No one likes to see random cracks in concrete floors. They're unsightly, they make floor cleaning difficult and, especially in installations such as food processing plants, they can harbor bacteria. Edges of the cracks may deteriorate when the floor is subjected to heavy use. All of this can be avoided by installing joints at proper intervals during floor construction.

Causes of floor cracking

Two of the most common causes of floor cracking are drying shrinkage and contraction due to cooling. Both of these cause a shortening tendency in slabs which is restrained by friction between the base and the concrete resting on it. The result: tensile stress builds up and because concrete is weak in tension it cracks.

Cracking can also occur when floor slabs aren't free to move independently of the building elements they're in contact with. Movement of slabs is likely to be different from that of other structural members, and if slabs are rigidly joined to the other members they may be unable to accommodate this differential movement. Again cracking is the result.

Curling of slabs on grade causes cracking, too. When the top of a slab dries and shrinks more than the bottom, the edges curl up. The weight of these unsupported edges plus any other load on the floor creates tensile stresses in the top of the slab and cracks occur.

Types of joints and how they work

Joints permit concrete to move slightly by creating planes of weakness where cracks can form. The idea is that if concrete cracks or separates at a joint it is less likely to crack at other locations. Joints are neater in appearance than random cracks and easier to keep sealed and clean. Also, the edges of a properly maintained joint are less likely to chip or span than the edges of random cracks.

Three types of joints are used in concrete floor construction: isolation joints, control joints and construction joints.

Isolation joints

(also called expansion joints) allow movement in both vertical and horizontal directions. They separate or isolate concrete slabs from columns, walls, footings and other points of restraint such as machine foundations and stairwells. No connection should be made across an isolation joint either by reinforcement, keyways or bond.

Control joints

(also called contraction joints) allow movement only in the plane of the slab and control cracking caused by restrained forces resulting from drying or cooling. Load is transferred across control joints by interlock of aggregates in crack faces formed at the joint or by contact of the tongue and groove in a keyed joint (Figure 1). Dowel bars are also sometimes used to transfer loads in floors which carry heavy wheeled traf-
fic. When wire mesh is used in the slab it should not cross a contraction joint. If it does, the joint won't open properly and cracking may occur at some other location.

Construction joints are stopping places for a day's work. They can be made to function as isolation joints by lining the bulkhead with a preformed sheet material or as control joints by using keyed bulkheads. If construction joints are located where no movement is wanted, tie bars or welded wire fabric can be used to hold the adjacent slabs together.

How to form joints

Isolation Joints—To permit slabs to move up or down very slightly relative to walls or columns, vertical surfaces of isolation joints are covered with joint material so that there is no concrete-to-concrete contact. Asphalt-impregnated sheets or other expansion joint fillers must be thick enough to permit the required movement. Joints with rough concrete surfaces require thicker joint fillers.

At columns, isolation joints are boxed out with square or circular shapes (see Figure 2). When square shapes are used, the wood form is placed so that its corners point at the control joints along column lines. Unless this is done, cracking can occur as shown in Figure 3. When circular forms are used they are generally made of plastic or fiberboard.

Figure 1. Control joints may provide load transfer through aggregate interlock, keyways or dowel bars.

Figure 2. Isolation joints separate concrete slabs from columns allowing movement in both a horizontal and vertical direction. Note that when square-shaped boxouts are used they are rotated so that the corners meet the control joints in the slab.

Figure 3. Cracking at a re-entrant corner created by failure to rotate the boxout at an isolation joint. This type of cracking can be avoided by proper joint layout.
Control Joints—Control joints can be produced in several ways: by saw-cutting, tooling, or inserting plastic strips. (See box for description of a recently developed method using a plastic ribbon.)

Cutting a groove with a power saw is the most common method of making a control joint. A variety of diamond-tipped blades is available to cut concrete containing hard or soft aggregates; blade suppliers can recommend the best choice. Lower-cost reinforced abrasive (silicon carbide) blades are suitable for use when the concrete is made with soft, free-cutting aggregates. One way of getting longer life from saw blades is to “pre-cut” the joint with a pointing trowel after the fresh concrete has been bull floated. This moves the aggregate particles aside so that when the joint is sawed later, only the mortar is cut. A straight board can be used as a guide for the trowel cutting. Further floating and troweling follow, making it important to mark exactly where the pre-cut was made so the saw operator will know where to saw the joint.

Saw cutting must be done as soon as possible after the concrete hardens; otherwise, random cracks may form in the slab. The concrete is hard enough when it isn’t torn or damaged by the blade. Saw operators should make trial cuts starting a few hours after the concrete hardens, then observe the results. If aggregate particles come loose, it is too soon to begin sawing. Joints should be sawed to a depth of about \( \frac{1}{4} \) the slab thickness. Shallower cuts are unlikely to weaken the concrete sufficiently at the joint and this can cause cracking between joints.

Another method of forming control joints is by tooling. This is usually less efficient and less economical than sawing but may be done on smaller jobs. Tooling joints are formed with a jointer having a bit deep enough to cut \( \frac{1}{4} \) the thickness of the slab. When making the joints made by plastic ribbon placed in fresh concrete

Like other methods of forming a control joint, a plastic ribbon placed on edge just beneath the surface of a freshly placed concrete slab creates a vertical plane of weakness in the slab. As the concrete hardens and the slab shrinks, the slab will crack along this plastic ribbon.

The ribbon is placed in the concrete with the tool shown here. The float pan of the tool is pushed across the slab with a wood handle or pulled across by a string attached to the front of the float pan. As the float pan is moved across the concrete slab, the vertical steel blade underneath the float pan cuts a groove in the slab and the ribbon is fed into this groove through a slender opening in the steel blade. Concrete is then finished over the top of the ribbon, and the ribbon is left in place, even after the slab cracks. If specifications require that joints be sealed, the manufacturer recommends a butyl or silicone sealant. Because the crack is so narrow less sealant is needed than would be required in other types of joints.

To be certain the ribbon is placed in a straight line, a screed or board can be used as a guide for the float pan, or a stringline can be struck on the concrete and used as a guideline. The ribbon is usually installed immediately after the concrete has been screeded, but it can also be installed when the concrete is just starting to set and is able to support the weight of a worker.

Any of three different ribbon widths, up to \( 1 \frac{1}{2} \) inches, can be placed by the same tool with only minor alterations. Regular surveyor’s tape in a \( 1 \frac{3}{16} \)-inch width can be purchased from most building materials suppliers for use in the tool.

By this method, a joint 25 feet long can reportedly be installed in about 30 seconds, and the cost to install joints is said to be less than 3 cents per foot. The tool used to place the ribbon costs about $100.

Figure 4. Butt-type construction joints may be formed with or without provision for load transfer. Bonded construction joints are occasionally needed and can be built using tie bars instead of dowels.
groove, a straight board can be used as a guide to ensure that the joint is straight.

Preformed plastic strips can also be used to form control joints. Before the strip is inserted into freshly placed and bull floated concrete, a stringline is snapped at each joint location. A slot should then be cut in the fresh concrete along this line. Care must be taken to keep the strip vertical when placing it in this slot. If placed at a severe angle, the plastic strip forms a wedge-shaped lip of concrete that may later break off. As with all other control joints, the depth of the strips should be at least \( \frac{1}{4} \) of the slab thickness.

Construction Joints—Butt-type construction joints (see Figure 4) are formed by a bulkhead and are satisfactory for thin floors that aren't heavily loaded. Dowels can be added at butt-type joints to provide load transfer in floors carrying heavier loads.

The side forms or bulkheads for slab-on-grade construction can also be keyed so that the slab will have a tongue and groove construction joint after concrete has been cast on both sides. These keyed joints act as control joints, permitting slight horizontal movement but no vertical movement. On the surface, a keyed joint often looks like a ragged line unless both sides of the joint are edged or a sawcut is made as shown in Figure 5.

Spacing and layout of joints

Figure 6 shows a typical layout of joints in a floor on grade. It is common practice to construct floors in long lanes and to locate control joints, whether sawed or keyed, along column lines. The contractor can start at one end and place each successive lane after the previous one has hardened; another approach is to construct alternate lanes, but this may require more side forms.

Joint spacing should also be chosen so that concrete sections are approximately square. If sections have length-to-width ratios greater than \( \frac{1}{2} \) to 1, they are likely to crack between joints.

Often, locating joints only along column lines doesn't provide close enough spacing to prevent cracking between joints. Curling is also more severe when joints are too far apart. A rule of thumb for plain slabs is that joint spacing in feet shouldn't exceed two and one-half times the slab thickness in inches. However, other factors besides thickness can influence the

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<th>Slab thickness, inches</th>
<th>Less than ( \frac{3}{4} )-inch aggregate: spacing, feet</th>
<th>Larger than ( \frac{3}{4} )-inch aggregate: spacing, feet</th>
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Note: Given spacings also apply to the distance from control joints to parallel isolation joints or to parallel construction joints. Spacings greater than 15 ft. show a marked loss in effectiveness of aggregate interlock to provide load transfer across the joint.
required spacing. These include the slump of the concrete and the maximum size of coarse aggregate. Suggested joint spacings based upon these factors are given in the table.

Another consideration in planning joint layouts is the need to eliminate re-entrant corners. As shown in Figure 3, cracking is very likely to occur at any location where a sharp inside corner exists. Joints should be located where cracks are most likely to appear.