Reinforcing steel in slabs on grade

Use welded-wire fabric or rebar to control cracking and increase strength

When properly placed, rebar and welded wire fabric (WWF) in a slab on grade provide many advantages, some of which can be achieved in no other way. Reinforcing steel can:

**Control cracking.** Steel reinforcement within a slab holds cracks caused by drying shrinkage, temperature changes, or applied loadings, tightly closed. Keeping cracks closed preserves aggregate interlock and prevents faulting.

**Increase joint spacing.** Increases in control joint spacing when rebar or WWF is used can range from slight to substantial, depending on the design and intended performance of the slab.

**Span soft spots in the subgrade.** Soft spots in the subbase or subgrade can occur due to moisture, last-minute excavation for a drain, or similar situations. A reinforced slab on grade will span soft spots by providing enough structural capacity to bridge the weaker supporting areas.

**Restrain curling.** Reinforcing the upper half of a slab on grade restrains drying shrinkage, thus reducing curling. The closer the steel is to the top of the slab and the more steel used, the more curling will be reduced.

**Add structural strength after cracking.** When overloading occurs and the cracking moment limit of the slab has been exceeded, structural cracks can occur. The steel acts as structural reinforcement and provides moment capacity.

**Add impact resistance.** Rebar or WWF reduces strain to slabs on grade caused by impact loading. This helps prevent premature cracking.

**Reduce slab and joint maintenance.** By keeping cracks tight and reducing curling, reinforcing steel substantially reduces crack and joint maintenance.

Eliminate the need for contraction joints. When using reinforcement, construction joints can be spaced according to the planned size of a day’s pour. This could be a strip or a large rectangular panel. No contraction joints are needed because the distributed reinforcement allows acceptable hairline cracking due to drying shrinkage.

**Work with shrinkage-compensating concrete.** Shrinkage-compensating concrete demands the use of reinforcing steel so the concrete can expand and contract as planned.

Eliminate the need for thickened slabs at joints and edges. Reinforcing steel gives slabs on grade adequate strength at the joints. This allows the designer to maintain a constant slab depth without thickening at joints or edges. Thickened edges add more restraint to drying shrinkage and cost more.

**Add confidence.** The presence of rebar or WWF in a slab on grade increases confidence in the ability of the slab to perform adequately, even though doubt may exist concerning the subgrade’s support capability.
General design process

Though many details must be included in the design of a slab on grade, three important components are slab thickness, reinforcement requirements, and joint spacing.

The designer determines the required slab thickness after determining the controlling loads, the appropriate safety factor, and the subgrade modulus appropriate for the base and fill materials. References at the end of the article discuss thickness determination in more detail.

The next step is to select the reinforcing steel area (bar or wire size and their spacing) along with an acceptable joint spacing. Both of these involve knowing the slab’s performance requirements, such as lanes of traffic, aisle and storage rack placement, flatness requirements, joint details, and dowel recommendations.

WWF or rebar are then selected for crack control, using the subgrade drag equation, or for structural strength, using common reinforced concrete design procedures.

Regardless of the intended purpose of the reinforcement, it must be structurally stiff (to support workers placing concrete) or widely spaced (so workers can step between bars or wires). Furthermore, the steel must be supported at the proper position in the slab. Design drawings should clearly show all these details.

Design examples

The following design examples for two different joint spacings illustrate how to select reinforcing steel for controlling cracks caused by shrinkage and temperature effects. Both use the subgrade drag equation for calculating the steel areas. The reinforcing steel is not to be continuous through any of the contraction or construction joints. This holds for both wire and bars.

Each example is for an 8-inch-thick industrial floor slab. Column spacings are 48 feet center to center. Construction joints also have this spacing for strip placement of the concrete.

24-foot joint spacing. A slab with this joint spacing may be reinforced with bars (ASTM A 615, A 616, A 617, or A 706) or WWF (ASTM A 185 or A 497). To select the appropriate steel area \( (A_s) \), use the subgrade drag equation:

\[
A_s = \frac{F \cdot L}{w/2 \cdot f_y}, \text{ where } F \text{ (the subgrade friction factor)} = 1.5 \text{ (a commonly used value)}, \ L = 24 \text{ feet}, \ w = 100 \text{ psf (weight of slab)}, \text{ and } f_y \text{ (working stress in steel)} = \frac{3}{4} f_y \text{, where } f_y \text{ (yield strength of steel)} = 60,000 \text{ psi.}
\]

\[
A_s = 0.045 \text{ square inches per foot of slab width, required each way.}
\]

Use #3 bars at 29 inches center to center in each direction, \( A_s = 0.046 \) square inches per foot. If following the American Concrete Institute (ACI) structural slab limitation of 5h or 18 inches, whichever is less, then use #3 bars at 18 inches, \( A_s = 0.073 \) square inches per foot.

For ASTM A 185 plain WWF

Values in the subgrade drag equation are the same except for \( f_y \), which is 65,000 psi.

\[
A_s = 0.042 \text{ square inches per foot of slab width, required each way.}
\]

Use W4.5 wire at 12-inch spacings in each direction, designated as: 12 x 12—W4.5 x W4.5

48-foot joint spacing. A floor slab with 48-foot-wide joint spacing could be considered a joint-free slab. No sawcut contraction joints are used longitudinally. However, if using strip placement of the slab, then cut a contraction joint at 48-foot spacings transversely along each strip. In the subgrade drag equation, the length \( L \) is now 48 feet and yield strength of steel, \( f_y \), is either 60,000 psi (bars) or 70,000 psi (deformed wire):

For Grade 60 rebar

\[
A_s = \frac{F \cdot L}{w/2 \cdot f_y}, \text{ where } F = 1.5, \ L = 48 \text{ feet}, \ w = 100 \text{ psf, and } f_y = \frac{3}{4} f_y = \frac{3}{4} \times 60,000 \text{ psi.}
\]

\[
A_s = 0.090 \text{ square inches per foot of slab width, required each way.}
\]

Use #4 bars at 25-inch spacings center to center each way, \( A_s = 0.096 \) square inches per foot (or #4 bars at 18 inches center to center to meet ACI criteria, \( A_s = 0.133 \) square inches per foot).

For ASTM A 497 deformed welded wire fabric

Values in the subgrade drag equation are the same as above except for \( f_y \), which is 70,000 psi.

\[
A_s = 0.077 \text{ square inches per foot of slab width, required each way.}
\]

Use D8 wire at 12-inch spacings in each direction, designated as: 12 x 12—D8 x D8 \( A_s = 0.080 \) square inches per foot.

The steel areas selected using the subgrade drag equation are for shrinkage and temperature effects. If the reinforcement is intended to be structurally active — to resist bending stresses produced by loads on the slab — then the subgrade drag equation is not appropriate (Ref. 2).

Positioning reinforcement

To be effective, reinforcing steel must be positioned at or above the mid-depth of the slab. Some authorities recommend placing the steel 2 inches below the top surface of the slab. Others recommend placing the steel one-third of the depth down from the top of the slab. Any of these locations can be appropriate, depending on reinforcement needs, such as for crack control or structural strength.

Never position a single reinforcement layer below mid-depth. Steel in two directions with the bars or wires in contact with one another is considered “one layer.” For most slabs on grade, position the reinforcement at one-third the depth from the top surface. If the slab is 5 inches thick or less, then position the steel at mid-depth.

Supporting reinforcement

Since positioning of reinforcement is critical, support devices must be used to keep the steel at the correct position during the construction process, especially during concrete placement.

When rebar are specified, they should be placed in two layers (one layer directly contacting the other), with bars in each layer perpendicular to the other. When WWF (deformed or plain) is specified, its wire diameters should be large enough so the fabric has enough stiffness to remain in proper position during slab construc-
tion. If bars or wires are not stiff enough to support workers standing on the steel, then their spacings must be wide enough—at least 12 inches center to center—for workers to stand between them.

What to do at joints
A question that often arises is what to do with reinforcing steel at joints, particularly contraction joints. The answer depends on the purpose of the joint. If the joint is to be a working joint that must open and provide relief for stresses due to shrinkage and temperature effects, then it’s best to discontinue all steel at the joint. Any steel that continues through a contraction joint will restrain joint movement. If the joint is to remain closed, then the steel may continue through the joint. If load transfer is required at the joint, but the distributed steel is interrupted, use dowels across the joint (see article on p. 532).

References
1. Guide for Concrete Floor and Slab Construction, ACI 302.1R-89, American Concrete Institute (ACI), Detroit, 1989.
2. The Structurally Reinforced Slab on Grade, Engineering Data Report No. 33, Concrete Reinforcing Steel Institute, Schaumburg, Ill., 1989.

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