DESIGN CONSIDERATIONS FOR WAREHOUSE FLOORS

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Everyone familiar with food distribution warehouses realizes that a quality concrete floor is essential to the success of their operation. But, does everyone understand which type of concrete floor is best suited to their needs according to performance and economy? While it may be possible to construct a concrete floor that will tolerate extreme abuse, it may be cost prohibitive and unwarranted for the intended use.

A quality, cost effective concrete floor begins with the soil on which it is constructed, or subgrade. Since the subgrade is an elastic medium, consideration must be given to its load-carrying capacity and resistance to movement or consolidation. To ensure that the floor will carry its imposed loads successfully, it is important to construct the subgrade as carefully as the floor itself.

The subgrade as found may need to be improved by drainage, compaction, or soil stabilization. The elastic ability of a soil to deform under load and rebound, when the load is removed, is termed the subgrade modulus. This value can vary greatly with different types of soil. A granular subbase, such as a 6” layer of crushed stone, can increase the subgrade modulus by providing a more uniform layer of support directly under the floor slab. It should be noted, however, that certain conditions may exist in the soil that would be adversely affected by using a granular subbase material.

Proper identification of the subgrade soil is important so that its potential problems can be recognized. Expansive soils consisting of clays with high plasticity, silts with high plasticity and organic clays are dangerous due to their large volume change potential associated with moisture content changes. Compaction of highly expansive soils when they are too dry can contribute to detrimental expansion upon future wetting. The construction of a granular subbase on an expansive soil may give subsurface moisture access to all areas of soil under the concrete floor. This causes objectionable swelling of the underlying soils throughout the building, creating an uneven and sometimes unusable floor system. Solutions to this potential problem usually center around avoiding construction in the area altogether, excavating and replacing the soil with a granular low plasticity soil, treating the on-site soils with lime through scarifying or injection, structurally supporting the floor above the ground or utilizing a post-tensioned floor slab. Naturally, each of these options have differing risks and costs that an owner and engineer must weigh to make a final selection.

We have discussed briefly the considerations for structural support. Now, let’s cover three major types of concrete floors on grade, their basic design procedures and advantages.

The most common and least expensive type of industrial concrete floor system is the conventionally reinforced slab on-grade. Conventional reinforcing can be either welded wire fabric or small diameter (No. 3 or No. 4) reinforcing bars. The reinforcing used in this type of floor slab is to control shrinkage cracking. Once the slab has cracked, the reinforcement holds the adjacent slab sections tightly together so that this unplanned floor joint does not deteriorate further. The slab thickness is influenced by several variables. Current methods for determining the minimum floor thickness utilize dynamic wheel loads of forklift vehicles, concentrated static loads such as storage rack posts, distributed loads due to staged product stacked on the floor and the strength of both the concrete and the subgrade. After these variables have been determined, the Portland Cement Association's design charts may be utilized in determining slab thickness. These charts have been developed from extensive data assembled during many years of laboratory testing and field research. This procedure provides highly reliable, conservative designs while maintaining reasonable economy.

Proper jointing of the conventional concrete floor will ensure a minimum amount of cracking and facilitate rapid concrete placement. This is accomplished by utilizing three kinds of joints:

1. Isolation Joints: To allow movement between the floor and fixed parts of the building, such as walls and columns;

2. Control Joints: Usually sawcut joints to induce shrinkage cracking at predetermined locations; and

3. Construction Joints: Locations where construction has been stopped between pours.

Where a conventional concrete floor is used, the slab is generally poured in alternating strips with sawcut joints in the opposite direction. This produces a slab with joints on a grid of approximately 20 feet. The relatively high frequency of joints designates this type of floor as a higher maintenance slab. Careful attention must be given to the filling of all construction and control joints where vehicular traffic will be occurring. It is important to select a material that will provide adequate support to the concrete edges to prevent shrinkage stress relief at the joint. These joints should be filled completely with a pourable epoxy sealant curing to a semi-rigid consistency. Elastomeric sealants should be avoided, as they typically are not rigid enough to provide adequate lateral support to the concrete edges at the joint to prevent spalling as wheel loads pass over the joint.

The interest in eliminating concrete floor control joints has promoted the use of shrinkage-compensating concrete. This is probably the second most common concrete floor system used today.

Shrinkage-compensating cements consist of conventional Portland cement, with added sources of aluminates and calcium sulfate. The moisture is proportioned such that the concrete will increase in volume after setting and during curing. When these concrete sections are properly restrained by internal reinforcement, expansion will induce tension in the reinforcement and compression in the concrete. This compression dramatically reduces the potential for shrinkage cracking and eliminates the need for control joints. As the slab dries, normal shrinkage allows tensile stresses to develop in the slab. Utilizing shrinkage-compensating cement, these tensile stresses are offset by the initial compression developed in the slab. Areas up to and sometimes exceeding 10,000 square feet can be poured without interior joints. The major limitation becomes the amount of floor that a normal crew can place and finish in one day.

The performance of shrinkage-compensating concrete in minimizing joints and shrinkage cracking depends largely on proper design and detailing. The mixture and design must be such as to ensure adequate expansion to offset subsequent drying shrinkage. The physical characteristics and durability of cured shrinkage-compensating concrete are very similar to that of Portland cement concrete.

Shrinkage-compensating concrete floor slab sections should be placed as square as possible with a maximum length to width ratio of 2:1. Sections should be poured with no more than two adjacent sides restrained from free expansion. A compressible filler material must be utilized for all isolation joints. In some circumstances, slab openings are constructed to permit movement around fixed objects such as columns and door guards.

Shrinkage-compensating concrete is slightly more expensive; however, many owners feel that the reduced joint maintenance offsets the higher first cost.

The last type of floor system is currently the least frequently used and may be the most expensive. However, larger expanses of floor areas and higher loads may increase its economy. This is the post-tension floor slab. A post-tensioned floor slab consists of a thin concrete section in which steel cables are placed. After the concrete has attained a predetermined strength, the cables are tightened producing an initial compressive strength across the entire concrete section.

The design procedure for these slabs is to provide a residual compressive stress in the slab after overcoming the tensile stress resulting from the subgrade friction, bending moments and concrete shrinkage. Generally, designs are based on using 1/2 inch diameter 270ksi unbonded steel tendons, at spacings of approximately 30 to 42 inches. Typically, warehouse floors are at least 5 inches thick.

Shrinkage-compensating concrete is sometimes utilized with a post-tension design to reduce the shrinkage cracking that occurs during the first 7 days, prior to post-tensioning. Normally, a slab is not tensioned until the concrete has reached its 7-day strength.

Up to this point, we have only considered the concrete floor design as a factor in selection and serviceability. However, the characteristics of the concrete surface are far more important when determining the serviceability of the floor. The top surface of any concrete floor can easily be of lower quality than the remainder through a lack of attention to concrete clump, water/concrete ratio and proper finishing techniques.

The durability and abrasion resistance of all concrete floors begins with the specified compressive strength of the concrete. The strength selected should be appropriate for the service and time. In no case should the compressive strength of a finish floor slab be less than 4,000psi.

When wear conditions are moderate to high, strong consideration should be given to utilizing a special aggregate hardener product. These products can, in most instances, be added during the finishing operations for a relatively low cost. Additionally, many of the products available are easy to apply and can be utilized by most concrete contractors.

There are three common types of floor topping categories in use today:

1. Monolithic surface treatments;

2. Monolithic two course floors; and

3. Bonded two course floors.

The monolithic surface treatments are generally in the form of dry shake mineral or metallic aggregate products. The application of these wear resistant products should immediately follow screeding (leveling) and floating after all excess free water has been removed. This material should be evenly distributed onto the concrete surface and trowled into place.

These toppings provide a wide range of wear resistance for a reasonable cost and are fairly easy to apply. The most common product of this category is the mineral aggregate hardener. This product has decided advantages over the metallic aggregates. It is more economical, less abrasive to rubber tired vehicles and it will not oxidize if exposed to moisture. This product will not be adequate if the floor is to be used for very heavy repeat traffic such as wire-guided vehicles. Since these vehicles operate in the same track, they require an alternate floor hardener system.

The monolithic two course floor consists of a top course of dense concrete and a special dense aggregate compressed into base structural slab. Immediately before the topping concrete is placed, several applications of dense aggregate are floated into the surface. Typical aggregate usually consists of a crushed natural fine to medium grained igneous rock such as diabase, basalt or black granite. This type of floor finish provides very high resistance to wear at a slightly higher cost than the monolithic mineral aggregate dry shake products. However, it should be noted that the successful application of this product may require the use of a specialty contractor.

The bonded two course toppings are the most expensive. This is a highly critical operation requiring the most meticulous attention to procedures. It is recommended that a specialty contractor be used to apply the bonded topping. The function and materials of this topping are similar to the monolithic two course topping; however, the base course may be completely set before the topping is applied. Generally, the base course is wet cured a minimum of three days prior to the application. All standing surface water is then removed from the slab and a cement paste (grout) is scrubbed in. While the grout is moist, the top course is spread and screeded. The floor is then floated and power troweled several times to a dense burnished finish.

This procedure is advantageous for reworking existing concrete slabs or where a very dense abrasive resistance floor finish is necessary, such as traffic ways for wire-guided storage vehicles.

Where concrete floors are considered critical to the operation of a distribution facility, an owner would be wise to seek the advise of a professional engineer prior to construction. All too frequently, the problems experienced with the serviceability of concrete floors could be avoided through better design or construction techniques. The cost of construction and maintenance of concrete floors should be minimized, not the cost of design.

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