Guide to Effective Warehouse Design, Maintenance, and Modernization

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A unique alliance

The **Global Cold Chain Alliance (GCCA)** exists to help its members build and strengthen the temperature-controlled supply chain worldwide. We do this by bringing third-party warehouse and transportation business leaders together in events and networking activities, providing advisory and educational services, and being a voice of cold chain to government regulators and other influencers around the world.

The **Global Cold Chain Foundation's (GCCF)** mission is to strengthen the global cold chain through education, research, and international development. Cold Chain Institute trains industry practitioners in the best practices of temperature-controlled product storage, handling, and transportation. Research manuals developed by the foundation serve as the definitive guide for the proper handling, storage, and freezing of perishable products as well as energy and facility management.

International development projects engage industry professionals in the development of cold chain infrastructure in emerging markets.

And a key partner to GCCA is the **Controlled Environment Building Association (CEBA)**. CEBA's mission is to represent expert builders who specialise in designing and constructing controlled environment buildings, including cold storage warehouses, food processing facilities, clean rooms, pharmaceutical facilities, food service, and retail distribution centres. With a strong value proposition and growth momentum, industry participation in CEBA programs has doubled since pre-pandemic levels.

Together we are the cold chain.

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Acknowledgement

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Executive Summary

This Design Manual establishes a unified set of standards and technical guidelines to support the planning, construction, operation, and maintenance of facilities, aligning with best practices in safety, efficiency, and performance. The manual is intended for engineers, facility managers, designers, and technical consultants who require clear, actionable direction across the full range of facility systems.

To improve accessibility and operational efficiency, this latest edition is being published in a modular format—organized into 15 focused chapters. Each chapter addresses a core system or component of facility design and management, enabling users to quickly reference specific content and apply standards directly to their area of responsibility.

1. Design – Foundational planning principles and performance objectives
2. Maintenance – Preventive strategies and operational reliability standards
3. Structural – Load-bearing frameworks and compliance specifications
4. Walls – Materials, insulation, and environmental controls
5. Floors – Surface treatments, drainage, and durability
6. Roofs – Construction systems, weatherproofing, and safety features
7. Refrigeration – Temperature control systems and efficiency metrics
8. Doors – Selection criteria, access control, and insulation
9. Lighting – Illumination standards, energy use, and fixture design
10. Material Handling – Flow optimization and equipment interfaces
11. Batteries – Storage, charging protocols, and hazard mitigation
12. Fire Prevention – Risk reduction measures and system integration
13. Racking – Load standards, anchoring, and spatial planning
14. Dock Equipment – Levelers, seals, and operational safety
15. Automated Systems – Integration of robotics, controls, and data systems

This format enables continuous updates and targeted usage while reinforcing technical consistency across disciplines. The manual is designed to serve as both a foundational reference and an evolving toolset for ongoing facility innovation and compliance.

What follows is Chapter 5
Floors – Surface treatments, drainage, and durability

Chapter 5: Floors

5.1 Design and Installation

5.1.1 Introduction

In large warehouse and industrial buildings, the floor surface is probably the most important building component because it can have the greatest impact on the cost of operations in the building. A good floor which has been properly designed and properly installed will be an asset for 30 years or longer.

It is important for everyone on a construction project team to have some basic concrete knowledge. This narrative has been prepared to provide an overview of the subject.

Typically, floors are concrete slabs bearing directly on the earth or a prepared subbase. However, if soil conditions dictate, they can be built over enhanced or deep foundations. Concrete slabs are often subject to high point loading (racking) and dynamic vehicular (forklift) loads. The slab is one of the few remaining site-built components in a building. As such, a concrete slab is dependent upon appropriate design, quality control, uniform materials, and skilled craftsmanship for placement and finishing.

The construction of a floor slab is outwardly simple. The contractor lays out the area which will become the slab and contains it with forms. Usually, a vapor barrier of plastic is installed between the subgrade or earth and the facility floor. Reinforcement consisting of steel rods wire mesh is installed, then the contractor places the concrete in the slab form work. The concrete is screeded or leveled, usually by a mechanical device. It is then floated using a bull float which resembles a long handled, flat squeegee. Floating opens the surface to allow the excess water in the concrete to migrate to the surface and evaporate. Depending on the abrasion or impact resistance requirement or other requirements (such antistatic properties of the floor) a dry-shake hardener can also be applied on the fresh concrete. Finally, the floor is troweled with a finishing machine usually consisting of rotating flat blades. The concrete is then cured for a number of days. Proper curing is very essential to completing the chemical reaction and the concrete reaching its maximum strength and performance properties.

Concrete is the result of a complex chemical reaction and the variables affecting a concrete floor are equally complex. The design of a concrete slab requires the Engineer of Record to make choices among many alternatives including strength, reinforcement, thickness, materials, cement type, subsurface, curing, placement, tolerances, joints, details and finish. The following discussions summarize the alternatives that must be considered by the owner and the engineer when selecting a concrete slab on grade.

There are four main variables which will play important roles in determining the long-term durability and productivity of any industrial concrete floor:

- Subgrade reliability

- Floor slab design
- Floor slab construction
- Floor slab maintenance

The slab performance is critical, and most slab problems can be avoided by proper coordination prior to bidding the work and starting construction. The design of the slab on ground is predicated on the controlling loads, ie storage rack (static) and fork truck (rolling) loading conditions, subgrade modulus and safety factor. These decisions affect the slab thickness, joint spacing, and reinforcement, and therefore all parties must understand them. The floor slab design and construction teams should communicate regularly with each other and with the building owner throughout the construction process to ensure that potential complications in floor slab construction process and ramifications of various design or construction decisions on the finished floor slabs are well understood by all parties. At a minimum, all three parties and all material vendors whose products will be used in finishing or enhancing the floor slabs should be involved in a pre-construction meeting to discuss the construction process and application of all relevant materials. In an ideal case, the design and construction should be executed by the same party, thus allowing for the best communication, and having one single source of responsibility. Where possible, material vendors should be asked to inspect/oversee installation of products at the start of construction and should be enlisted to discuss or provide guidance on the best ways to maintain the long-term durability of the floor and the installed floor protection products.

5.1.2 Concrete Type

Concrete consists of cement, water, and aggregate (various sizes of rock). Many modern concrete mixes include admixtures designed to enhance the placement and end-result properties of the concrete. The water and the cement chemically react and form a paste that bonds to the aggregate and then the entire mass hardens to form concrete. Concrete's hardness comes from the chemical reaction not from the evaporation or drying process.

Two types of concrete for floor slabs are being used today. Conventional Portland cement concrete is the most used material. Expansive concrete, also known as shrinkage compensating concrete, is a more specialized material.

Portland cement concrete is the standard type of concrete that uses Type I/II Portland cement. Type I/II is used when the special properties of any other type are not required. About 95% of concrete is made with Type I/II cement. One of the inherent features of concrete is that more water is added to the concrete mix than is necessary for it to react with the cement. The excess water is used as a lubricant to make the concrete flow more easily to aid in placing the concrete. However, as this excess water leaves the slab it reduces its volume and results in drying shrinkage. Some limited amount of the shrinkage will occur also during the curing period in terms of the so-called chemical shrinkage, which happens when the reaction participants (essentially cement any other binders and water in concrete) occupy slightly higher volume than the reaction products (hardened cement stone). However, most of the shrinkage in the form of drying will take place long after the casting (typically at least for 2 years until the moisture equilibrium with the environment is slowly

reached). Different types of concrete compositions can have very different drying shrinkage potentials. This is the reason why careful mix design is of a crucial importance for the flooring applications. It is not recommended to use a standard composition from the ready-mix supplier, without allowing a qualified engineer to verify it. The main reason for this is because concrete suppliers are normally designing their mixes to guarantee a certain level of concrete compressive strength and workability, without taking into consideration the characteristics that are essential for flooring, such a drying shrinkage potential of the mix or setting time.

As the concrete shrinks, it must slide across the surface of the earth beneath it. Because concrete is inherently weak in tension, and especially weak while it is new ("green"), the restraint in the form of friction against the earth substrate will prevent concrete from sliding and cause concrete cracks as it shrinks. Straight, uniform joints are usually preferable to random cracks. Therefore, joints are in the slab to induce cracks at the joint in a pattern that is acceptable. All joints need to be designed to support the transfer of loads across the joint. The American Concrete Institute (ACI) provides guidelines for joint spacing based on the slab criterion. If joints are not provided, or if provided, they are not at the correct depth and locations, random cracks will occur, and in most cases, will be unacceptable with respect to subsequent use and maintenance of the floor.

Shrinkage compensating concrete expands while the concrete is curing. Expansion normally is complete in approximately 7 days, but it will stop sooner if curing is inadequate or the expansive cement or the concrete mix is inadequate. After expansion is complete, the concrete shrinks in the same manner as conventional Portland cement concrete. Ideally, the initial expansion of the concrete offsets or compensates for the shrinkage. As expansion occurs in the concrete, in which reinforcing bars, or certain types of steel fibers have been placed, the steel resists the expansion and pre-stresses the concrete. When the concrete shrinks, the amount of pre-stress is reduced and the tensile stresses remaining in the concrete are low enough that the slab does not crack. Thus, it is possible using shrinkage compensation concrete to eliminate many of the contraction or sawed joints in slabs. The extended – joint floor, consisting of expansive concrete, can be built with joint spacing up to 100 feet apart thus reducing the number of floor joints and associated maintence costs.

The cementitious properties of shrinkage-compensating concrete can be produced by several alternate methods. Historically, in the U.S. substituting Type K cement for Portland cement has been the "traditional" method of making shrinkage-compensating concrete. An alternate method uses a powdered admixture which is mixed with Portland cement to create an expansive concrete. This admixture is usually cheaper than Type K, but the two methods may not produce exactly the same product. Since the first applications of these materials in the 60s, many other innovative ways of producing shrinkage compensating concrete have also been developed globally.

5.1.3 Slab Pour Width

It is common practice to place conventional Portland cement concrete slabs in long lanes or strips because this is the most efficient method. A checkerboard pattern sequence of placement was used in the past, but this method is no longer recommended. The checkerboard is costlier to install and the joint quality is not as good. In racked storage facilities, it is good practice to locate the slab

lanes so that construction joints are concealed beneath the rack. This reduces the amount of traffic that must travel over the construction joints.

Determination of the width of the slab pour is influenced by many factors:

- The available concrete placing equipment
- The column bay spacing
- The desired joint spacing
- The required floor flatness
- The type of concrete being used

Contractors usually use a vibratory screed to strike off the placed concrete to the proper elevation. A vibratory screed is a piece of equipment that incorporates a long straightedge with a motor attached. This motor vibrates the straightedge, thus allowing it to easily level and strike off the placed concrete. Vibratory screeds can range in length from 10 feet up to 80 feet. However, for ease of concrete placement, 40-50 feet is a generally accepted upper limit. Both ends of the screed must be supported on a carefully established edge or temporary rail to control the floor elevation. A laser screed is a mobile version of a vibrating screed that can be used to level wide expanses of concrete.

The Somero Laser Screed is a four-wheel drive vehicle that has a vibrating straightedge mounted on an extended arm that is guided vertically by lasers. This equipment has improved production and allows much larger pours.

Slab pour width for Portland cement concrete should be some fraction of the column bay spacing. Joints are installed primarily to control cracking. Guidelines have been established limiting the distance between joints. For example, if we assume the column bay is 40 feet wide, a joint could be installed at 20 feet, cutting the slab in half. This slab could be poured either 40 feet wide with a joint at 20 feet or the slab could be poured as two (2) 20 foot lanes. Alternatively, a 40-foot bay in a racked storage warehouse might be divided in thirds so the joints occur beneath the racks.

The floor flatness tolerance for a slab can also dictate the width of the slab pour. The narrower a pour, the better the surface flatness. Conversely, the wider a pour, the harder it is to achieve a very flat floor.

Using shrinkage compensating concrete requires different criteria for slab size. As previously stated, conventional Portland cement concrete is preferably placed in long, narrow strips. However, for shrinkage compensating concrete, square, or nearly square, slabs are required to provide even expansion and contraction to help eliminate shrinkage cracks. An optimum size pour would be 100 feet x 100 feet, even though some shrinkage compensating systems can allow for even bigger slabs, thus allowing for even faster concreting operations and even fewer joints. It should be noted that the concrete is placed in 20 foot sections, but it is done all in one day, thus avoiding a cold joint between the sections.

The previous paragraphs deal primarily with slabs with shake-on hardener and base slabs under topping. For pouring a topping on a base slab, most of the same guidelines apply. However, from practical experience, a topping pour width from 15 to 20 feet is the optimum.

5.1.4 Floor Joints

Minimizing floor joints in a conventional warehouse floor can increase material handling speed, reduce fork truck maintenance expenses, and minimize lift driver / operator fatigue. There are three main types of joints found in a floor slab:

- Contraction (Control) Joints – Joints which are sawn into the concrete slab surface early in the shrinkage process to control the location of cracking. These joints are typically sawn into the slab at intervals of 12 to 18 feet depending upon slab thickness. Depth of the sawn joint is typically ¼ of the slab thickness. Best practice is to discontinue the reinforcing and include some means of positive load transfer across the joint with reinforcement or dowels. These joints can reach miles in length for a single building. However, they will not be present in the so-called "joint less" flooring solutions.
- Construction (Cold) Joints – Joints which are formed and mark the end of a concrete pour and should be designed to provide positive load transfer. Depth of the joint is the same as the slab thickness. Construction joints are typically sawn at the top after pouring to a nominal depth of ¾"-1" to provide a structurally sound joint for filling and to remove inherently weak edges which can occur during the concrete placement/finishing process. Construction joints are sometimes "armored" to provide additional joint edge protection against deterioration by placing a steel edge or plate along the joint edges during the concrete placement process.
- Isolation Joints – Joints which isolate the concrete slab from other structural building elements such as walls, columns, curbs, etc.

Dowel bars for load transfer add cost to the initial slab on ground but offer long term performance benefits. Vertical load transfer is any means keeping opposing sides of the slab at a joint from moving separately as a wheel load crosses a joint. The two methods to provide vertical transfer are aggregate interlock and dowels. Aggregate interlock relies on the crack at a control joint to transfer load across it due to the roughness on one side of the crack to the other. With high traffic volumes in warehouses, caution should be used when counting on this load transfer especially in the main traffic aisles. Providing load transfer devices, extending across a construction and control joint, whether round, rectangular, diamond, other are a proven success strategy.

Joint sealant and filler installation timing is very important to ensure proper performance and long-term durability of the joints. Because this joint widening occurs gradually, it is important to delay the filling and sealing of joints if possible to allow for joint dimension to widen closer to its ultimate width after drying shrinkage is complete. The American Concrete Institute recommends that filling of joints be deferred a minimum of 28 days after slab placement to ensure enough moisture has evaporated to allow for proper joint filler adhesion. ACI further recommends that the filling of contraction and construction joints be deferred 60-90 days or longer after concrete placement to allow for joints to widen closer to their ultimate width prior to filling. Refer to American Concrete Institute's Guide for Concrete Floor and Slab Construction ACI 302.1R-04.

It should be noted that deferring joint sealing or filling 28 days, 60-90 days or even longer will not guarantee that joint dimensional changes will not continue to occur during the life of the concrete floor and impact the installed filler/sealant. Many factors can affect joint dimensional movement including slab thickness, concrete mix design, joint spacing, ambient temperature changes in the building, etc.

Cold Temperature Considerations

Cooler temperatures and reduced humidity affect the rate at which the drying shrinkage process of concrete occurs. Decreases in temperature and ambient humidity will accelerate the concrete shrinkage process and thus accelerate the rate at which joints widen. This temperature drawdown should occur gradually over a period of days (depending on ultimate temperature) to avoid potential cracking or other negative impact to the concrete slabs which can result from rapid drying shrinkage. Consult American Concrete Institute Guide for Concrete Floor and Slab Construction ACI 302.1R-04 for more information.

Because of the effects of temperature drawdown on joint dimension the American Concrete Institute recommends that in addition to standard recommended slab cure times joint filling in areas to be temperature controlled should be deferred until such areas are drawn down to ultimate operational temperature and stabilized at those temperatures. For coolers, the recommendation is to stabilize the area for a minimum of five days. For freezers, the recommendation is a minimum of fourteen days. In both cases the longer the filling is deferred after temperature stabilization the better. Installing fillers prior to area temperature drawn down is one of the most common reasons for filler adhesive failure and/or filler-to-concrete separation.

Construction Joint Consideration

Construction joints may in controlled environment facilities becomes the location of slab expansion / retraction. Upon commissioning and pull down, the concrete slab will retract at the joints, hence opening these joint, due to a combination of two phenomena, dry concrete shrinkage and concrete thermal shrinkage. While dry concrete shrinkage is associated with concrete curing and can be minimized upon using advanced slab building routes, thermal shrinkage cannot be minimized. The two components causing concrete shrinkage (dry and thermal) add up and materialize at the construction joints which open.

This means that construction joints will always open to some extent, generally proportionally to the distance between two joints. Concrete mixes inherently displaying more dry shrinkage will cause floor joints to open more. Construction joints may also open more, as slabs retract more, when the operating temperature is lower.

Due to the reduction for the count of concrete joints, so called jointless floors may display construction joints with larger openings. *Extended joint slab systems* (distance between two floor joints of 50-150 LF) and, even more so, *super seamless slab systems* (distance between two floor joints of150+ LF) may show larger joint openings than a concrete floor with saw-cut joints placed every 15 LF. Extended joint slab systems in freezers may often show slab joint openings of one full inch.

When slab construction joints receive forklift traffic, construction joints should be selected to perform smoothly, including when displaying larger joint openings. The use of steel armoring at

the joint location, as with *concrete armor or armored joint systems,* is advisable with all docking and warehousing spaces where traffic is expected. The optimal selection of a concrete armor joint system is straightforward and should be guided by the following criteria:

Constructability: the armor joint system forms the slab's level reference for the concrete slab's finishing crews. Hence an effort should be made to maximize joint constructability, as this drives desirable outcomes including slab levelness and slab joint durability. The use of complex steel assemblies will decrease joint constructability and, consecutively, will increase both risks of malfunction and imperfect installation for the armor joint. The selection and use of welding-free steel armor joint systems may reduce fire hazards especially when installing such armor joint over XPS insulation such as in freezers.

Armoring: steel armoring improves durability at the trafficked joint itself; hence, larger armored steel edges may be better. The armoring should be oriented vertically at the joint and should be located at both trafficked slab edges. Horizontal plate armoring flush with the slab' surface is not advisable because such armoring type may be more susceptible to joint spalling.

Load transfer: In the context of freezers slabs with construction joints opening significantly, load transfer between concrete slabs should be provided at the construction joint. Load transfer may only be granted by the presence of rigid (steel) members extending, on both sides of the armor joint, into both concrete slab panels. These rigid members may be square, rectangular or cylindric steel dowels. Armor joints which do not have these members may lack the necessary load transfer capacity, especially at the much larger joint openings seen within freezers slabs and seen at all trafficked doors.

Armor profile type: provided all three criteria above have been given full consideration, a *sinusoidal* armor joint profile may perform better than a *straight* armor joint profile. The reason is that the wheels of a trafficking forklift will not typically sink into the opening of sinusoidal joint, while these wheels may be more prone to drop into the space between two straight steel armored edges, even when a filler is present. The use of a sinusoidal profile may then reduce shocks and vibrations associated with traffic, thereby further increasing the durability of the joint, and improving the lifespan of forklift wheels.

A straight, dowelled, concrete armor joint system shown as installed over XPS installation in a freezer. Courtesy Alphacon, Inc.

A sinusoidal, dowelled, concrete armor joint system being installed over a radon barrier in a food service facility. Courtesy Alphacon, Inc.

Semi-Rigid Joint Fillers

ACI guidelines call for the use of a semi-rigid joint filler to fill contraction and construction joints and provide joint edge protection in high traffic areas of concrete floors. Such fillers should exhibit a minimum hardness of Shore A 80 as measured using ASTM D-2240. There are two types of semi-rigid fillers which meet these requirements – epoxies and polyureas.

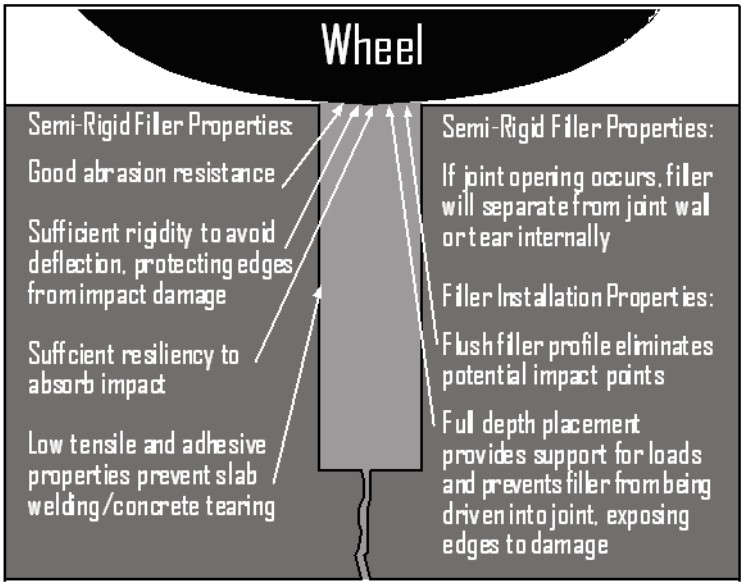

Figure 5.1

Semi-Rigid Filler Concepts

Epoxy joint fillers are typically two part 100% solids materials which can be hand mixed and placed using a bulk-type caulking gun or two component bulk dispensing pump. Epoxy joint fillers typically take 8-12 hours to cure to sufficient hardness to allow for traffic and cure time can be delayed dramatically as temperatures decline. In general, the installation of epoxy joint fillers is limited to areas in which ambient temperatures exceed 50 degrees F (10 degrees C).

Polyurea joint fillers are typically two part 100% solids materials which due to their short potlife cannot be hand mixed but rather must be dispensed using a dual component bulk pump or dual cartridge set. Polyureas are particularly well suited for installation in lower temperature as temperature does not dramatically affect their chemical cure. Most polyurea fillers can be installed at temperatures as low as -30 degrees F (-35 degrees C) and still exhibit proper cure. Because finishing characteristics may vary, however, it is generally advisable to select a polyurea filler formulated specifically for use in freezer or cooler areas.

Proper Installation of Semi-Rigid Joint Fillers

For a semi-rigid joint filler to provide solid structural joint edge support it must be installed properly. Semi-rigid fillers are designed to be installed to the full depth of the saw cut in sawn joints and/or a minimum depth of 2" (50 mm) in joints where depth exceeds 2" (50 mm). Installation of semi-rigid fillers at depths less than this, over compressible foam rods or inert materials, etc. will not exhibit adequate structural support under loading and will often result in the filler collapsing or being pushed down below the joint edges, exposing them to impact and ultimately deterioration.

In order for a semi-rigid filler to achieve good adhesion to joint sidewalls and be installed to the proper depth the joints must be cleaned or prepared mechanically, typically using a dustless concrete saw equipped with a diamond or masonry blade. This method cleans the joint face back to bare concrete and ensures the removal of any existing curing compounds, concrete laitance, etc. that could potentially compromise filler to concrete adhesion. Raking or vacuuming joints out is not an acceptable method of joint cleaning.

Additionally, it is important that the finished profile of the installed filler be completely flush (level) with the concrete slab surface. If the filler profile is concave (cupped) or lower than the floor surface joint edges will be exposed to impact damage.

Elastomeric Joint Sealants

Unlike semi-rigid joint fillers, joint sealants exhibit high elongation and lateral movement capabilities and are designed to accommodate great joint expansion and contraction, often up to 35%. Joint sealants are recommended for isolation and other non-traffic joints. Joint sealants can be one or two component materials and are typically either polyurethane or silicone based though there are other chemistries such as polysulfides or acrylics designed specifically for certain properties such as chemical resistance, temperature fluctuations, etc. Expected durability and performance, long term hardening, and other property changes over time can vary tremendously from one product or chemistry to another. Careful consideration should be given to expected service life and replacement costs for joint sealants when selecting products.

Performance, proper curing, and many other characteristics can also be compromised with lower temperatures. Accordingly, it is strongly recommended that a sealant designed specifically for use in temperatures expected to be present in the area be selected.

Proper Installation of Joint Sealants

In order to achieve greater movement capability, joint sealants are mostly installed over a bond breaker such as a compressible foam backer rod to ensure the sealant only has two-point contact,

allowing for greater extensibility. It is also very important that concrete substrates be clean, frost free, and free of contaminants and surface tension reducing materials such as water repellents, oils or other coatings.

Joint sealants are designed to be "tooled" or exhibit a concave profile when properly installed. Some sealants may require primers to achieve proper adhesion.

5.1.5 Slab Thickness

The design of concrete floor slabs on grade depends on the types and magnitudes of the service loads. Thickness requirements vary according to the intended use of floors. The ACI 318 Building Code does not cover the design of slabs on ground. Section 1.4.8 states: "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." However, the American Concrete Institute (ACI) and the Portland Cement Association (PCA) publish tables and charts as a guideline for the design of slabs on grade. Additionally, finite element software programs can be employed to analyze specific design scenarios to provide a more exact solution. A structural engineer familiar with the performance characteristics of cold storage floors should be consulted.

The obvious advantage of increasing the slab thickness is that the slab will support additional loads. Increased slab thickness may compensate for minor defects in subgrade or for excessive placement tolerances. Increased slab thickness also reduces a phenomenon called curling, which is similar to wood cupping from uneven moisture. Also, increased slab thickness permits increased joint spacing. Of course, increasing slab thickness results in higher costs and does not by any means guarantee that many of the potential problems, such as cracking, wide joint openings and curling will be prevented. Excellent results can also be achieved through more slender and innovative designs at a more reasonable cost.

5.1.6 Reinforcement

Some concrete slab designs call for steel reinforcement and some do not. The amount and location of the reinforcing can vary from sheets or rolls of gauged wire mesh to a rebar grid. For industrial floor slabs, there is a subtle move away from using gauged wire mesh as reinforcing. However, even slabs with reinforcement are technically considered unreinforced because the amount of reinforcement is less than the minimum needed to qualify the concrete as "reinforced concrete".

The primary purpose of most slab reinforcement is to limit the width of shrinkage cracks. If jointing and sub- grade installation are done properly, reinforcement would theoretically not be needed. However, because this is not a perfect world, many designers recommend using reinforcement. Concrete and cracks in concrete can be somewhat predictable but it requires experienced slab installers reviewing the slab design and constraints (re-entry corners, load transfer, etc.…) to minimize cracking. Slab reinforcement must be designed to work with the concrete floor design.

Shrinkage cracks in concrete slabs are usually widest at the slab surface. To keep the crack width as small as possible, the reinforcement must be located near the top of the slab. Reinforcement that is resting on the subgrade is useless insofar as keeping cracks at the surface tightly closed. Reinforcement should be located no more than 2" below the surface of the slab.

Keeping the reinforcement at the correct location is challenging. The preferred method is to use either concrete bricks or metal or plastic chairs for reinforcing support.

The selection of the proper reinforcement can also help keep the reinforcement at the best location. Walking on the reinforcement bars to place the concrete pushes them down from the top surface. By choosing a reinforcing bar spacing that is large, such as 18" x 18", the workers can walk between the bars rather than on the bars.

5.1.7 Fibers

Fiber reinforcement is becoming more commonplace in floor slabs. Fibers are added directly to the concrete truck and then thoroughly mixed into the load of concrete. By using fibers, the construction sequence can be greatly accelerated by the ability to place concrete as soon as the subgrade is ready, thereby eliminating the time spent laying out reinforcing bars.

There are two types of fibers used: synthetic and steel. Synthetic fibers are typically polypropylene or nylon. These fibers are used to minimize plastic shrinkage cracks in the floors. They typically work only while the concrete is still plastic to help bind the materials together and prevent the so-called plastic shrinkage cracks due to fast drying of the concrete surface while it is still fresh.

Typical synthetic fibers (polypropylene and nylon) ~~do not~~ provide long-term durability, structural enhancement, and effective secondary / temperature crack control. The synthetic fiber reinforcement objective is to inhibit plastic and settlement shrinkage cracking prior to the initial set, and to reduce hardened concrete shrinkage cracking, improve impact strength and enhance concrete toughness and durability as an alternate to mild steel temperature and shrinkage reinforcement.

The use of the correct type of steel fibers will also increase the flexural and shear strength as well as fatigue endurance, impact resistance, toughness and punch-out resistance for pile supported flooring slabs, while low quality fibers are typically used only to minimize shrinkage cracking. The effect of the steel fibers is very much dependent on the quantity used and the steel fiber properties, such as length, diameter, aspect ratio (length/diameter), geometry configuration and steel quality. Typically, steel fibers have to be at least 1.5-2 times longer than the maximum aggregate (stone) size in the concrete, in order to be able to bridge between the cracks that will form in the cement paste between the aggregates. As well, the actual dosage of the fibers should be selected by a qualified engineer because a recommendation of fiber dosage in terms of lbs./ cu yard cannot be universal, it will depend on the given fiber type, subbase properties as well as floor thickness and loading conditions.

5.1.8 Post-Tensioned Concrete

Post-tensioned floors involve installing cables in the slab instead of reinforcing bars. The cables are run from one side of the pour to the opposite side. The day after the concrete is placed, the cables are stretched to put them in tension. Only a small force is applied at first; the final tensioning is done 7-14 days later. Tensioning the cables puts a compressive force on the concrete. When the concrete starts to cure, and shrink, the shrinkage stresses are offset by the compressive force in the slab resulting from the post-tensioned cables. The result is the elimination of shrinkage cracks in the slab. Post tensioning is considerably more expensive than most conventional and steel fiber

reinforced slabs. However, in thick slabs, such as those used for rack-supported high-rise structures, this measure can reduce slab thicknesses and reduce costs. Another alternative would be using a system with chemical pre-stressing of the concrete, with the aid of shrinkage compensating concrete and steel fibers. **It should be noted that cutting into a post-tensioned floor made with cables is very dangerous.**

5.1.9 Curing

Evaporation of the water in the mix is not what hardens it. The chemical reaction of the cement mix and water is what hardens or cures the concrete. Doing a great job with mixing, pouring and finishing the concrete is only part of the combination of a good slab. The hardness and durability of the wear surface of the end product is very much contingent on how well the concrete is cured. It is a best practice to allow the mix to cure under relatively variable environmental conditions for about 7-14 days. However, allowing the curing concrete to freeze or allowing the water to evaporate too quickly can be very detrimental. Keeping the slab covered and damp with a membrane and a water source is a recommended best practice. Alternatively, commercial products are available that can be sprayed on the freshly finished concrete that do a similar job in keeping the moisture from evaporating too quickly.

5.1.10 Floor Flatness and Levelness

Taller storage rack systems and automated material handling equipment may dictate strict tolerances for the flatness and levelness of a floor. Specifying the tolerance for flatness, or how close to planar the floor is and levelness, a statistical measurement of how wavy or bumpy a concrete floor is and considers the amplitude (height if the waves) and the wavelength (horizontal distance between waves), provides a quality standard for a warehouse slab on ground.

F-numbers are more accurate than the measurements taken with a straightedge since the profiling machines take a measurement every foot in multiple perpendicular directions when measuring floor flatness. F-numbers provide architects and contractors a method of determining the flatness and levelness of a concrete floor slab. They are calculated using the standards set forth in ASTM E1155, which is the Standard Test Method for Determining FF Floor Flatness and FL Floor Levelness Numbers. The higher the number the more level and flat the floor. The acceptable ranges for flatness and levelness per PCA chapter 7 is as follows:

FF/FL = 25/17 for normal lift traffic alone (no racks)

FF/FL = 35/25 for shorter racking (20 feet tall)

FF/FL= 50/35 for taller or automated racking with racking 35 feet or higher

Super flat floors may also be specified to have FF 100 and FL 50, but these are for defined-traffic (single direction of travel) installations such as narrow-aisle warehouses and ASRS as opposed to a random-traffic floors that the ACI 117 standard covers.

5.1.11 Under Floor Design/Frost Heave Prevention Design

It is important to ensure that a proper underfloor heating system is installed below a low temperature refrigerated space. If the temperature of the soil beneath the concrete slab drops below freezing temperatures, the moisture it contains will freeze, expand, and could cause frost heaving. The ice that forms beneath a building structure will expand and create enormous pressures that can buckle floors and even raising the columns that support the roof. The fundamental solution to prevent this from happening is to keep the soil beneath the refrigerated space above freezing temperatures with a heat source. There are three main conditions that must exist for frost heave to occur are freezing soil temperature, water source, and subsoil that supports capillarity. If any one of the above conditions do not exist, the possibility of floor heave is reduced.

The higher thermal conductivity (k-factor) you have between the low-temperature refrigerated space and the soil, the easier it is for the heat to be absorbed by the cold temperature. If no heat source is available to replenish this loss, the soil will eventually freeze. Just installing floor insulation underneath the concrete will only lower the thermal conductivity or in other words, only slow down the time for soil to freeze. In rare occasions, if you have a relatively narrow low-temperature box located in consistent hot climates, it is possible that the heat energy in the soil surrounding the area of refrigerated space, is enough to prevent the soil beneath this space from freezing. However, this should always be verified by a geotechnical expert.

The typical construction of an underfloor system is as follows: concrete slab, rigid closed cell insulation, vapor barrier, permeation bed (where your heating source will dissipate) usually sand or a low-quality concrete and your heating source which is embedded in the permeation bed.

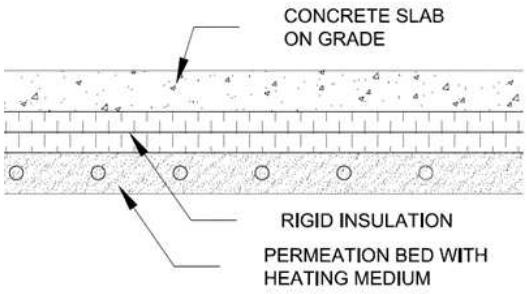

Figure 5.2 Cross-section of Typical Underfloor Heat System

5.1.12 Types of Underfloor Heating Systems for Freezer Slabs

Liquid Systems

A liquid underfloor heating system uses the process of recirculating liquids that have been heated to a required temperature. The liquids can be oil or glycol solutions and the pipe lines are placed in a sub-floor material and covered with the remaining floor assembly. The source of heat for the liquids can also vary depending on the requirements of the owner. The two common practices for the liquid heat source are boilers and heat reclaim. A boiler system is much like a traditional hot water heater, the liquid is stored in a boiler and heated up using either a gas or electric power

source and then the liquid is circulated through the underfloor piping. A heat reclaim system works in conjunction with the refrigeration equipment. The heat that is being removed from the freezer by the refrigeration system is captured, and with the use of a heat exchanger, it is introduced into the stored liquid to bring it up to the required temperature. Once at temperature the liquid is circulated through the underfloor piping.

The draw back to a liquid system are the repair costs if a blockage or damage to the underfloor piping occurs. When the piping is installed, it should always be pressure tested to ensure there were no punctures during installation. This pressure test should continue until after the finished floor slab is installed to verify if punctures have happened during installation of the floor slab. One way to mitigate potential repairs due to blockages and punctures is to minimize spacing between pipes and alternate glycol loops.

Figure 5.3 Glycol Piping

Figure 5.4 Glycol Equipment

Air Systems

There are two types of air systems, gravity and forced air. Each system works with the use of circulating air below the sub-floor.

- Gravity Air Systems (Natural Convection) – A gravity air system uses air vent ducting below the sub-floor. The piping must be placed with a slope to allow air flow as well as drainage for condensation. The drawbacks to the gravity air system are that a consistent temperature is difficult to maintain in certain climates, the amount of heat cannot be controlled. It is recommended that this system not be installed north of Atlanta, Georgia. the pipe ends are not covered with screens, small rodents can get into the piping and cause blockages. Also, if there are any low points condensation will build and could freeze.

Figure 5.5 Gravity Vent Duct

- Forced Air Systems (Forced Convection) – A forced air system also uses air vent piping below the sub-floor. Heat is introduced on one end of the piping and forced with blower fans through the pipe. The forced air system allows for consistent air temperatures within the air vent piping. Like the gravity air system, if the ends of the air vent piping are not covered with dampers and screens small rodents can cause blockages in the piping.

Figure 5.6 Forced Air Unit

Electrical Systems

Electrical underfloor heat tracing is installed inside of conduit below the subfloor. The conduit that the electrical heat tracing is installed in must be placed within the sub-floor. The electrical heat tracing can be installed after the final finished floor slab has been installed by fishing the heat tracing in the conduit. The electrical heat tracing is a self-regulated cable, meaning, the cable is set to a certain temperature. When the temperature drops below the set point the heat tracing is then activated until the temperature set point is met again. The self-regulating electrical cables ensure that only the minimum amount of heat that is required to prevent freezing is used.

Figure 5.7 Electrical heat conduit

Electrical heating cables can also work in conjunction with a thermostat and temperature sensor, the sensor will be placed within the sub-floor and relay the sub-floor temperature. The thermostat will then regulate the heating cables to maintain the desired temperature.

Regardless of the system chosen, monitoring the temperatures in the soil is a necessity. Being proactive and determining early warning signs of frost is the best way to eliminate any chances of ice forming. On a basic level, every underfloor heat system should be installed with a few RTDs (Resistance Temperature Detectors) placed in strategic locations and connected to thermostats for monitoring. However, it is highly recommended to add audible or visual alarms to indicate that the sub-floor temperatures have gone below a specific threshold. In addition to temperature alarms, there should be alarms for failed equipment such as: electrical heat cables losing power and mechanical equipment (pumps, fans etc.) failing. If the system is pressurized with a liquid source, it is recommended that pressure indicators are installed in strategic locations to determine a loss in pressure, which usually means there is a leak, blockage or break in the lines.

Checklist of items that should be considered in the proper design of a subfloor heating system:

- Operating temperatures in the completed structure
- Size of freezer area
- Depth of heating system
- Heat distribution
- Structure of sub-slab
- Proper insulation type
- Sub-floor temperature monitoring
- Relative economics- installed cost and energy consumption

- Maintenance capability of system
- Future expansions
- Ability to replace failed components
- Voltage availability
- Safety of system
- Compliance with all applicable local codes
- Ambient exterior temperatures
- Location and variation in ground water table
- Location of area within facility
- Subsoil classification
- Subsoil sustained temperature
- Drainage

5.2 Maintenance

5.2.1 Introduction

The concrete floor literally serves as the work surface for your entire distribution operation. A well-maintained concrete floor, largely free of interruptions in the floor surface, is an important part of ensuring that the floor remains productive. Concrete floor deficiencies, such as deteriorated (spalled) floor joints, pop-outs, divots, random cracks, or delamination in the surface negatively impact operations in many ways, including:

- **Productivity and Cost of Material Handling Operations** - Defects in the floor surface result in material handling vehicle operators slowing down or even taking less productive paths through the facility from Point A to Point B to avoid jarring and impact points. Defects in the floor also increase wear and tear on the material handling vehicles themselves, increasing damage to bearings, wheels, electronics, etc., thereby increasing the costs of maintenance and replacement parts.
- **Reduced Operational Safety** - Defects in the floor and the resulting impact on material handling vehicles can lead to driver fatigue and neck and back strain, as well as tripping hazards for warehouse employees. In extreme cases, sever defects can lead to load tipping or pose other hazards to the safe operation of material handling vehicle.
- **Increased Slab Maintenance Costs –** Given the constant and dynamic loads on slabs, nearly all slab defects will continue to deteriorate in an accelerated fashion unless they are corrected immediately.

- **Food Safety/Sanitation Concerns** - Open cracks and other unsealed/unfilled floor defects create spaces for bacteria or viruses to grow and dirt/debris collection, which can lead to dust settling on packaged products and customer complaints. They also create spaces for insects and other pests to live.

5.2.2 Typical Floor Problems

Figure 5.8

There are many variables involved with providing a poured floor slab. These variables include, but are not limited to the subgrade reliability, the concrete mix, the quality of the labor, environmental conditions during the pour and during the curing period. Given the diversity of the variables it is best to conclude that each floor may have some built-in deficiencies.

A concrete floor's condition can have a direct effect on a facility's productivity. Deteriorated floors lead to increased material handling vehicle maintenance costs, increased sanitation concerns, and driver slowdowns and defect avoidance. As well as, floors in a bad condition would greatly reduce the resale value of the facility.

Additionally, it is important to remember that a concrete floor is not a "static" building component. Concrete floor slabs can experience dynamic changes throughout their service life, especially during the first few years after placement. These changes can be caused by a wide variety of factors, both naturally occurring and operational, which can ultimately affect the condition of a concrete floor.

This outline is intended to provide a basic overview of the most typical floor slab condition issues that should be monitored and maintained or corrected as required. The chart below highlights some potential floor maintenance issues which can occur because of both environmental and operational issues.

	Potential Issues
Operational Changes	
Change in operating temperature in area	Development of cracks, joint dimensional changes leading to filler separation.
Change in material handling vehicle types, loads, traffic patterns	Increased deterioration of joint edge wear/deterioration resulting from smaller, harder wheels.
Dragging or pushing of pallets	Increase in floor scuffing, surface gouges, surface wear. Surface may exhibit dusting or delamination.
Change in floor scrubbing equipment or chemicals	Chemical or abrasive attack to concrete surface may lead to deterioration of finish, dusting, delamination.

Change in rack loading, locations	Slab may not have been designed for change in loading, could result in additional cracking, slab panel rocking.
Environmental Changes	
Concrete drying shrinkage	Development of cracks, joint dimensional changes leading to filler separation. Slab edge curl, elevation differences at joints, rocking slab panels.
Change in ambient humidity or temperature	Development of cracks, joint dimensional changes leading to filler separation.
Unstable subgrade, improper drainage	Development of unstable concrete panels, development of cracks.

Table 5.1

Industrial Concrete Floor Joints

The heavy and dynamic moving loads from the material handling environment make concrete floor joints the most vulnerable parts of a floor. These joints should be designed to smoothly transfer the loads across the joints to minimize potential deterioration and damage.

Maintaining these floor joints is critical to ensure their long-term stability and serviceability. All joints will need periodic maintenance. If left untreated, the joints will chip or "spall" under impact from the wheels and will lead to widening joint edge deterioration, even under nominal material handling vehicle traffic. Smaller diameter or harder wheels will cause more joint edge deterioration in a shorter period of time.

In addition to causing potential floor deterioration, open or poorly maintained joints can also present problems for proper sanitation and can harbor bacteria, insects, etc. Add to these factors the potential vibratory and wheel damage to the material handling vehicles crossing deteriorated joints and it is understandable why floor joints are typically reported as the most typical concrete floor slab issue.

Another contributor to joint damage is slab curl that results in uneven horizontal transitions of slab edges. The condition causes accelerated wear, and under extreme circumstances can become a tripping hazard for the pedestrians. Joint repair at curling conditions require more significant repairs than just filling the joints.

Designing the floor joints with a steel armored joint and/or reducing the number of joints in the slab with "Control Joint Free" concrete floor solutions can greatly reduce potential problems including slab curl.

Floor Joint Issues Potentially Requiring Maintenance/Repair

The need to repair/maintain joints can be the result of many variables, including unfilled joints, improperly filled joints, improper joint filler compound, joint filler separation (resulting from concrete shrinkage related joint opening), concrete floor slab curling or rocking conditions. It's not possible to comprehensively address every potential joint deterioration condition and cause

that a facility owner might encounter in this document, but virtually all conditions can be caught and corrected before substantial damage occurs if floor condition is audited regularly.

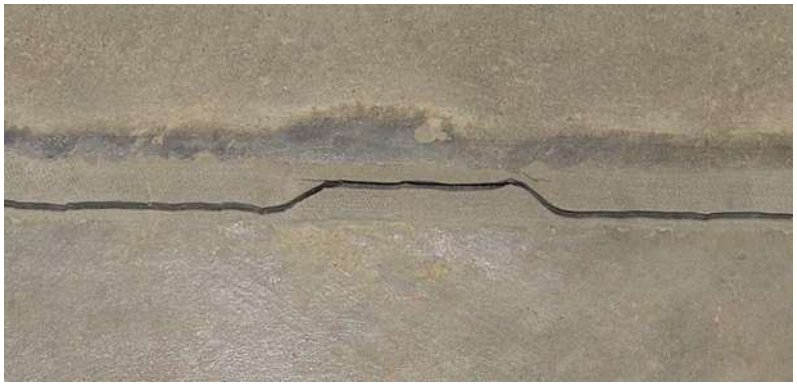

Figure 5.9 Cohesive (internal) joint filler separation

Joint Filler Separation

Concrete shrinkage results in a reduction in the mass of the slab. It should be noted that in addition to normal water evaporation shrinkage thermal shrinkage will occur in cold storage environments as the space temperatures are reduced. Concrete shrinkage affects joint dimensions - as the concrete panel mass shrinks, joint width increases. This applies to both contraction and construction joints, though the widening can be more apparent at construction joints. Because semi-rigid floor joint fillers used to fill industrial floor joints have minimal lateral movement capability (they are structural fillers, rather than sealants), and because they are almost always installed prior to substantial concrete shrinkage occurring, it's likely that the filler will tear, either internally or along the edge of the joint, as filled joints widen. This can result in a void in the filler itself or between the filler and the joint wall.

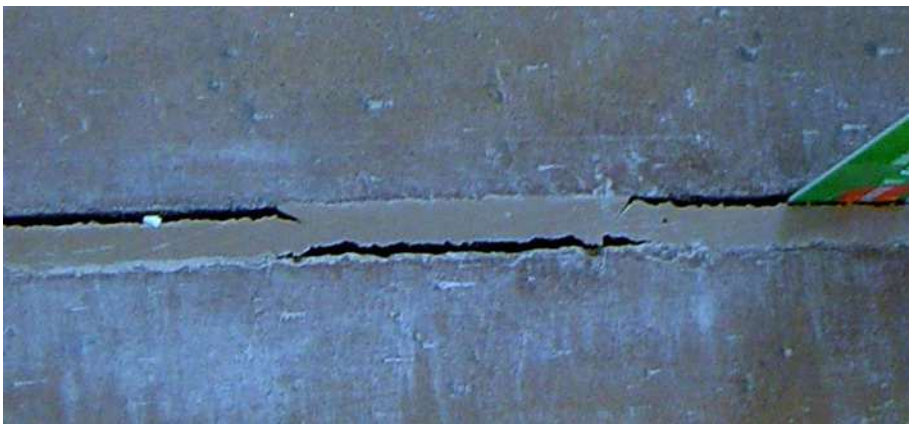

Figure 5.10 Adhesive (filler-to-sidewall) joint filler separation

Joint Filler Collapse

Sections of joint filler which experience complete adhesion loss in the presence of substantial joint dimension opening can be "punched down" below the joint edge, exposing edges to impact. This

would normally occur only in the presence of extreme joint opening (i.e. joint opens wide enough for filler to be driven below base of saw cut) or if there were underlying deficiencies in the original filler installation (i.e. shallow joint filler depth, placement over compressible foam rods or debris, inadequate joint preparation/cleaning, etc.). Joints exhibiting truly depressed filler should be easily identifiable as joint edge deterioration will likely be noted in any area where the filler has dropped in profile, substantially exposing joint edges to impact/damage. Typical repair of joints exhibiting filler collapse involves removing existing filler, re-chasing or saw cutting joint to establish clean, structurally sound edges, and refilling the joint with a semi-rigid epoxy (ambient temperatures) or semi-rigid polyurea (freezer/cooler rooms or for faster access). If deteriorated joint width exceeds 1 ½" (38 mm) structural rebuilding of concrete edges may be desirable for optimal long term durability.

Figure 5.11

Semi-rigid epoxy joint filler installed over compressible backer rod collapses, exposing joint edges to deterioration under material handling vehicle traffic.

Joint Edge Spalling

In addition to the possible cause noted above, joint edge spalling can occur as a result of many factors, including improper saw cut timing at the time of floor construction, concave or low installed joint filler profile, the installation of an improperly soft joint sealant or filler, uncorrected separation voids, and more.

Facility owners should always be on the lookout for any sign of floor joint deterioration and should seek outside assistance if the cause of the joint edge deterioration cannot be readily identified as resulting from one of the above noted conditions or if unusual conditions are noted.

While most joint edge deterioration conditions occur as a result of one of the above conditions, deterioration can also occur as a result of certain poor material handling operational behaviors (i.e. dragging or pushing of pallets, not lifting forks when crossing joints, dropping pallets or other floor impact behaviors, etc.). Deterioration resulting from material handling operations can generally be identified by either its randomness (i.e. isolated chip or spall where a fork impacted a joint edge or where a nail or other hard object was dragged under a wheel) or by its consistency in one general location where a problematic operational behavior has been identified or suspected (i.e. a particular operator drags his pallets and is in charge of loading at Door 8, all the joints at Door 8 show spalling but joints elsewhere look fine).

Figure 5.12

As with any building component, concrete floors require periodic maintenance to ensure optimal performance. Joint edge deterioration (spalling) is one example of a floor condition that can harm operational productivity if left un- maintained.

Slab Edge Curl

Slab edge curling along joints is readily identifiable by a difference in joint edge elevation across two panels. Slab edge curl is to some degree common on virtually every industrial floor, if no special means are taken to avoid it. While the causes of curl are many and still the source of much disagreement within the industry, it occurs as a result of slab panel edges or ends drying faster than the center of the slab panel, leading to a curling or warping effect, similar to the behavior exhibited by a wet sponge when left out to dry. It should be noted that there are proprietary systems available that claim to prevent curling.

Depending upon the degree of curl, it may not present any problem at all, or it may be a condition requiring corrective action. Slab edge curl warranting assessment and potential corrective action should be evident as the joint edge will begin to exhibit spalling/deterioration under material handling vehicle traffic (the higher joint edge being impacted and chipped away).

If slab curl conditions are present to the degree that material handling operations are impacted leading to joint edge deterioration, or if panels show evidence of rocking (vertical movement or deflection as material handling vehicles cross the joint) it is important to bring in an engineer, consultant or trusted industrial floor resource to determine potential need for correction and the best long term correction options.

Corrective procedures for this condition would not normally be performed by in-house maintenance staff and vary depending upon conditions, cause and degree of curl and thus will not be addressed within this narrative.

Figure 5.13

Slab edge curling leads to differential elevations between panels at joint locations, creating impact points on the higher side that can lead to joint edge deterioration. tripping risk and risk of wheel-loader accidents.

Floor Surface Issues Potentially Requiring Maintenance/Repair

Potential surface deterioration issues should be readily identifiable visually, the most likely being scratches, gouges, etc. Some surface defects, such as cracks may be related to construction or design issues, while many others tend to result from abuse of the floor directly related to material handling practices, vehicles, or housekeeping. Scratches and gouges often result from inadequate cleaning of the floor and the subsequent friction resulting from debris, wood slivers from pallets, nails, etc. being dragged under the wheel of a material handling vehicle across the floor. Improper driver material handling practices such as pallet dragging, pallet pushing, driving with forks dropped, dropping loads too quickly, etc. are all the most likely contributors and causes to any floor surface defects which might become visible. If signs of substantial or abusive surface wear are present on the floor it is recommended that the facility owner work with material handling vehicle operators to identify the potential causes leading to the deterioration and work to change the practices suspected as the most likely cause.

Some degree of general surface wear is inevitable in any distribution operation and does not necessarily pose problems for the long-term serviceability of the floor. Surface defects with the potential to become an issue can typically be identified by monitoring them for one of the following signs:

- Defect creates a substantial interruption in the continuity of the floor surface, creating potential safety concerns (i.e. tripping hazard).

- Defect creates an interruption in the continuity of the floor surface, impacting material handling operations through driver slowdowns, abrasion to material handling vehicle wheels, or impact points for material handling vehicle wheels.
- Defect shows signs of chipping, spalling or other deterioration.
- Defect compromises floor sanitation by creating a space difficult to properly clean and maintain.
- Defect shows signs of dusting, erosion, or other gradual deterioration.
- Defect shows signs of continual growth/degradation.

Among the most typical floor surface defects are the following:

Dusting

Dusting is generally a result of improper hydration of cement paste at the concrete surface at the time of slab curing or finishing procedures. It can also result from contamination of the slab surface by certain environmental sources (i.e. allowing the carbon monoxide from direct fired temporary heaters to buildup on the curing slab). If the floor slab surface is porous, chalky or inherently weak, cement paste or aggregate fines can become airborne under traffic, leading to dust settling on packaged product.

Figure 5.14

Surface Delamination

Delamination occurs when a substantial portion of the concrete paste is lost at the concrete surface, exposing larger aggregates and leading to a rough "washboard" like concrete surface. Delamination is typically related to improper concrete finishing operations during construction but can spread rapidly across the surface due to abrasion and impact of affected areas by material handling vehicle wheels or other material handling practices such as dragging or pushing pallets.

Figure 5.15

Pop-Outs, Potholes, Surface Spalls

Gouges, spalls, or holes in the concrete surface can result from many factors, both construction and operations related. Some may be a result of foreign materials finished into the concrete surface (i.e. wood) or improperly mixed concrete and some result from impact on the floor by the building owner.

Figure 5.16

Bolt-Holes

Bolt holes are holes or pop-outs left in the floor after removal/relocation of racking. In many cases where bolt removal proves challenging, bolts are often cut off in place, leaving potential impact points or tripping hazards behind.

Figure 5.17

Surface Scratches/Gouges

Deep scratches or gouges in the concrete are often caused by material handling operation related activities such as pushing or dragging pallets, having nails caught underneath lift tires, etc. Scratching can also be noted prevalently along the high sides of curled slab edges.

Figure 5.18

Floor Heaving Due to Frost

If floor heave has taken place and has deformed the floor or building, the first step in restoration is to inject heat beneath the floor by whatever means possible. The time or cost to repair damage like this varies on how much ice has formed beneath the building.

5.2.3 Repair of Freezer/Cooler Floors

While the repair methodology for freezer/cooler concrete floors is similar to that of ambient concrete floors, refrigerated areas pose some unique challenges which may require more specialized repair materials or cause the repair area to be out of service for longer periods of time. Since many refrigerated facilities have a short window of opportunity when repair work can be conducted, pre-planning defect preparation time and slower material curing times around operational access limitations is critical.

In freezer/cooler rooms, all work is being done in a closed, controlled environment and that environment typically contains consumer-bound food product. If the food product cannot be removed or isolated from repair areas, caution should be used in selecting the repair material(s). These rooms are a closed environment with minimal air exchange. This increases the potential for contamination of product stored within the room. USDA/FDA/CFIA approval/acceptability of repair products and their relative odors should be considered and established by reviewing product technical data or contacting the manufacturer of the intended repair product(s) to discuss the products in greater detail.

The effectiveness of repair products depends largely on adhesion to clean, dry concrete. Obtaining a clean dry repair area in a 24/7 cooler dock or normally wet area along with potential

contamination of the product are very common problems with slab repairs. Special equipment is often required to perform durable, lasting repairs.

Figure 5.19

5.2.4 Basic Repair Recommendations

Who Will Perform the Repairs?

The decision as to who will perform the repairs will require consideration of many factors. If the goal is to self-perform the repairs, an objective analysis of in-house personnel availability and qualification should be made. Proper repair procedures to effect long-term, permanent repairs often require specialty tools and equipment not normally found in the typical maintenance arsenal (i.e. vacuum-equipped dry-cut saws for concrete cutting and crack- chasing, hammer drills, etc.). The costs of renting or purchasing such equipment will need to be factored in to the overall repair costs.

There is no one size fits all answer to whether it is best to use in-house staff or to bring in a contractor. As a rule, it is normally best to bring in a contractor when in-house staff has limited time and capability levels, or when the amount of work to be done is substantial in scope.

But if providing significant areas of work areas at any given time appears impossible, then using in-house personnel may be the only practical option. Under these circumstances, it may be wise to arrange for the proper training of your staff by an outside source with expertise in floor repairs. Some repair material manufacturers may offer low or no cost training or can likely refer you to an appropriate source.

Avoid employing contractors who lack specific knowledge or expertise in performing floor repairs in refrigerated areas. Such work requires a level of expertise that must be attained by experience, rather than by reading manuals or product literature. If the use of an outside contractor appears to be the best option for a repair program, seek out qualified contractors by asking for references from industry associates, specialty consultants, or by contacting manufacturers of the repair products you would like to be used. It is also recommended that any contractor you consider be able to furnish you with a list of successful project references and be willing to perform some example repairs in the facility to demonstrate the skill of their work and its durability.

The use of specialty contractors is almost always mandated for the repair of substantial surface deficiencies. The application of toppings or high-build coatings requires sophisticated equipment to properly clean and/or scarify the surface in order to achieve proper adhesion. The same applies to the repair of rocking/curled slabs, major structural deficiencies, etc.

Repairs should always be performed at the area's normal operating temperatures. Raising the area temperature for the comfort or convenience of the workers will result in dynamic movement of joints and cracks due to expansion of the concrete. When the temperature is later dropped back to its original level, the joints and cracks will open wider (as the concrete shrinks) and the repair will be compromised. Instead provide workers with proper low-temperature apparel.

Floor scrubbing should be discontinued 24-48 hours prior to the start of any repair to ensure that defects are as dry as possible. Excessive moisture/frost can compromise the adhesion of repair materials or adversely affect their cure.

Preparation of the defect prior to the introduction of the repair product is critical for the success of any repair. All concrete at the defect that is structurally unsound, or contaminated by grease, oil or other foreign materials must be removed. The outer points of all repairs should have a vertical edge; feathered patches are seldom as durable as "notched-in" repairs.

Avoid shallow or tapered repairs. Because the repair can be made to vertical, straight edges, there is no need to "feather" a thin layer of concrete or patching material adjacent to the edge of the repaired area. This thin layer has a tendency to set up faster than the rest of the patching material and poor bonding results. During feathering, fine particles of the patching material are worked to the surface, and consequently, with some material(s) at that surface, where maximum strength is needed, becomes the weakest point. Flaking, spalling or breaking away can start and the result is an even more difficult maintenance problem.

Generally cracks should not be routed. If the cracks are not wide enough to accept gravity fed epoxy routing them will do more damage than good. Widening the crack (by sawing, routing) may merely increase their exposure to hard wheeled impact. Cracks that are credit card width (1/32") or greater can often be repaired merely by gravity-flowing the proper repair product into the crevice after blowing/brushing the crevice clear of dirt and debris. Cracks that exhibit edge spalls (deterioration) or "islands" should usually be "chased" (sawn out) before filling.

When outlined first by saw cuts, damaged areas can be chipped out in less time than it takes to do the job using other methods. Cuts are made around the damaged area, to a depth approximately 1/6 the slab thickness. The clearly defined area is then chipped out and the hole refilled with concrete or other flooring material.

Sawing can be done in advance; all areas can be pre-sawed, and actual repair work handled during regular working hours. The water used to cool the blade makes sawing dustless, so machinery in the area is not adversely affected. However, depending on the amount of sawing required and the location of the work area it may be prudent to schedule the work during off hours due to the noise of the sawing and possible tracking "saw mud" throughout the area. This problem is often critical when floor repairs are being made near high traffic areas of operation.

Slab curl can result in an uneven profile at the edges of adjoining slab panels and create an impact point along the edge off the higher elevation slab. This can also result in "slab rocking" when traffic loads are imposed. When repairing joints, it is always a wise to load-test each edge to determine if it deflects under load or is a discernable impact profile exists. If panels elevations vary but no vertical deflection is detected, grinding, or leveling of the higher edge may be required

prior to repair. If panels do deflect (rock), stabilization of that panel should be considered prior to repairing the joint. Continued rocking will usually cause any repair to deteriorate in short order.

Figure 5.20

Curled panel edges or rocking slabs will require special attention prior to undertaking joint repair.

Some repair material manufacturers provide basic repair advisories that repair personnel can use as guides. Consultants who specialize in floor repairs in refrigerated facilities can also be a valuable resource.

Again, it is recommended that you discuss your floor problems with industry partners who have experienced similar problems and have had them successfully addressed.

Repair Material Selection

There is a vast range of floor repair products available, and the list keeps growing., Not all are suitable for use in refrigerated facilities. A careful reading of the literature for each product is necessary. For example, many products cannot be used below 50 degrees F (10 degrees C), while others are formulated specifically for use in lower temperature ranges, including sub-zero applications. Some repair materials have maximum width limitations, are not USDA/ FDA acceptable, or may have other limitations. The selection of a high quality, suitable repair material is an important factor in guaranteeing the long-term success of any repair.

When reading product literature, you should be aware of the product hardness. The American Concrete Institute and the Portland Cement Association have indicated that products having relative hardness's of less than Shore A80 are not sufficient in rigidity to support hard-wheeled traffic without deflecting. Such deflection leaves joint and crack edges subject to hard wheel impact and the resulting edge spalling (deterioration).

On the other hand, some products may have hardness's more than Shore A100, which is literally rock-hard. These materials often have adhesive strengths greater than the strength of the concrete itself and if used to repair joints or cracks still experiencing even minimal dynamic movement they may "weld" the defect and "tear" or fracture the concrete in other areas.

Figure 5.21

If using harder “structural” types of repair materials, be certain to understand their adhesive strengths and hardness as well as the original design of the defective area being repaired (i.e. joints are cut or formed to allow movement, etc.).

In general, you should use materials classified as “semi-rigid” to fill joints and cracks, and use “structural” materials to rebuild joint edges (prior to filling), repair surface delamination and gouges, etc.

The most common repair materials for concrete floors are epoxies and polyureas. Epoxies are known for their outstanding durability but cannot be applied in sub-freezing temperatures since they may not cure. They will generally cure in cooler room environments, but their cure times are slower than at ambient temperatures and will likely require longer traffic access times.

Polyureas have much faster cure rates than epoxies, and many will cure well even at sub- zero temperatures. Both epoxies and polyureas are two component products. Polyureas are more moisture-sensitive, and repair surfaces must be completely dry. In most cases the room temperature and traffic-free time available will determine the proper material choice.

Since all refrigerated facilities deal in food and/or pharmaceutical products, it is critical that you avoid any product that might cause contamination of your merchandise. Avoid products that contain solvents if at all possible. When a product’s literature states that its solids content is, for example, 90%, this means the product contains 10% solvent. Most solvents leave a residual odor that may remain noticeable for hours, days, even months. More importantly, some solvents have the ability to penetrate packaged goods. Be especially alert to the term “methacrylates.” These products release a significant odor that holds a high potential for contamination and are known to be able to penetrate even polyethylene wraps. There are many suitable 100% solids products on the market from which to choose from when selecting the appropriate repair material.

Your standard practice should be to have any proposed repair product evaluated by the person(s) responsible for your merchandise safety. He/she should not only read the product literature and MSDS, but also perform a physical test to determine problems not identified by printed matter.

Since the early 1990’s USDA and FDA no longer test repair/maintenance products and certify them as “approved” for use in regulated facilities. All products are therefore “self-certified” by the manufacturer as meeting federal, state, and other criteria. Do not accept the term “USDA/FDA acceptable” on a data sheet as proof-positive that it is fully acceptable for your use in any given application. The final burden for acceptability and merchandise safety falls upon the facility owner.

The Installation

Figure 5.22

Repair materials should be ground or shaved flush with the floor surface to restore surface continuity.

It is always a good idea to move merchandise as far away as possible from the repair work. Closely follow manufacturer's instructions. The finished profile of all repairs should be flush (level) with the adjacent floor surfaces to facilitate the smooth movement of material handling vehicles. A flush profile with semi-rigid fillers is best achieved by overfilling the defect then razoring off the overfill once the filler has cured into a solid. Structural products must be installed perfectly flush (troweled flush) or ground flush after they cure.

5.2.5 Monitoring and Preventative Maintenance

Being a "floor conscious" owner is one of the best ways to help ensure that your distribution operation achieves maximum productivity and that your material handling vehicle maintenance costs remain low. It is recommended that a single person (generally in the operations or maintenance department) be assigned as a "steward" for the floor. An inspection of the floor should be conducted on a periodic basis (monthly or quarterly). During this inspection, any areas noted that show signs of potential deterioration or unusual wear should be mapped out and documented with pictures. This report should then have reviewed by the facility/maintenance director and any areas requiring additional monitoring, maintenance or repair can then be identified and acted upon accordingly.

Key Components of a Good Monitoring and Maintenance Program

- **Potential Corrective Action Areas Should be Prioritized** - Floor areas requiring attention should be prioritized and ranked according to severity, relative impact on operations, and urgency of any necessary corrective action.
- **Guidelines for Corrective Action Should be Standardized** - Develop an internal "Floor Repair and Correction" manual which outlines methods and materials to be used for past or typical floor defect conditions.
- **Responsibility for Corrective Action Assigned; Scheduled** - Determine whether corrective actions and/or ongoing maintenance will be performed with in-house personnel or outsourced and schedule action items.

- **Consistently Scheduled and Performed** - Whether it is weekly, monthly, quarterly, etc. will depend on each individual facility, its conditions, and resources.
- **Inspection is Comprehensive** - During the inspection, all aspects of the floor should be monitored and any changes in surface or the condition of joints, cracks, or previously performed maintenance/repairs should be observed.
- **Documentation Should be Clear and Consistent** - Areas requiring attention or additional monitoring should be mapped and photographed for easy identification by maintenance personnel or management. Documentation should be available for follow up after corrective action is taken or future monitoring inspections.

Facility owners should monitor joint activity periodically, looking for evidence of the following:

- Separation voids opening between joint filler material and joint edge on one or both sides of joint edge.
- Separation voids or tears within the joint filler material itself.
- Separation voids will generally first be seen as dark hairlines within material or along joint edges. Voids are usually not a concern to the structural integrity of the filler and its ability to protect unless they open to a width of 1/32. (credit card width) or greater. Even when voids do occur to this extent, potential exposure to joint edge damage will be dependent largely on the location and pattern of the voids. Internal separation (tears within filler) require less maintenance as they do not lead to joint edge exposure.
- Separation voids which jump back and forth across the joint or occur dominantly along one edge may require refilling if they exceed credit card or if there is evidence of joint edge deterioration/breakdown occurring at void locations. If evidence of edge deterioration is present, voids should be cleaned and filled with a semi-rigid polyurea filler. Voids showing no evidence of compromising joint edge integrity should be monitored monthly to determine overall activity over a period of time. If voids remain at consistent width over the period of 6 months, refilling activity can be considered. But it is more likely that void dimension will open and close seasonally to some degree. If no signs of joint edge deterioration are present and sanitation issues are not a concern filler separation voids generally will not require maintenance. If either concern is present, refill the voids.
- Separation void at credit card width (1/32”) = Maintenance suggested.
- Early minor separation void (<1/32”) = No maintenance generally required.

Summary

The repair of your concrete floors can provide an excellent ROI if performed properly. Most facility owners find that their floor repair expenditures are usually recouped within a year or two via increased productivity, fewer worker compensation/injury claims, lower vehicle maintenance costs (bearings, transmissions, etc.) and greatly reduced wheel replacement expenditures, etc. Always remember that your facility’s concrete floor is literally the work surface for your entire operation. Anything you do to improve and maintain its condition and productivity will pay dividends in nearly every area operation.

5.3 Modernization

5.3.1 Future Floor Designs and Practices

The future steps in the evolution of sub-floor heating systems are in the controlling, monitoring, and maintaining of the underfloor heating system. One key element in underfloor heating is to generate and disperse only enough heat to prevent the subfloor from freezer, while not introducing excess heat into the freezer. The use of a more accurately calibrated and tested equipment (sensors and controls) will allow the end user to achieve the required set points without introducing the excess heat.

Another future component to underfloor heating may be the use of heat reflective materials. By introducing a heat reflective material just above the sub-floor, you will be able to minimize the amount of heat infiltration into the concrete floor slab and lower your heat load on the freezer. Types of heat reflecting materials include ceramic coatings, films, and heat reflecting tarps. Introduction of these items will increase costs to the install of your projects, and they may currently be cost prohibitive.

Future floor designs should also include concepts of reducing the maintenance costs and needs for downtime due to repairs of the problems of the traditional concrete floor design. This would involve, considerably reducing amount of the joints in the floor, improved joint design and elimination of curling.

Figure 5.22 Heat Reflecting Tarps

Figure 5.23 Ceramic Coating On Piping

Figure 5.24 Heat Reflecting Film

5.3.2 Food Processing Floor Requirements

To ensure safe food and adequate sanitation programs, the floor requirements within the facility in which food processing and handling operations are conducted must be designed and constructed with consideration of sanitary design principles.

Here are a few key performance requirements for floors within a food processing, handling or storage facility:

- Floors in areas where product is handled or stored should be constructed of durable, easily cleanable materials.

- Floors should have slip resistant surface.
- Floors should be sloped to avoid puddles or depressions where water will stand.
- Floors should be installed and maintained to reduce the likelihood of depressions or other low areas that would accumulate moisture.
- Coved (45 degrees) at the wall to floor joints and sealed.
- Floors should have adequate drainage.

Floor Coating

Due to daily exposure of a variety of chemicals and food products in a food processing and handling facility, the floors should be smooth, impervious, corrosion resistant, cleanable, non-absorbent and in good repair. Many facilities will face the challenge of selecting a floor coating type that will preserve and protect their concrete floors while controlling any kind of cross contamination. Selecting the right type of floor coating will be essential in creating a safe working environment for employees, employers and everyone exposed to the food products within the facility.

Here are some considerations to be made, in addition to the mandatory requirements listed above, when selecting a floor coating:

- Types of chemicals that will be exposed to the floors.
- Temperature of water that will be exposed to the floors.
- Temperature setting of rooms exposed to the floors.
- Can operations shutdown to apply floor coating?
- Schedule and method of floor washing
- Heavy loads on floors.
- Any time restrictions that will require fast cure rate for floor coating.

Always consult a floor coating manufacturer or supplier to assist in providing correct product selection and choose a knowledgeable contractor with experience in the food processing industry to ensure a foundation of success.

Floor Concrete

One of the main objectives of a floor coating is to preserve the concrete floor beneath the coating, although floor coatings cannot protect the concrete against all forces. Food processing floors are subject to very extreme conditions which require a slab design that must consider several elements. The structural floor designer will be able to best select a concrete type, strength, class and composition, although they must be aware of the conditions exposed to the floors.

Some conditions to consider when designing a floor in a food processing and handling facility:

- Will the floor be present in a freeze-thaw environment?

- Will the floors be exposed to hot water wash down or any other moisture?
- Will there be any heavy traffic over the concrete slab?
- Will there be any corrosive or acidic products exposed to concrete slab?
- Will the concrete floor be exposed to thermal shock?

Floor Drains

Within a food processing and handling facility, special attention should be made to the floor drains as they can be a major source of contamination. Floor drains must:

- Be appropriately located so that they are easily accessible and equipped with removable covers that are flush to the floor.
- Have an adequate number and size.
- Be maintained in good repair.
- Be designed and installed so that they are cleanable.
- Have drain lines that are sloped, individually trapped, and properly vented to outside air.
- Be equipped with backflow preventer.

Additionally, the drainage system within the food processing, handling and storage areas should be constructed so that there is no connection to any domestic or other non-food processing drainage.

Here are some considerations to be made, in addition to the mandatory requirements listed above, when designing a drainage system:

- How often are rooms washed, for how long and with what temperature?
- Is there any heavy machinery that will mobilize over sloped floors?
- Do any equipment release water or other liquids into the drains?
- How much solids are anticipated to enter the system?
- What products are being processed that could enter the drainage system?
- Types of chemicals that will enter drainage system.

It is recommended that the drain design be created by a professional engineer with experience in food processing facilities to ensure a proper design that will meet your operation requirements.