Questions from the field about concrete floor construction

For those who know something about it but want to know more

BY A.H. GUSTAFERRO, CONSULTANT
THE CONSULTING ENGINEERS GROUP
GLENVIEW, ILLINOIS
AND THE EDITORS OF CONCRTETE CONSTRUCTION

The most consistently popular seminars at the World of Concrete have been the two-session seminars on concrete floor construction. This popularity is shown not only by large attendance year after year but by the unusual number of written technical questions that registrants turn in to be answered by the speakers. Over a period of four years, A.H. Gustaferro, seminar chairman, has collected more than 200 such questions, mostly from individuals who are dealing with concrete floor construction and its problems in the field.

The editors of CONCRETE CONSTRUCTION, in consultation with Mr. Gustaferro, have selected some of these questions and their answers for publication. Most of them were selected either because they represent a broad general interest or because they resolve a somewhat unusual problem. They have been classified as follows:

CONCRETE MIXES

Cement type

Q. *Do you recommend the use of Type I or Type II cement for concrete slabs on grade?*

A. Normally Type I is used but Type II or V should be used in slabs built on sulfate soil.

Cement content

Q. *How does too much cement affect shrinkage?*

A. It may increase the shrinkage by increasing the distance between the aggregate particles. However, the subject is debatable. Tremper and Spellman, in "Shrinkage of Concrete—Comparison of Laboratory and Field Performance," found that in the range of practical concrete mixes (5 to 8 bags of cement per cubic yard) the cement factor has little effect on shrinkage.

Calcium chloride

Q. *Can you explain the advantages and disadvantages in using calcium chloride in flatwork during cold weather?*

A. The advantage is that it cuts down on the amount of overtime by speeding up the setting and hardening rate. The disadvantages are that it causes slightly increased shrinkage and may cause discoloration. Note that calcium chloride is not an antifreeze, but is used to accelerate the rate of setting.

Air entrainment and high altitude

Q. *How does altitude affect air entrainment? Do you need to add more air-entraining agent to achieve the same quantity of air for concrete mixed at 4000 feet and transported by truck mixer to 10,000 feet?*

A. The apparent air content increases in going from a low altitude to a high altitude because the air expands. Actually, this would increase bubble size but not have as much effect on the bubble spacing. The total volume of the air would be increased by possibly three-tenths of its volume in the range that you inquire about. (Concrete with 5 percent air would increase to about 6.5 percent air.) This would cause a slight increase in yield and slight loss in strength if not compensated for. A decrease in temperature causes an increase in air content, particularly for high-slump mixes, so if the slum is high and the concrete cools during its trip uphill, the air content could increase even more. So add less air-entraining agent to get the same air content.

JOINTING

Checkerboard placement

Q. *Is it the best practice to use the checkerboarding system of placing to eliminate or minimize cracking?*

A. Checkerboarding has been advocated on the assumption that it allows some shrinkage to take place in the first group of panels before the intervening panels are placed. But this is generally a wrong assumption. Almost none of the shrinkage takes place during this period if the concrete is being cured. Actually it takes 30 days of normal drying for one-third of the water to come out of the concrete and a year for 90 percent to come out. Hence, shrinkage doesn't really begin until after the intervening panels have been placed and curing is completed. Checkerboarding requires much more work than placing the slab in strips and is generally a waste of time.

Keyed or doweled construction joints

Q. *What kind of construction joints do you recommend? Do you recommend doweling slabs together by means of steel dowels?*

A. Construction joints can almost always be of the keyed type. However such joints may allow excessive movement under heavy lift truck traffic, so if such traffic is anticipated, dowels are preferred. These dowels should be 3/4-inch diameter for slabs 5 to 6 inches thick, 1-inch diameter for 7- to 8-inch slabs and 1 1/4-inch diameter for 9- to 11-inch slabs. They should be 18 inches long and located on 12-inch centers. All dowels should be well lubricated and properly aligned so that they do not restrain floor movement. Doweling should always be done in one direction only, not in two.

Jointing at obstructions

Q. *In sidewalk construction how do you avoid diagonal cracks coming from the corners of obstructions around which concrete has been placed, such as fire hydrants, lamp posts and steel doors to basements?*

A. The best way is to run a joint to the obstruction. With proper planning this can often be done without locating this joint close to another one. In many instances it is desirable to run joints in both directions at right angles to one another, especially where, as in the case of a protruding steel doors the obstruction creates a re-entrant corner in the concrete. Fire hydrants, lamp posts and other obstructions should also be surrounded by diamond shaped or circular isolation joints in the same manner as around columns.

An alternative solution to the use of joints is to place several reinforcing bars diagonally across all re-entrant corners.

Wrapping columns

Q. *Is it acceptable in slabs on grade to separate steel or concrete columns from the slab by simply wrapping them with felt?*

A. This is a standard method of creating isolation joints in residential construction. Wrapping with felt does not eliminate, however, the need to run joints across the floor to the columns.

Saw joints for lift truck traffic

Q. *On floors to be subject to fork-lift traffic, should control joints be formed by hand or sawed?*

A. Hand-formed joints generally don't last long under fork-lift traffic. Sawed joints work better. These should be filled with epoxy sealants.

How soon to saw

Q. *How do you know when concrete has reached the 400- to 600-psi strength necessary before it is safe to saw joints in the slab?*

A. There is no easy way of making a very accurate, in-place strength test of the concrete. Actually the simplest and best way of knowing whether it is safe to saw a slab is to make a sample cut and note whether the concrete surface is firm enough so that it is not torn or damaged by the blade. A slight raveling of the top edge of the joint is to be expected. This can usually be done within about 4 to 12 hours after the slab has been placed or finished. If too long a time elapses before testing in this manner and making the cuts, random shrinkage cracks may form in the slab.

Depth of joints in toppings

Q. *How deep do you cut control joints in a 2-inch topping bonded to a concrete base slab that has a broom finish?*

A. Control joints should be positioned directly over the joints in the base slab and cut 1 inch deep, or half the thickness of the topping.

REINFORCEMENT

Mesh for minimizing crack size

Q. *What is the need or lack of need for wire mesh?*

A. This question is fairly debatable. Some agencies always specify wire mesh and others never do. It is possible to get an adequate job without the mesh. If you use it, be sure to locate it properly The Wire Reinforcement Institute recommends placing it 2 inches below the surface. Mesh located near the top of the slab will tend to minimize the size of cracks that might occur.

Crack-free slabs without welded wire fabric

Q. *Some unreinforced slabs do not crack and some reinforced slabs do crack. Is it possible to minimize the shrinkage in unreinforced slabs in order to be able to eliminate the welded wire mesh entirely?*

A. There are large numbers of unreinforced slabs that have not cracked and there are a number of procedures that are recommended to prevent cracking. If every one of these is followed most cracking can be prevented. Familiarize yourself with all the procedures included in the ACI Committee 302 "Recommended Practice for Concrete Floor and Slab Construction (ACI 302-69) and follow the procedures given there. A new edition is in preparation.

Slab reinforcement doesn't prevent cracking, it merely minimizes the size of cracks, provided that the reinforcement is located near the top of the slab.

Positioning welded wire fabric

Q. *How do you keep welded wire reinforcement within 1 to 1 1/2 inches from the top surface of a 6-inch-thick slab?*

A. The mesh really ought to be 2 inches below the surface according to the Wire Reinforcement Institute. Put down 4 inches of the slab, then lay the mesh, then put in the rest of the concrete. A second method is to support the mesh on chairs. A third method is to work the mesh in—that is, lay it on the top surface and walk over it to depress it the required amount. Another method is to lay the mesh on the ground and lift it into the required position just ahead of the flowing concrete so that the concrete is placed both under and over the mesh at the same time. Laying the mesh on the ground and waiting until after the concrete has been placed to bring the mesh up from the bottom with hooks is not recommended.

CRACKING AND CRACK PREVENTION

Not enough coarse aggregate

Q. *When you receive concrete containing little or no coarse aggregate with the sand, what is the best method of preventing cracking?*

A. First, every effort should be made to see that concrete with an adequate amount of coarse aggregate is supplied. If this is the only concrete available, however, we would suggest two ways of overcoming the difficulty. One, reduce the joint spacing to about 8 to 10 feet on centers, and two, use welded wire fabric in the floor. The cross sectional area of the mesh should be no less than 0.1 percent of the cross sectional area of the floor, for example, 0.072 square inch per foot for a 6-inch-thick floor. If steel mesh is used it should either not cross the joints or the joints should be deep enough to cut through the steel mesh.

Cracking on metal deck

Q. *I have been placing 8000- to 9000-square-foot slabs 3 inches thick over corrugated metal deck and diamond cutting them into 20- by 25-foot panels the next morning. Cracks appear 3 inches away from the diamond cuts and parallel to them, or sometimes 12 to 16 inches away. Why?*

A. We don't know the answer to this one. Possibly the problem is related to deflections and these cracks are occurring on a line where the slab is undergoing maximum flexure. If the joints are located directly over beams, the problem should be minimized.

Cracking in high-strength concrete

Q. *Many people say that high-strength concrete in slabs on grade cracks more than low-strength concrete. Is this so? Why?*

A. It is not strictly a function of strength. It is a matter of the amount of shrinkage, the amount of restraint to shrinkage offered by the subgrade and the tensile strength. Some high-strength concretes may have high shrinkage. If the increase in shrinkage is greater than the increase in tensile strength the concrete may be more subject to cracking.

FINISHING

The bleeding process

Q. *After the slab has bled and before troweling begins, where does the bleed water go? Is it troweled back into the concrete, is it squeegeed off, or does it evaporate? How do you know when bleeding is completed?*

A. Most of the time bleed water evaporates. Bleeding is completed when the surface begins to lose its sheen. Sometimes, however, bleed water does not evaporate as rapidly as it moves to the surface. If this happens, a film of water may remain for a considerable time after bleeding has actually stopped. This occurs when humidity is excessively high and no air is moving. In such circumstances the contractor and workmen may discover that the concrete has already begun to stiffen while bleed water remains on the surface. If this happens, the bleed water should be drawn off with squeegees or by dragging a rubber hose over the surface and possibly by blotting. Floating and troweling should then begin immediately.

Setting and stiffening

Q. *Sometimes the subgrade and the weather draw water out of the mix to make concrete immovable after a short time. Is this initial set?*

A. This is not initial set in terms of the condition of concrete that is measured by laboratory tests of initial set. It is, however, a time at which the concrete is ready to be floated and finished—provided bleed water has stopped coming to the surface.

Plastic shrinkage cracking

Q. *How soon after placing concrete should one start expecting plastic shrinkage cracking if there is going to be any?*

A. It could happen right after strikeoff or it may occur during finishing operations. Plastic shrinkage cracking can occur under any set of conditions which provides rapid evaporation. It is not limited entirely to hot, dry weather. For example, hot concrete on a job in Duluth, Minnesota, underwent plastic shrinkage cracking even though there was fog.

Floating and troweling

Q. *What causes the trowel to chatter when finishing a concrete slab? Also, why is a magnesium or aluminum float used?*

A. Chattering, which results in a series of straight radial lines distributed along the sweep of the trowel, is caused by tilting the trowel blade at too steep an angle.

A magnesium or aluminum float is used on concrete because it does not tear the concrete surface the way that wood floats sometimes do and it produces a smoother surface. This makes the work easier for the finisher while he is floating the concrete and also makes it easier later on for him to trowel it.

Surface tolerances

Q. *I see many specifications that require tolerances of only 1/8 inch in an 8- or 10-foot length. Are special techniques necessary to achieve this or can the average flatwork contractor meet such a tolerance? If not, what is a good tolerance that the average contractor can meet using normal techniques?*

A. A tolerance of 1/8 inch in 10 feet is probably not achieved in a large part of concrete flatwork. It is also probable that it is not needed as often as it is specified.

For this reason ACI Committee 302 (Construction of Concrete Floors) is planning to recommend several levels of tolerance so that the specifier can call for only the degree of tolerance that is needed and that he is willing to pay for. It has been suggested that these tolerances be as follows:

Finish	*Tolerance*
Class A	1/8 inch below a 10-foot long straightedge
Class A-2	3/16 inch below a 10-foot-long straightedge
Class B	1/4 inch below a 10-foot-long straightedge
Class C	1/4 inch below a 2-foot-long straightedge

The Committee recognizes that Class A tolerances are difficult to obtain and expensive. Class A-2 tolerances are more practical for many applications. Class B tolerances are generally considered practical for floors over metal decking or precast beams and they are generally suitable for residential or tile covered floors as well as floors in most offices, schools and hospitals. Class C tolerances could be specified wherever the specifier considers them adequate.

TOPPINGS AND TWO-COURSE FLOORS

Thicknesses of toppings

Q. *Can you put a 2-inch topping on a slab?*

A. Most toppings are 1 to 3 inches in thickness.

Prewetting base slab

Q. *Is the water-cement ratio in the topping affected by prewetting the surface of the base slab?*

A. Not if the prewetting is done properly. The base slab should be wetted only enough to prevent it from robbing the topping of moisture and not enough to supply additional water to the topping.

Epoxy bonding agents

Q. *Do you recommend using an epoxy to bond the topping to the base slab on ground?*

A. An epoxy bond coat can be used but it will cost more than bonding with a portland cement grout.

Portland cement bonding grout

Q. *In bonding a topping in hot weather should you use a retarder in the cement grout?*

A. A retarder is not needed if the grout is applied to the base slab just ahead of the placement of the concrete topping .

Unbonded toppings

Q. *You talked about 2-course floors, both bonded and unbonded. When would an unbonded floor be put down and why? If bonded, which bonding agent would be used?*

A. An unbonded floor topping can be used under any circumstances where it is desired to maintain some independence between the base floor and the topping. One of these is in a factory floor subject to chemical attack. For this use some companies prefer to use unbonded toppings which are left in place until they deteriorate too badly and are then removed. A new topping can then be put in place without replacing the complete floor. Another circumstance would be where there is an existing slab that is unsatisfactory in itself but that would make an acceptable base for an unbonded topping. This saves the cost of tearing out the old floor and putting in a new floor of full thickness.

No bonding agent is needed for bonding a topping to a base slab if the topping is placed on the same day as the base and not more than 75 feet behind the placing operations of the base slab. In such cases the base slab is usually given a brush finish.

If a longer period of time elapses before the placing of a topping, a bonding agent should be used. Before applying the bonding agent make certain that the surface is free of dirt, plaster, oil or debris. An excellent bonding agent is a portland cement-sand mixture made with minus 30-mesh sand. The cement and water are mixed at a water-cement ratio of 0.5 and sand is added to a creamy consistency. This mixture is scrubbed into the base slab immediately ahead of the operations of placing the topping. Another acceptable bonding agent is an epoxy adhesive which meets the requirements of ASTM C881 Type II used according to the requirements of proposed ACI Standard 503.2, "Standard Specification for Bonding Plastic Concrete to Hardened Concrete with a Multi-Component Epoxy Adhesive."

Cracks in base slab

Q. *Discuss treating old cracks in an existing concrete slab before placing a new topping. Will sand between the old slab and the new slab work to prevent cracking?*

A. It is a good idea to seal old cracks in the base slab to minimize the possibility of further movement before applying the topping, particularly if the topping is thin, and if bond between the base slab and overlay is important. This could be done by injection grouting with epoxy, by routing out the crack and filling it with an epoxy mortar, or by widening the crack and filling it with dry-pack mortar. The details for each of these techniques can be found in the literature.

If an unbonded topping is wanted, or if the base slab is no longer substantially plane, a leveling layer of sand can be used between the old slab and the topping to prevent cracks in the base from creating cracks in the topping. The topping should be at least 2 1/2 inches thick and should be provided with control joints at intervals of not more than 15 to 20 feet so that any cracks that form will be in these predetermined locations. It is advisable to cover the sand with polyethylene or other sheet material to prevent cement paste from penetrating the sand and forming a partial bond with the slab below.

Leveling a slab on decking

Q. *I have a concrete slab poured over steel beams and metal decking. The steel beams deflected more than calculated and we have a dish-shaped slab. What kind of topping should I use to level it?*

A. It depends on the kind of service to which the slab will be subjected. If it will be covered and not subjected to wear, you can use a topping that is not designed for wear-resistance. In this case you might use a concrete made with a latex such as an acrylic latex. This would have the advantage that it could be feather-edged.

If the concrete will be subject to wear you would want a topping of 3500- or 4000-psi design strength. You would have to build it up to a minimum of 1-inch-higher elevation at the edge and this would require that you use an aggregate such as pea gravel with about 3/8-inch maximum size. If this will add too much to the weight, you may want to go to a structural lightweight aggregate concrete.

VACUUM DEWATERING

Productivity of crew

Q. *How large a crew is required for vacuum concreting? What is their productivity?*

A. The crew consists of two laborers and two finishers. These four men can put down 3500 square feet per day.

Finishers operate vacuum equipment

Q. *What kind of labor disputes regarding vacuum dewatering have come about in this country? What craft operates the dewatering equipment?*

A. In this country the finishers claim the work of operating the pump. In some countries they get paid a special rate for vacuum concrete work.

High slumps acceptable with vacuum

Q. *We use a 4000-psi, 6-bag, 3-inch slump mix. Our finishers do not like the 3-inch slump. Can the slump on this mix be increased to 5 inches and still maintain 4000-psi design strength when using the vacuum dewatering process?*

A. Since the concrete will be in effect lower than 3-inch slump after dewatering is completed there is no reason why you cannot start out at a slump of 5 inches or more and still attain 4000-psi concrete or stronger.

Admixtures in vacuum dewatered concrete

Q. *What can you tell one about the use of vacuum dewatering on concrete containing various admixtures?*

A. Admixtures can be used in mixes for vacuum dewatering but it is usually unnecessary to use water-reducing admixtures.

Load applied by vacuum

Q. *Is it true that the vacuum actually creates a pressure of 1900 pounds per square foot?*

A. It is more like 1500 to 1600 pounds per square foot. A pressure of 10 psi is 1440 pounds per square foot.

High screeds for vacuum dewatering

Q. *Does vacuum dewatering compress the concrete sufficiently so that it is necessary to screed a little bit high to compensate for it?*

A. Yes. The slab is compressed about 2 percent. This means that for a 6-inch-thick slab the screeds must be set high by 1/8 inch.

Vacuum loss of fines

Q. *When minus 50-mesh material gets sucked up in the bleed water during vacuum processing and becomes lost to the concrete can this detract from the surface hardness?*

A. It does not seem to detract and may increase the wear resistance.

Sawing joints in vacuum concrete

Q. *How soon after finishing can joints be sawed in vacuum concrete?*

A. Concrete of 3000- to 4000-psi strength can be sawed within 24 hours. It is best to saw when the temperature is rising, not when it is falling.

Apparent contradiction in water retention

Q. *Please comment on the apparent contradiction of removing water by vacuuming and retaining water by curing.*

A. Although the amount of water that combines chemically with cement in the hydration process is only about 0.25 times the weight of cement, all concrete is made with larger amounts of water than this. The reason is threefold. First, water serves to provide workability. Second, having some extra water available ensures that none of the cement particles will lack the water that they need for hydration because there is a sufficient amount to surround the particles completely and fill the intervening space. Third, workable concrete with a water-cement ratio of 0.25 would have a very high cement content and would be very expensive.

When concrete is processed by vacuum a considerable amount of this water of convenience is removed. Nevertheless, there is still enough water available to the cement particles because they have now moved somewhat closer to one another though they are still separated by a continuous body of water. The amount of water in the concrete is still more than the amount required for complete hydration.

If, however, concrete of any kind—whether vacuum dewatered or not—is not cured by retaining the water, there will be cement particles which do not have adequate access to water. This is particularly true at the surface of the concrete where water will evaporate rapidly enough so that some of the particles have virtually no water in contact with them. The space between these particles will become filled with air. For this reason the cement particles will not hydrate properly and the concrete will not reach its intended strength and surface hardness.

Hardener application with vacuum dewatering

Q. *How would you apply premixed metallic hardener at the rate of 1.5 pounds per square foot when vacuum dewatering is to be used?*

A. The metallic hardener can be added immediately after removal of the vacuum mat. As an alternative it can be added before vacuuming, but adding it after removal of the mat is preferred.

Using dry subgrade to remove water

Q. *Can a dry subgrade be used in normal concrete work to produce the effect of vacuum dewatering of the slab from the bottom?*

A. This is not recommended. Although it would remove water from the concrete it would not be as rapid and effective as vacuum dewatering. Furthermore the major portion of the water would be coming from the wrong side of the concrete so that the slab would be consolidated more at the bottom than at the top where consolidation is most needed.

CURING

Begin curing soon

Q. *How soon after final troweling should a curing agent be applied?*

A. It should be applied as soon as possible to do so without marring the slab.

Discoloration from curing sheets

Q. *What is the best or proper curing method for a concrete slab containing integral color? Will the use of polyethylene as a curing sheet discolor the concrete?*

A. The use of sheet materials for curing creates a “greenhouse effect.” Moisture which has evaporated from the top surface of the concrete condenses on the bottom side of the polyethylene. Since the sheet usually does not lie completely flat this moisture collects and runs down onto the concrete, creating puddles. The concrete surface then has varying amounts of water on the surface. Calcium hydroxide from the concrete leaches into these puddles and is deposited. When the sheet is removed the surface is covered with white blotches. These really do no permanent harm and will ordinarily wear off in time but they are usually objectionable to an owner. It is usually preferable to cure colored concrete with liquid membrane curing compounds rather than with sheet materials.

Curing paper or curing agent

Q. *If water collects under curing paper, isn’t membrane curing superior?*

A. If you are concerned about the discoloration caused by the water, then membrane curing would be superior. If you are not concerned about discoloration, then curing under paper would be superior because it retains more moisture in the concrete, thus producing higher strength.

Clear versus pigmented polyethylene

Q. *Do you recommend clear or white polyethylene for outdoor curing?*

A. For most work clear polyethylene is satisfactory. During very hot weather there is an advantage in white polyethylene because it reflects sunlight and prevents excessive heat buildup. Conversely, it is advantageous to use black polyethylene in cold weather in order to absorb some of the radiant heat from the sun.

Hot-weather curing

Q. *We do some floor slab construction in weather that gets as hot as 90 to 105° F. To obtain the hardest most dust-free surface under these conditions would you allow use of spray-on curing agents?*

A. Liquid membrane curing agents meet specifications for curing of floors in this temperature range, but if they are to be used they should be applied at the earliest possible moment. For the hardest, most dust-free surface, however, it would be more effective to cure the concrete under a sheet material or—better yet—by some system of continuous contact with additional moisture, such as burlap curing, curing with soaker hoses or ponding.

Curing-and-coloring agents

Q. *Is there a curing compound available which can also be used to shade or color concrete permanently?*

A. Some companies make compounds which are combined curing compounds and sealers. We suggest that you consult with the manufacturers or distributors to see whether they have such materials available. It may be worth noting that linseed oil emulsions, used for curing and sealing concrete, have the effect of darkening the concrete. This may satisfy your requirements for some applications.

COLD STORAGE FLOORS

Materials and cooling procedure

Q. *In building cold storage floors on grade what type of cement should be used? Should the concrete be air entrained? What is the recommended procedure for lowering the temperature in the building from 70° F to -20° F?*

A. Any type of cement normally used in concrete floor construction can be used for building floors in cold storage facilities. The concrete should be air entrained with the amount of air recommended for exterior winter service for concrete of the particular maximum size of aggregate used. Recommendations can be found in the ACI 302 Standard. We do not know of any recommended procedure for lowering the building temperature but it would do no harm to lower it slowly—only about 5° F at a time—and allow an hour to elapse between stages.

SURFACE PROBLEMS

Venting heaters

Q. *Do kerosene-fired heaters used for temporary heat cause slabs to dust? If so, why?*

A. The use of heaters, if vented to the exterior so that they do not exhaust their combustion products into the room where the concrete slab in being cured, will cause no problems. However, heaters that burn fuel of any type—whether kerosene, oil, gas or coal—produce carbon dioxide. If the carbon dioxide comes into contact with the concrete, it will react with the calcium hydroxide in the unhardened concrete surface to form calcium carbonate which is a white powder. Furthermore it prevents the concrete from hydrating properly. Permanent damage will be done and the concrete will dust.

Tool-discoloration of chloride mixes

Q. *You said that curing and tools can cause problems when calcium chloride is used in the mix. What tools should not be used? What curing practice causes discoloration?*

A. Steel trowels can cause discoloration, especially with hard steel troweling. Curing with sheet materials can also cause discoloration.

Preventing curling

Q. *Slabs on grade often curl up where they meet the isolation joints around columns. How can this be minimized?*

A. When slabs curl the greatest curl is at the corners whether a column is located there or not. Most curling occurs because the concrete dries more rapidly on the top than the bottom. The top surface contracts and pulls up the edges and particularly the corners. Anything that can be done to minimize the rate of drying and to keep the moisture content as uniform as possible from the top to the bottom of the slab will reduce the curling. Some suggested measures are:

- Do everything possible to reduce the total water content of the concrete mix. This can include selecting aggregates that are well graded and provide good workability at minimum water content, using the largest maximum size aggregate possible, reducing the sand content as much as possible without interfering with workability and using low slump.
- Avoid aggregates that are known to have high shrinkage potential.
- Schedule concrete for prompt placement so that there are no delays that require the concrete to be retempered with additional water.
- Locate joints at closer intervals to reduce the total curling in each panel.
- Do not use vapor barriers under slabs but place them directly on crushed rock or gravel fill so that moisture can migrate from the bottom. Such fills should be 5 to 12 inches thick or more and designed not to retain water.
- Cure the slab well. Use curing compounds rather than water curing so that a small amount of moisture will begin to leave the concrete at an early age.
- After curing apply a coating, sealer or wax which will not only slow down the rate of moisture loss but will minimize carbonation which would otherwise contribute to the shrinkage of the concrete surface.

Hardness not directly related to curling

Q. *If you were to improve the toughness of the concrete surface would you get a reverse effect on curling due to shrinkage? In other words, would the concrete curl downward instead of upward?*

A. The hardness of the surface, in and of itself, has little or no effect on curling. It is primarily a matter of the relative moisture content of the top and bottom surfaces.

DETERIORATION AND PROTECTION

Corrosion of steel

Q. *Does calcium chloride corrode away the wire mesh or steel in the concrete?*

A. There is some uncertainty about this question. It is generally thought that if steel is covered with at least 1 1/2 inches of concrete and the concrete is kept relatively dry there will be no problem. However, in some recent experience calcium chloride has been shown to attack steel that seemed adequately protected.

It has become a standard precaution in recent years to avoid the use of more than one kind of metal in the same concrete because if the two metals come into contact they create a galvanic cell that causes corrosion of the metals and disruption of the concrete. This interaction is worsened if the concrete also contains calcium chloride.

Resistance to food acids

Q. *Lactic acids get spilled on floors in dairying, cheese processing and food processing plants as well as in some bottling plants. What type of Portland cement or what procedure would you use to produce a concrete floor that is resistant to lactic acid other than coating it with an epoxy?*

A. Resistance to lactic acid can be improved by several methods. One is to use a calcareous aggregate, such as limestone. Limestone provides additional material which can be attacked by the acid. This means that the cement will not be eroded as quickly as it would be otherwise and the floor will last longer before it must be replaced. Another method would be to use a high cement content and low water-cement ratio so that the acid would not penetrate the concrete as quickly and could be more readily rinsed off before it does as much damage. The application of a sealer such as linseed oil would make the concrete less permeable and more resistant to acid. Changing from one portland cement type to another would have little recognizable effect on the degree of resistance to lactic acid. However, high-alumina cement concrete floors have proven to be more immune to lactic acid than portland cement concrete; such floors have been adopted quite extensively by the dairy industry.

Sealers

Q. *What does a sealer do to a concrete floor? Does it protect it against salt? Do you really need it?*

A. If the concrete floor is designed and built to specifications a sealer should seldom be necessary. Sealers are applied to help plug the pores and keep liquid from penetrating them. They are also used on floors that have been improperly made or improperly cured and which have dusting problems as a result. The sealer may help bond the loose, weak particles in the surface. Most of the time you do not really need or want a sealer.

Sealers, especially linseed oil, are sometimes used to protect against salt scaling caused by deicers. If the concrete has been properly air entrained a sealer should not be needed for this purpose.

REPAIRING

Spalled joints

Q. What is the best method for repairing spalled joints in warehouse floor slabs subject to forklift truck traffic?

A. First, make saw cuts about an inch deep parallel to the joints just beyond the spalls, remove all debris and get down to sound concrete between the saw cuts. Any exposed steel should be coated with epoxy. Then apply a one-to-one portland cement-sand grout and scrub it into the surface. A 6-bag concrete mix with a water-cement ratio of 0.45 should be placed immediately and kept wet overnight. The next day a new joint should be saw cut over the old one. The concrete should then be cured. The floor can be put in service after one week.

Cracks in tank floors

Q. *How do you compensate for cracks in slabs in the bottoms of tanks that must retain water, oil, gasoline or other liquids?*

A. The cracks must first be sealed. Follow the specifications of the proposed ACI Standard 503.4, “Standard Specification for Repairing Concrete with Epoxy Mortars.” It may also be necessary to line the tanks in order to prevent absorption of the contained liquid into the concrete. If so, ACI 515, “Guide for the Protection of Concrete Against Chemical Attack by Means of Coatings, Linings and Mortars,” should be consulted.

PUBLICATION #C790033