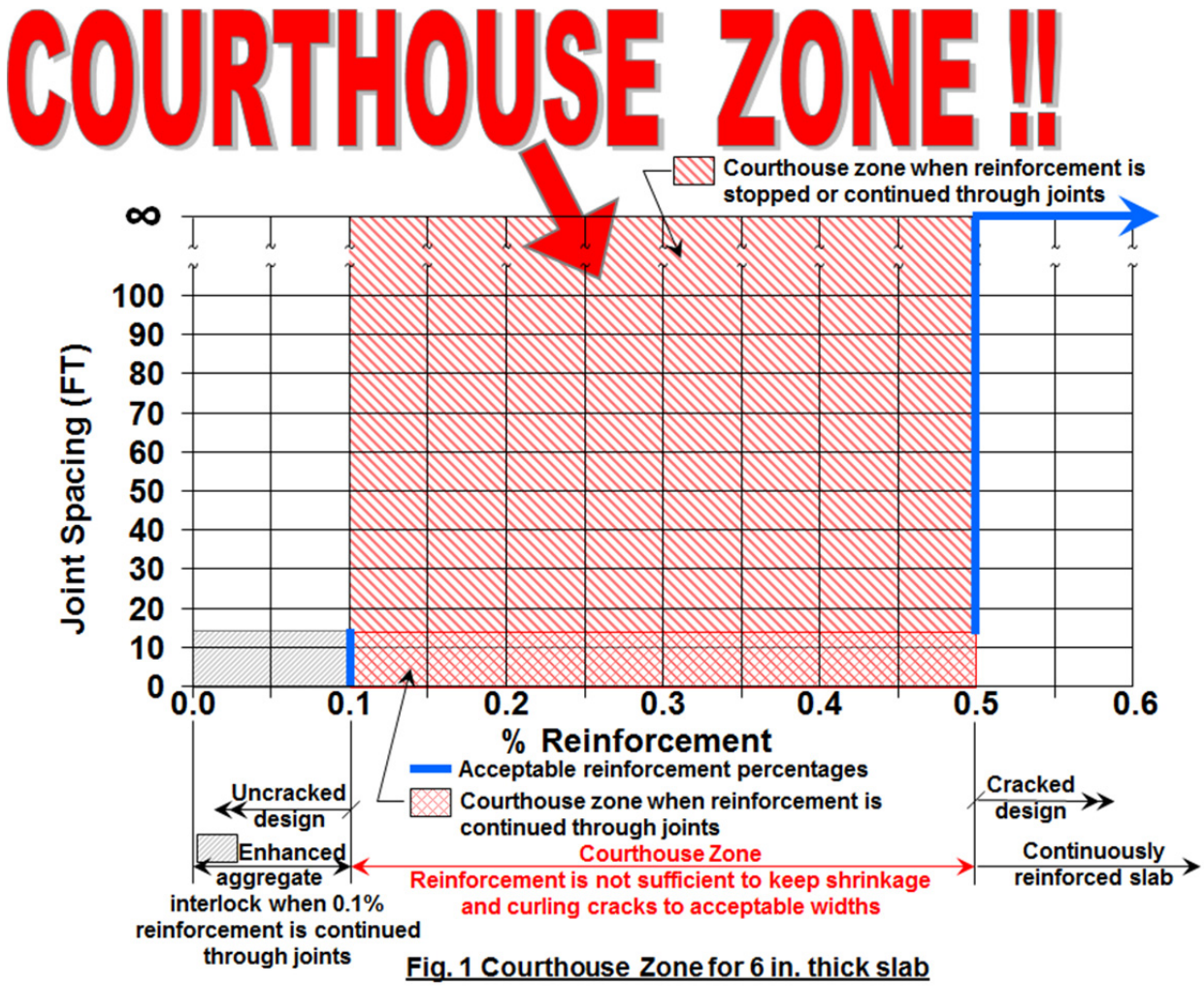

Fig. 1 Courthouse Zone for 6 in. thick slab

The Courthouse Zone reinforcement ratios are between 0.1% and 0.5%. Utilizing 0.1% of deformed reinforcement through the joints allows joints to activate (activation is when cracks form under the joint locations to help minimize random, out-of-joint cracking due to linear shrinkage/thermal movement and curling stresses) but maintains joint stability (a stable joint is when both sides of the joint are nearly equal in deflection when a vehicle wheel load travels across the joint). The slab is designed and jointed the same as an unreinforced uncracked section, and the reinforcement is only used for joint stability.

ACI 360R-10 (Ref. 1, P. 28) refers to this design as “enhanced aggregate interlock” because the small amount of reinforcement maintains the aggregate interlock.

To eliminate the contraction joints, a minimum of 0.5% continuous amount of deformed reinforcement in the upper part of the slab can be used to control the crack widths (Ref. 1, P. 34). As per ACI 360R-10 Section 8.3 – Reinforced for crack-width control only (Ref. 1, P. 34), the slab is designed as uncracked and unreinforced with the 0.5% of reinforcement used only to control the crack widths. Additionally, because such a slab will have tight cracks, the aesthetics of these cracks and crack widths needs to be discussed with the owner to ensure the performance of the slab will meet the owner’s expectations (Ref. 1, P. 6). The 0.5% is a minimum amount; ACI 224R-01 (Ref. 2, P. 16) recommends a higher amount and states “The minimum-reinforcement percentage, which is between 0.18 and 0.20%, does not normally control cracks to within generally acceptable design limits. To control cracks to a more acceptable level, the percentage requirement needs to exceed about 0.60%.”

When reinforcement ratios between 0.1% to 0.5% are used, problematic issues often occur because the reinforcement amounts are too high to allow joint activation to occur but are not sufficient to control crack widths to an acceptable level for most owners. Therefore, random cracking with insufficient reinforcement to control the crack widths will often occur, which have resulted in court cases for slab designers.

How do slab designers get into the Courthouse Zone?

There are typically three design methods that we see most often that put slab designers into the Courthouse Zone. The first method is the use of the subgrade drag equation. The second is the use of ACI 318 (Ref. 4) minimum reinforcement amounts. The third is to use a reinforcement size and spacing for which the designer has done no calculations or has no other justifications but just “feels good”.

The subgrade drag equation was in the ACI 360R-92 document but was later removed when the ACI 360R-06 document was published because the use of the equation was producing problematic designs. The subgrade drag equation produces problematic slab designs because the equation did not address the much higher curling stresses that occur when the joints are extended. Figure 2 below shows the equation for the tension stress in the slab due to only the subgrade drag.

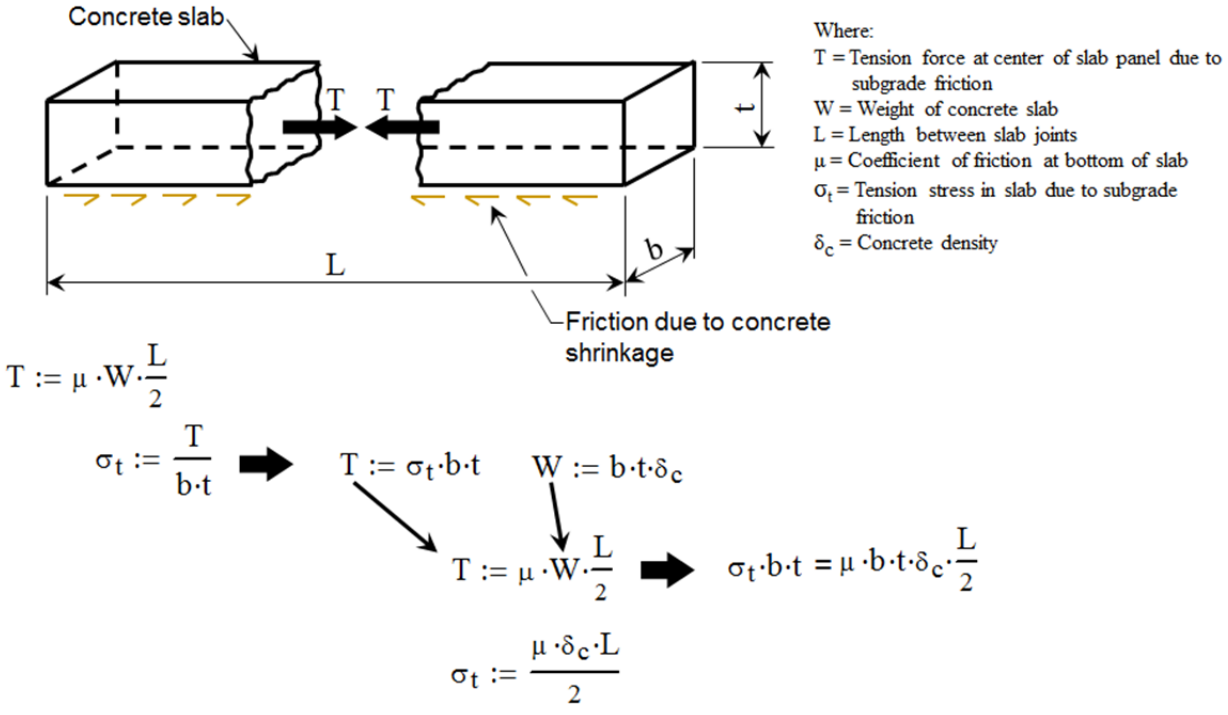

Fig. 2 Subgrade drag stress

However, the curling stresses increase non-linearly at rapid rate as the joint spacing increases (Ref. 1, P. 50, & Ref. 3). In Fig. 3 below, we used the curling stress data from Ref. 3 for a 6 in. thick slab and compared those stresses to the subgrade drag stresses. As can be seen in Fig. 3, there is a significant stress differential, which is why the subgrade drag equation was removed from the ACI 360 document.

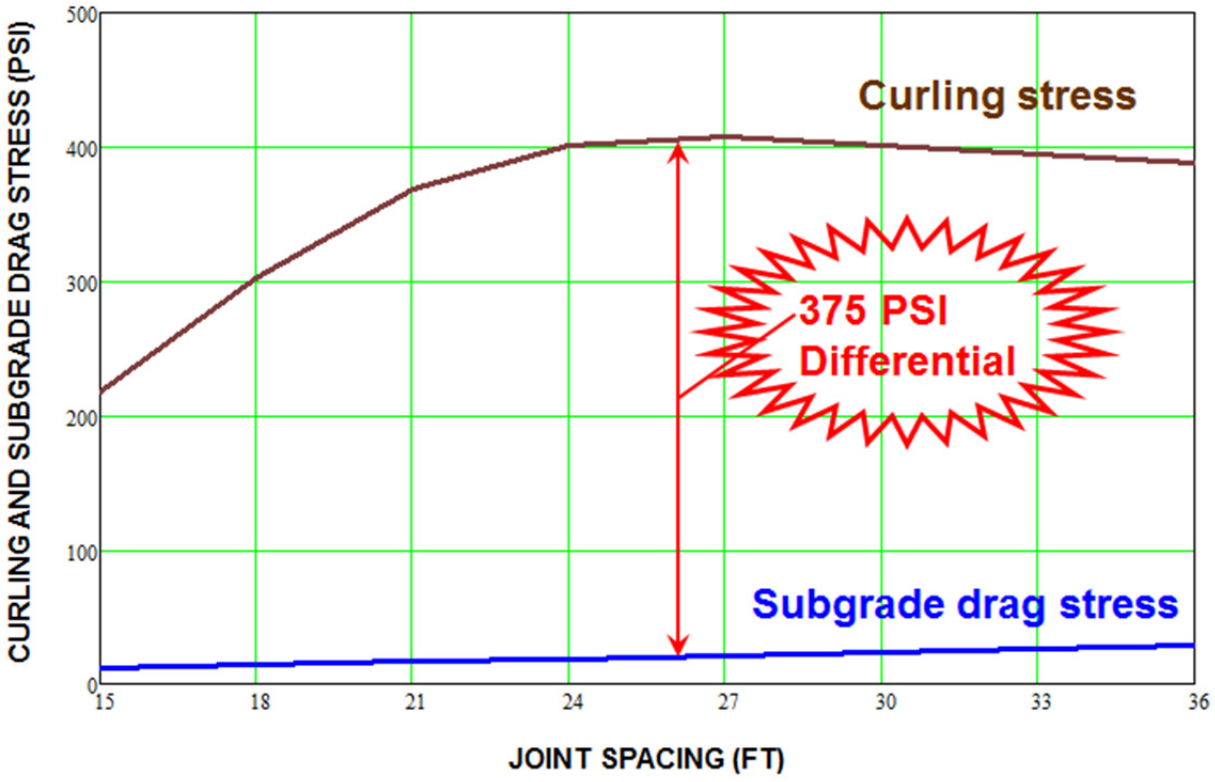

Fig. 3 Curling and subgrade drag stress

The second common way a slab designer gets into the Courthouse Zone is using ACI 318's (Ref. 4) minimum reinforcement ratios; for f_y=60,000 psi the reinforcement ratio is 0.18%. The first design consideration for the slab designer is to determine if the slab is actually required to meet ACI 318. As stated in ACI 318 (Ref. 4, Section 1.4.7) "This Code does not apply to design and construction of slabs-on-ground, unless the slab transmits vertical loads or lateral forces from other portions of the structure to the soil." If the slab is not required to meet ACI 318, then the 0.18% reinforcement is not required. However, if the slab is required to meet ACI 318, then exceptions permitted by ACI 318, along with analytical techniques, can be used to keep the slab out of the Courthouse Zone.

The third way is when the slab designer is used to having reinforcing in all concrete elements and does not like the idea of an unreinforced slab-on-ground. Thus, the designer does no calculations but uses a rebar size and spacing that "feels good" and calls for it to run through the contraction joints. For example, we often see unacceptable cracking when the slab designer calls for a 6" slab with #4 rebar at 18" (or 12") o.c., which is in the Courthouse Zone. The slab designer often uses this design for a covered slab and has had success but then uses this same design for an exposed slab or later the cover is not used; in these cases the owner is dissatisfied with the unacceptable cracking exposed to view.

Conclusion

This paper provides information needed to explain the transitional slab behavior between unreinforced/uncracked versus reinforced/cracked concrete and how this lack of understanding and industry information has resulted in court cases for slab designers. Additionally, we showed that the subgrade drag equation, which had been in published information for a long time but no longer, has been causing problematic designs and should not be used. It is our hope that the information in this paper will help keep slab designers from being involved in court cases by staying out of the Courthouse Zone.

References:

1. American Concrete Institute (ACI) 360R-10 "Guide to Design of Slabs-on-Ground".
2. American Concrete Institute (ACI) 224R-01 “Control of Cracking in Concrete Structures”.
3. Walker, W. W., and Holland, J. A., 1999, “The First Commandment for Floor Slabs: Thou Shalt Not Curl Nor Crack… (Hopefully),” Concrete International, V. 21, No. 1, Jan., pp. 47-53.
4. American Concrete Institute (ACI) 318-14 "Building Code Requirements for Structural Concrete".

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