WHY JOINTS ARE NEEDED

This paper focuses on the need for and how to install control (relief) joints in concrete. To a limited extent, other joint types (expansion, isolation and construction) are discussed in order that the difference between a control joint and other common joints employed in the concrete industry.

There is movement in structures; regardless of size, height, width, the structure moves. To accommodate or cushion structural movement, there is need for elastic joints at varying strategic locations throughout the exterior of a building. In addition to the problem of potential torsion, seismic, or vibration stresses, the dimension and location of joints are directly related to the tolerances and thermal movement characteristics of various substrates that make up the structure, potential shrinkage, and design aesthetics.

Concrete is normally subject to changes in length, width, depth or volume caused by changes in its moisture content and/or temperature, reaction with atmospheric carbon dioxide, loads (dynamic and/or static) and other forces. Joints are a designed feature, because of the dimensional changes concrete goes through to allow for:

Control
1. Drying Shrinkage
2. Carbonation
3. Irreversible creep

II. Cyclical Contraction
1. Environmental Differences (Humidity, Moisture Content and Temperature)
2. Application Loads (Expansion or Contraction)

III. Abnormal Volume Changes
1. Permanent Expansion
   a. Sulfate Attack
   b. Alkali Reaction (between cement and certain aggregate)

The results of these changes are movement (permanent and/or transient) of the concrete element.

STRUCTURAL DESIGN REQUIRING JOINTS

I. Structures not under fluid pressure (most civil-engineered projects)
II. Containers subject to fluid pressure (dams, reservoirs, tanks, pipe linings)
III. Pavement highway and airfield

TYPES OF JOINTS AND FUNCTIONS

Control: When contraction forces associated with curing shrinkage and movement associated with thermal actions or mechanical loads are restrained, then cracking will occur within concrete when the tensile stresses exceed the strength of the concrete. Joints and cracks will open up and become wider as the concrete contracts (shrinks).

Expansion: If expansion movement is restrained, it may result in distortion and cracking within the unit or crushing of its ends and transmission of (design) unanticipated forces to the abutting elements. Joints and cracks will be closed and the forces will cause spalling if objects preclude the closing.

Deflection: When deflection (torsion, flexural, etc.) movement stress is anticipated that may exceed the materials structural design strength limitations, isolation joints are employed.

I. CONTROL (RELIEF) JOINTS

Control joints are saw cut, tooled, formed or a bond breaker (plastic or metal strip) is added to provide a weakened plane. They are designed to regulate and control shrinkage crack locations that normally occur in concrete segments. Since the joint is expected to control the location of crack, these joints are often referred to as control or (stress) relief joints. Without the control joint, tensile stress induced cracks would occur at unpredictable locations, thereby relieving the concrete of build up internal stresses.

They are frequently used to divide large, relatively thin, structural units or sections, for example:

- Pavement
- Floor slabs
- Canal linings
- Retaining walls

Control joints form a complete break, which in the case of floor slab, the joint is designed to go completely through the unit. Allowing each floor slab to function independent of the other.

They can also be designed to not act isolated from the adjoining floor slab. If the control joint is saw cut or tooled to one quarter of the floor slab thinness (and the joint is not wide) there may be aggregate interlock, perhaps coupled with wire mesh restraint. Where greater continuity is desired from floor slab to floor slab dowel (usually slip bars), stepped or keyed joints may be employed, To protect the floor slab contraction joint from the deleterious effect of hammer loads (impact from small wheeled carts or vehicles) it is necessary to fill the joint with a semi-rigid stress relieving epoxy material expressly designed to reinforce joint nosing to prevent spalling and raveling,

NOTE: Semi-rigid epoxy resin system should comply with ACI 302.1R-15

II. EXPANSION (ISOLATION) JOINTS

Expansion joints (also referred to as expansion contraction joints) are used to isolate on structural element from another to prevent crushing and distortion, such as displacement, buckling and warping. They are sometimes called isolation joints because they are used to isolate structures that behave in different manners. Example, they are used to isolate abutting concrete structural units that might otherwise cause distress in one or both of the units that might otherwise cause distress in one or both of the units due to transmission of compressive forces that develop during expansion, under applied loads or differential settlement.

Isolation joints are used primarily to isolate walls from floors or roofs, columns from floors or cladding, and pavement slabs and decks from bridge abutments - thus the name "isolation joint".

Where greater continuity is desired from one structural unit to the next (floor slab to floor slab or floor slab to stem wall) reinforcing bars or dowels, stepped or keyed joints may be employed.

To protect and fluid proof the joints (prevent egress of fluids in or out of the structure) when movement will occur required the use of a flexible joint filler (sealant or assemblage).

NOTE: Elastomeric (urethane, silicon, etc) joint sealants should comply with ACI 302.1R-15 and ACI 504.

III. CONSTRUCTION (INTERRUPTION) JOINTS

Construction joints may be planned or unplanned. Planned construction joints are incorporated into the structural units for several reasons, such as precast elements length restriction or during a concrete pour due to configuration or "trick" form placement requirements. Planned construction joints can be called upon to function as expansion joints to accommodate the normal or even radical movement of a structure. Planned construction joints are usually treated in a similar fashion to expansion joints listed above.

Unplanned construction joints usually occur due to unforeseen concrete placement difficulties or forming restrictions.

In the case of unplanned and unwanted construction joints due to unforeseen interruption of concrete placement, an injection adhesive can be used to bond the units together. Thus, providing a monolithic structural unit as originally designed, by permanently welding the unit together at the construction joint.

NOTE: Epoxy injection adhesive should comply with ACI 503 and ASTM C 881-87 Type W. 1.0

CONTROL JOINT DESIGN CONSIDERATION

Epoxy joint fillers are formulated to reduce or prevent the deterioration of industrial floor joints subjected to impact and point loading from steel and hard-wheeled vehicular traffic. The semi-rigid epoxy joint grouts were designed to reduce spalling of the floor joints caused by steel or hard rubber wheeled vehicles in warehouses, manufacturing facilities and industrial plants.

1.1 Joint Fillers: Semi-rigid epoxy joint grouts were specifically developed to fill control (relief) joints and inductive loops in concrete floor slabs.

Caution: A semi-rigid epoxy joint filler, in most cases, should not be used if the joint to be repaired is an engineered expansion and/or isolation joint, or in otherwise working or moving. The benefits of reinforcing the joint, out weigh the effects of a small stress crack which may develop between the epoxy joint filler and one side of the concrete joint or as a cohesive failure within the joint filler itself.

Semi-rigid epoxy joint fillers are formulated to provide a joint grout material with a tough resilient wearing surface capable of accommodating limited joint movement. Separation of the joint filler from either side of the joint or internal cohesive hairline cracking does not necessarily indicate failure of the semi-rigid epoxy joint filler application. Further, curing shrinkage after the joint has been filled, or other contraction movement may exceed the stress-relieving capabilities of the epoxy joint filler, leading to cracking or splitting. When separation does occur, actual in-service conditions will determine whether or not Bother repairs are required.

Semi-rigid epoxy joint fillers subjected to "excessive movement" may be subject to cracking and spalling, thereby failing to or reinforce the joint as intended.

1.2 Temperature Changes: The upper and lower service temperature limits must be considered. If the slab will be exposed to thermal cycling, freeze/thaw or extreme seasonal variations in temperature, or if there are other special conditions (freeze rooms, etc.), consult the manufacturer.

1.3 Construction Sequence: Construction sequence or joint filler installation sequence will require a compromise between working and curing time. A fast curing product has a short working time; the advantage is that the floor can be put back into service sooner than a product that is slow to cure. Corresponding longer working time products may be easier to work with, but they are slower to cure. Sufficient cure prior to exposure to traffic is necessary to insure against costly repairs and additional downtime in the future.

2.0 MATERIAL CONSIDERATION

2.1 Application Characteristics: All epoxy joint fillers change their handling characteristics when they are conditioned to the prevailing ambient temperature fluctuation.

At low temperature they become more viscous (less fluid) and, unless they are heated, often time more difficult to apply. High temperature causes a decrease in viscosity and a reduction in non-sag properties.

It is important to determine the application temperature range and select a product with handling characteristics suitable for that range. Use of more than one product or product modification may be required to accommodate a wide temperature range associated with year-round work.

2.2 Curing Characteristics: Working time and cure times are affected by the ambient and substrate temperatures.
Working Time: Pot life and open time are the two elements, which make up working time.

Pot Life: Pot life is the time a predetermined quantity of mixed product is workable in the mixing vessel just prior to gel. Elevating the material's temperature and/or increasing the volume of the material mixed will decrease its pot life.

Cure Time: Cure time or cure rate accelerates with an increase in ambient and surface temperature. There is a minimum temperature below which formulations will cease to cure and/or cure at a rate that is too slow for the intended use.

2.3 Cure Characteristics: The bond strength of epoxy joint filler to the concrete surface is dependent on the surface preparation, substrate durability at the interface, the bonding ability of the epoxy joint filler material itself and the sand loading, if any. An epoxy's ability to bond can be formulated to tolerate both dry and damp surface conditions, however, for best results the substrate should be clean and dry.

2.4 Toughness: To maintain integrity in use, joint filling epoxies must be tough and impact resistant to prevent gouging, chipping and spalling from steel and hard rubber wheeled vehicular traffic and other abusive conditions.

2.5 Chemical Resistance: The resistance to chemicals is dependent on the inherent resistance of the resin and hardener formulation, the temperature and duration of exposure and the integrity of the application. If chemical resistance is an important design consideration, the installed epoxy joint filler should be free of pinholes, holidays, dishing and other defects, as well as having resistance to the specific chemical(s) that is required to withstand (consult the material manufacturer for chemical resistance details).

3.0 SURFACE PREPARATION

3.1 General: Joints to be filled must be clean and sound, if a bond is desirable. In all cases this will require some form of surface preparation.

3.2 Contaminants: The presence of grease, wax, or oil may be detected by dropping a small amount of muriatic acid onto the surface. No reaction or a little reaction indicates that the surface is contaminated. Oil penetration of the concrete surface can also be detected by raising the temperature of a small area to about 150T with a heat Iamp. Oil contamination is indicated if an oil film appears or if the surface becomes greasy to the touch, 3.3 Cleaning Procedures:

1. Grease, wax and oil contaminants can be removed by scrubbing with an industrial grade detergent or degreasing compounds, followed with mechanical cleaning. Severely contaminated joints may be saw cut with a blade slightly oversized.

2. Weak or deteriorated concrete must be removed to sound concrete by bush hammering, needle scaler, abrasive grit blasting, vacuum shot blasting, scarifying, water blasting or other suitable mechanical means.

3. Dirt, dust, laitance, form release agents and curing compounds should be removed by water cutting or abrasive grit blasting.

   Caution: Acid etching (15% solution of hydrochloric acid) is recommended only when there is no practical alternative. Etched surfaces must be thoroughly scrubbed and flushed with a large volume of potable water. A moist pH paper reading of 10 or more will indicate that the acid salts have been removed.

4. Dust residue from mechanical cleaning may be removed by vacuuming, water jet or by clean, oil free high pressure air.

4.0 APPLICATION TECHNIQUES

4.1 General Installation Techniques of Epoxy Joint Fillers: Prior to installing the epoxy joint filler, the joint surface must be dry and free of all substances detrimental to the bonding of the epoxy compound. Concrete should be prepared in accordance with the procedures outlined in Section 3. (If "cannot dry" conditions exist, contact the manufacturer for product and/or procedural recommendations, including special installation techniques, if any.)

4.2 Installation Contractor: Only installation contractors who are experienced specialty contractors should install the epoxy joint filler. Epoxy joint filler contractors with control joint grouting experience and competent trained application personnel will provide installation services that meet the owner's needs.

Contractors with limited experience or no previous experience in placing epoxy joint fillers should contact the manufacturer for application assistance or subcontract the work. Contractors with limited experience should start out in a small area, mixing only enough material to complete a few feet of joint.

The installed material should then be allowed to cure before attempting *any* further installation work. If the test is successful, the contractor can proceed at an increasing application rate until reaching maximum productivity. If the trial application fails for any reason, contact the manufacturer for additional application assistance.

4.3 Material

Preconditioning: To facilitate speed of cure, mixing and application of the epoxy joint filler, it may be preconditioned above ambient temperature. Uniform preconditioning will require approximately 24 hours (in most cases, do not exceed 90°F).

CAUTION: While preconditioned material may facilitate ease of installation, higher material temperature accelerates gel time and shortens pot life and corresponding working life.

4.4 Mixing: Epoxy joint filler materials must be thoroughly mixed to disperse pigments and fillers, which may have settle during storage.

To ensure proper cure, it is important that all components of the epoxy joint filler are carefully measured and adequately mixed per the product technical data sheet. While the components are being mixed, the sides and bottom of the mixing vessel should be scraped with the mixing paddle.

Thorough mixing will take 3-5 minutes using a Jiffy® mixer with a blade guard type mixer and a variable speed drill set at a low speed to avoid entraining excessive air.

CAUTION: Do not add solvents unless that procedure is specifically recommended on the technical data sheet.

4.5 Method of application: Epoxy j o t fillers can be installed with a wide range of application tools, such as a deformed or "v" bent tin can, to state-of-the-art plural component metered mixing equipment.

4.6 Installation Procedure: Installation procedures *vary* based on job conditions and equipment available.

Prepare the joint: Prepare the joint to epoxy grouted per the instructions listed above and per the manufacturer's recommendations.

Mixing: Mix the material with an electric variable speed drill, at a low speed (less than 400 Rpm's). A Jiffy mixing paddle or other similar paddle with a blade guard should be used.

Always thoroughly mix each component separately to ensure proper pigment and filler dispersion, before mixing the components together. If sand is to be added as a third component, it must be added only after a complete and uniform mix of the resin and hardener has been obtained.

Epoxy joint fillers installed to or or reinforce a control joint are normally installed without the use of "backer rods" or other foam fillers.

Joints with exceedingly wide "through cracks" at the base should be filled to 118" of #70-90 mesh U.S. Sieve size fine aggregate poured directly into the control joint just prior to placement if the material to reduce epoxy joint filler material loss.

If the crack is wide enough to allow fluid outflow, a second epoxy grout pass may be required. Allow the first application to gel prior to placing the second application.

Fill the joint to the top and crown if conditions permit. All liquids, except water, will shrink as the liquid transform to a solid. The over-filled or crowned epoxy grout will allow for shrinkage to occur and any remaining crown material will be worn flush by vehicular traffic.

Uneven or Sloped Slabs: Most epoxy joint filler materials will attempt to self level. When a self leveling material is not desired, a high build series of epoxy joint fillers should be specified to reduce the materials tendency to self level. Under severe sloped conditions, the use of high build material alone may not be sufficient to avoid excessive flow of the epoxy joint filler from the joint. Under these conditions, it may be necessary to use the high build series in conjunction with multi-pass applications to accomplish full-depth, level grouting, while avoiding excessive material loss.

5.0 OPEN TO TRAFFIC

5.1 Open to Traffic: Ideally, traffic should be kept off of the epoxy grout material until full cure is reached. However, access can usually be granted to moderate traffic prior to full cure. The actual time when the slab can be "open to traffic: will vary based on reactivity of the epoxy grout installed and the temperature of the host substrate. Open to traffic time, in most cases, will run between 4-24 hours, depending on the material selected.

5.2 Early Access: If access must be granted to the owner or operator prior to the epoxy joint filler reaching a tack free state, broadcast a 70-90 mesh aggregate, to excess, on the exposed epoxy joint filler to reduce tracking of the material. In most cases, premature access will, however, void the warranties and guarantees offered by the manufacturer for that area where the access is required.

6.0 PHYSICAL PROPERTIES

6.1 Semi-Rigid Epoxy Joint Filler: semi-rigid epoxy joint filler should possess these physical properties:

Long term adhesion to the faces of the joint
Resistance to creep, slump pr cold flow
Resistance to shrinkage
Non-bleeding and non-staining properties
Adequate elastic properties to accommodate movement without splitting
Resistance to aging
Compatibility with floor and overlay design
Resistance to specified chemicals
Adequate hardness and abrasion resistance
Retention of physical properties
Stability in storage
Ease of mixing
Ease of installation

6.2 Reasons for Failure: Prior to replacing semi-rigid epoxy joint filler the reason for failure should be determined.

Unsuitable joint filler specified and installed
Joint dimensions that do not match specification and/or product capability
Joint movement is greater than anticipated
Incorrect mixing of multi-component material
Improper application of material
Lack of chemical resistance