

TECH FACTS
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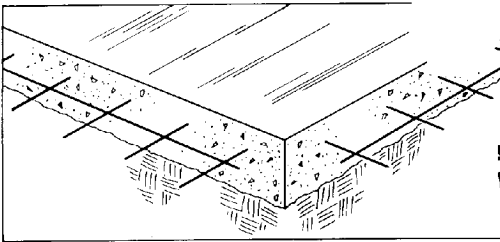
REINFORCING STEEL IN SLABS-ON-GRADE



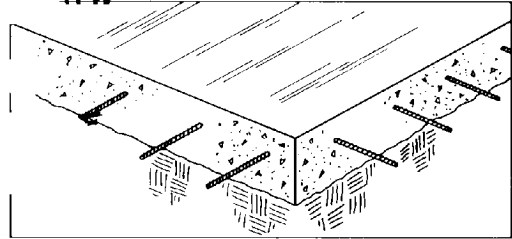
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WIRE REINFORCEMENT INSTITUTE
CANADIAN CHAPTER

REINFORCING STEEL INSTITUTE OF CANADA



WELDED WIRE FABRIC



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 with a slab prevents cracks from 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.

- **Adds 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.

- **Adds 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 day's 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 joint 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.

The amount of reinforcement required is estimated on the basis of the subgrade friction drag theory which equates the tensile force in the steel to the force required to overcome the subgrade friction.

$$A_s f_s = W (L/2) F$$

For these design examples, assume that a 200mm slab is required. Column spacings are 16m center-to-center and construction joints will have this spacing for strip placement of the concrete.

1. 8m JOINT SPACINGS:

This joint spacing, commonly encountered in the field, of 8m using a saw-cut contraction joint, may be reinforced with **bars** (CSA G30.12 or G30.16) or **welded wire fabric** (CSA G30.5 or G30.15). The appropriate areas are selected using the subgrade equation as follows:

• For Grade 400 reinforcing bars:

$A_s = F L w / 2 f_s$ where F (friction factor) = 1.5 (commonly used value), $L = 8\text{m}$, * $w = 4720 \text{ N/m}^2$ and $f_s = 2/3 f_y$ where f_y is 400 MPa.

$A_s = 107\text{mm}^2/\text{m}$ of slab width, required each way.

Use 10M bars at 500mm C.-C. in each direction, ie, maximum spacing allowed in CSA CAN3-A23.3, clause 7.83, $A_s = 200\text{mm}^2/\text{m}$.

* Based on a design density for reinforced concrete of 23.6kN/m^3 .

• For CSAG30.5 plain welded wire fabric:

The subgrade drag equation is the same except for the use of f_y which is 450 MPa.

$A_s = 95\text{mm}^2/\text{m}$ of slab width, required each way.

Use MW37.4 wire at 305mm spacings in each direction, designated as 305 x 305 MW37.4 x MW37.4 or 12 x 12 W5.8 x W5.8 equivalent to 6 x 6 6/6. Both styles are available as standard product.

2. 16m 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 joint would be cut at 16m spacings transversely along the pour strip. In the subgrade drag equation, the length L is now 16m and the yield strength, f_y , is either 400 MPa (bars) or 485 MPa (deformed wire), as follows:

• For Grade 400 reinforcing bars:

$A_s = F L w / 2 f_s$ where $F = 1.5$, $L = 16\text{m}$, $w = 4720 \text{ N/m}^2$ and $f_s = 2/3 f_y = 2/3 \times 400 \text{ MPa} = 266 \text{ MPa}$.

$A_s = 213\text{mm}^2/\text{m}$ of slab width, each way.

Use 10M bars at 450mm spacings c.-c., each way.

• For CSA G30.15 deformed welded wire fabric:

The subgrade drag equation is the same except for the use of f_y which is 485 MPa.

$A_s = 176\text{mm}^2/\text{m}$ of slab width, required each way.

Use MD58.1 wire at 305mm spacings in each direction designated as 305 x 305 MD58.1 x MD58.1 or 12 x 12 D4/D9.

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.

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

It is absolutely essential for the **rebar or the wire mesh** 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 50mm 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 125mm 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 305mm 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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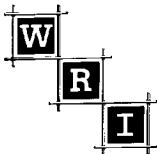
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