REINFORCING STEEL IN SLABS-ON-GRADE

A SERVICE OF THE CONCRETE REINFORCING STEEL INSTITUTE

CRSI

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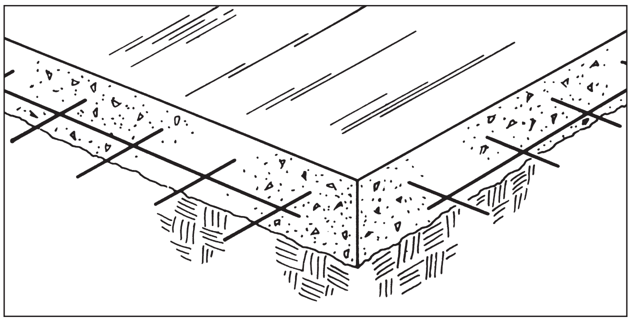
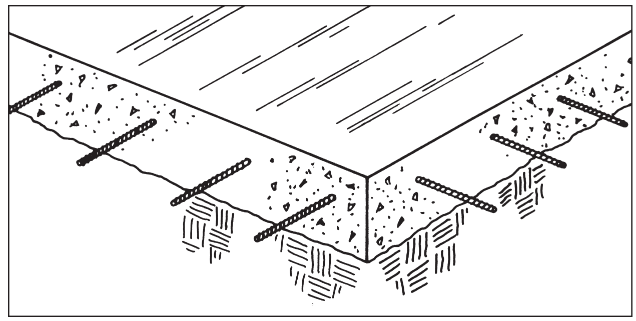
933 N. Plum Grove Rd., Schaumburg, Illinois 60173-4758



WELDED WIRE FADRIC



REINFORCING BARS

INTRODUCTION

The phrase slab-on-grade, as commonly used in practice, covers a number of practical slab applications. Included are industrial and commercial floors, residential floors, parking lots, pavements, airport slabs and other practical uses of ground-supported concrete slabs. This report applies to all of these applications.

Reinforcing steel, in the form of welded wire fabric or deformed bars in both directions, may be placed in the slab-on-grade for a number of reasons. This form of reinforcement adds to the strength of the slab, acts as crack control including the well-known restraint of shrinkage (as well as temperature) effects, reduces future maintenance, and generally helps produce a higher quality concrete slab. A complete listing of advantages is included elsewhere in this report.

Reinforcing bars or welded wire fabric (WWF) functions as reinforcement because such steel is supported and thus placed in a specific position in the slab prior to the placement of the concrete. Visual inspection verifies that the reinforcement is properly positioned and will have the positive effects desired.

When reinforcing bars are specified, they are to be placed in two layers (one layer directly in contact with the other), with bars running in two perpendicular directions, tied together so as to maintain the spacing requirements, and they must be supported.

When welded wire fabric (deformed or plain) is specified, it should have sufficiently large wire diameters so as to be structurally stiff enough to remain in its proper position during construction, with a wire spacing selected for construction stability and convenience, and the WWF must be supported.

ADVANTAGES

There are numerous advantages that result from placing reinforcing bars or welded wire fabric in a slab-on-grade. The following list shows what reinforcement can do for the slab. Some of these can be achieved in no other way:

- **Controls Cracking**

  Reinforcement within a slab prevents cracks from opening and becoming wide and objectionable. These cracks may be due to drying shrinkage or due to externally applied loadings. When these cracks are kept tight, aggregate interlock will still exist and faulting will not occur. Cracks are frequently kept so tight as to be difficult to see.

- **Allows Increased Joint Spacings**

  The spacings of construction and control joints may be increased when distributed reinforcement is used. The increase can vary from ‘slight’ to ‘substantial’ depending upon the concept of design and the intended performance of the slab. The subgrade drag equation (explained in design example) has been used to relate wider joint spacings with given areas of reinforcing bars or welded wire fabric.

• Spans Soft Spots in Subgrade

During the construction process of grading, filling, and compacting of the subgrade system, it is not uncommon to encounter or produce soft spots. These can occur due to local moisture, last-minute excavation for a drain line, or similar occurrences. The reinforced slab-on-grade will span these so-called soft spots by providing enough structural capacity to bridge the weaker supporting areas.

• Restraint to Curling

Reinforcement in the upper half of the concrete slab will act as a restraint to concrete shrinkage. When the shrinkage in the upper portion of the slab is restrained, and thereby lessened, curling will be reduced. The closer the steel is to the top and the more steel area there is, the more the curling will be reduced.

• Structural Strength After Cracking

When overloading occurs, such that the cracking moment limit of the concrete slab has been exceeded, structural cracks may occur. The steel will then act as structural reinforcement and provide moment capacity according to normal, cracked-section, reinforced concrete theory. This concept may also be intentionally used in the original design concept of the slab; that is, designing the slab to have structurally-active reinforcement under externally applied loadings.

• Increases Resistance to Impact

In numerous slab applications, loading is such that impact is caused on the slab. Such loading increases the stress level in the concrete. Reinforcement will reduce the strains caused by the impact loading, thereby preventing premature cracking, and provide structural strength to the slab if the impact is so much that cracking does actually occur.

• Reduces Slab and Joint Maintenance

When cracks are maintained in a tighter condition and when curling is reduced, both by the presence of reinforcing steel, maintenance of these items is reduced. With supported steel in the top half of the slab, the maintenance costs should be substantially reduced.

• Allows Construction of a "No—Joint" Slab

With reinforcement, construction joints may be spaced according to the planned size of a single daVs concrete placement. This can be in strip shape or large panel shape. In such a slab, no contraction joints are used. The distributed reinforcement allows acceptable hairline cracking due to drying shrinkage.

• Required for Shrinkage Compensating Concrete

The use of shrinkage-compensating concrete demands the use of reinforcing steel. All the advantages of the steel will exist even though the steel is required for the concrete to expand and contract as planned.

• Avoids Use of Thickened Slabs at Joints and Edges

Reinforcing steel can be selected to give the concrete slab adequate strength at the joints. This will allow the slab to maintain a constant thickness without thickening at joints or edges. This thickening adds more restraint to drying shrinkage as well as requiring additional construction effort and costs.

• Gives Confidence when Conditions of Support are in Doubt

It is common for a slab-on-grade to be planned and designed without a complete report on the soil, fill material, or the subgrade support capability. The presence of reinforcing bars or welded wire fabric creates a confidence in the ability of the slab to perform adequately even though some doubt may exist concerning the subgrade support.

THE GENERAL PROCESS OF DESIGN

The design of a slab-on-grade includes all decisions and details made before the job is bid and constructed. Three of the more obvious items included in the design process are slab thickness, reinforcement requirements and joint spacings. After determining the controlling loadings, the appropriate safety factor, and the subgrade modulus appropriate for the base and fill materials, the designer determines the required thickness.

References for thickness determination include publications of the Portland Cement Association, the American Concrete Institute, the Concrete Reinforcing Steel Institute, and the Wire Reinforcement Institute.

The next most common step is the selection of 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 placements, flatness requirements, joint details, dowel recommendations and the like. Reinforcing steel, in the form of welded wire fabric or patterns of deformed bars, is then selected for purposes of either crack control, using the subgrade drag formula, or for structural strength, using common reinforced concrete design procedures.

Regardless of the intended purpose of the reinforcement, it must be structurally stiff (strong enough to support working loads) and/or widely spaced (individual elements spaced wide enough so that workers can walk between them). Further, it must be supported at the proper position, so as to provide its intended advantages. All requirements for a quality slab-on-grade should be detailed and clearly shown on the design drawings.

DESIGN EXAMPLES

These design examples illustrate the selection of reinforcing steel for the purposes of controlling cracks caused by shrinkage. The subgrade drag equation is used for calculation of the steel areas, which are determined here for both a common loint spacing as well as for a wide joint spacing. The reinforcing steel is not to be continuous through any of the contraction or construction joints. This holds for both wires and bars.

For these design examples, assume that an 8-in. slab is required. Column spacings are 48 ft center-to-center and construction joints will have this spacing for strip placement of the concrete.

1. 24—ft loint spacings:

This joint spacing, commonly encountered in the field, of 24 ft, using a saw-cut contraction joint, may be reinforced with bars (ASTM A 615, A 616, A 617, or A 706) or welded wire fabric (ASTM A 185 or A 497). The appropriate areas are selected using the subgrade drag equation as follows:

- For Grade 60 reinforcing bars:

  A_s = F L w / 2 f_s where F (friction factor) = 1.5 (commonly used value), L = 24 ft, w = 100 psf and f_s = 2/3 f_y where f_y is 60,000 psi.

  As = 0.045 sq.in./ft of slab width, required each way.

  Use #3 bars at 29 in. c.-c. in each direction, A_s = 0.046 sq.in./ft. (If the disigner follows ACI's structural slab limitation of 5h or 18 in. (whichever is less), then #3 bars at 18 in. are selected, A_s = 0.055 sq.in./ft).

- For ASTM A 185 plain welded wire fabric:

  The subgrade drag equation is the same except for the use of f_y which is 65,000 psi.

  A_s = 0.042 sq.in./ft of slab width, required each way.

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

  12 x 12 - W4.5 x W4.5.

2. 48—ft joint spacings:

This is a wide joint spacing and could be considered as a "no joint" slab design. No saw-cut contraction joints are used longitudinally; however, if strip placement of the slab is used, then a contraction loint would be cut at 48 ft spacings transversely along the pour strip. In the subgrade drag equation, the length L is now 48 ft and the yield strength, f_y, is either 60,000 psi (bars) or 70,000 psi (deformed wire), as follows:

- For Grade 60 reinforcing bars:

  A_s = F Lw / 2 f_s where F = 1.5, L = 48 ft, w = 100 psf, and f_s is 2/3 f_y = 2/3 x 60000 psi = 40,000 psi.

  0.090 sq.in./ft of slab width, each way.

  Use #4 bars at 25 in. spacings c.-c., each way (or #4 bars at 18 in. c.-c.)

- For ASTM A 497 deformed welded wire fabric:

  The subgrade drag equation is the same except for the use of f_y which is 70,000 psi.

  A_s = 0.077 sq.in./ft of slab width, required each way.

  Use D8 wire at 12-in. spacings in each direction, designated as:

  12 x 12 - D8 x D8

The steel areas selected using the subgrade drag equation are for shrinkage (and temperature) effects. If the reinforcement is intended to be structurally active and to resist bending stresses produced by loading to the slab, then the subgrade drag equation is not appropriate. (Refer to ORSI's EDR No. 33).

REINFORCEMENT: ITS POSITION, ITS SUPPORTS, & WHAT TO DO AT JOINTS

It is absolutely essential for the reinforcing steel to be in the proper position to provide the advantages cited. The proper position is at or above the mid-depth of the slab. Some authorities recommend the steel be placed 2 in. below the top surface of the concrete. Others recommend the steel be placed 1/3 of the depth down from the top of the slab. Some recommend the steel be placed at the mid-depth of the concrete. Any of these can be the appropriate choice, depending on the concept of design (reinforced for crack control, structural or for shrinkage compensating concrete). There is no question, however, that for a single reinforcement layer (steel in two directions, where they are in contact with one another, is considered as "one layer"), it must not be allowed to be below mid-depth. In general, positioning the reinforcement at 1/3 the depth from the top surface is reasonable and, when so positioned, will be effective. If the slab is to be 5 in. or less in thickness, then positioning the steel at the mid-depth is recommended.

Since positioning is critical, support devices are essential. The steel must be supported with devices spaced so as to maintain the steel at the correct position during the construction process and during the concrete placement. This, then, also involves the diameter (stiffness) of the bar or wire in combination with the support spacings. If the bars or wires, as supported, are not stiff enough for concrete workers to stand upon, then their spacings must be wide enough for the workers to stand between the wires or bars. Spacings should be at least 12 in. center-to-center. Bar or wire diameters should be of sufficient size and adequately supported to be stiff enough to remain in position during the construction process.

When reinforcement is placed in a slab, there is always the question of what to do with the steel at joints, particularly at contraction joints. The answer to this question is dependent upon the intent of the joint. If the joint is to be a working joint, that is, to open and provide relief for drying shrinkage strains in the concrete, then it is best to discontinue all steel at that joint. Any amount of steel which continues through the contraction joint will offer restraint to motion depending upon the amount of that area. If the joint is to be closed, that is, it is not expected to open at all over time, then the steel may be continued through the joint. If load transfer is required at the joint, but the distributed steel is interrupted, then dowels should be specified.

Contributed by Boyd Ringo

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