Concrete crack and joint repair with water reactive polyurethane injection resins / foams

PART 1 GENERAL

1.1. SECTION INCLUDES

A. Materials, equipment and procedures to pressure inject water reactive polyurethane injection resins / foams, for sealing concrete cracks.

1.2. REFERENCES

A. Test certificate K-25015-15-Ko according to the Guideline for Hygienic Assessment of Organic Coatings in Contact with Drinking Water, Hygiene-Institut des Ruhrgebiets
B. Test certificate K-197565-10-Ko according to the Guideline for Hygienic Assessment of Organic Coatings in Contact with Drinking Water, Hygiene-Institut des Ruhrgebiets
C. Test of the Performance and Specific Properties of the Polyurethane Resin. According to DIN EN 1504-5. MPA TU Braunschweig, Doc.-No. (5176/511/13)

1.3. SUBMITTALS

A. Submit two copies of manufacturer's literature for products furnished, including:
   1. Application instructions.
   2. Appropriate Material Safety Data Sheets (MSDS).
   3. Other safety requirements.

1.4. PERFORMANCE REQUIREMENTS

A. The base of crack and joint repair / waterproofing system should be water reactive polyurethane injection resins / foams. Resins only react when in contact with water and immediately form a stiff or elastic, waterproof polyurethane foam which permanently seal the cracks. The injection is carried out using conventional single component injection pumps, injecting the mixed resin through injection packers inserted in previously drilled holes. The waterproofing system shall be manufactured by KOSTER Bauchemie AG, Aurich, Germany.

1.5. QUALITY ASSURANCE

A. Manufacturer Qualifications:
   1. Manufacturer shall have no less than five years experience in manufacturing water reactive polyurethane injection resins / foams, for sealing concrete cracks. The system shall be specifically formulated and marketed for crack injection waterproofing. System design shall not have changed for a minimum of five consecutive years prior to start of the work.

B. Submit a letter attesting to the following:
   1. Workers that will perform work for this section have a minimum of 5 years experience, successfully applying the materials specified in the section, or that workers have been properly trained, and will be supervised by someone who is properly trained and has the necessary experience.
   2. Workers and supervisors have read and understand requirements described in the manufacturer's literature, and application instructions.
   3. Workers will have proper and adequate equipment, including two separate pumps; one for pumping water, and one for pumping resin, so as to be able to complete the work according to provisions of this section, and the manufacturer's instructions.

1.6. DELIVERY, STORAGE AND HANDLING

A. Deliver materials to job site in sealed undamaged containers with labels intact and legible, indicating material name, date of manufacture and lot number.
B. Store products indoors or outdoors and covered, in an approved ventilated dry area; protect from contact with soil, dampness, freezing and direct sunlight.
C. Handle products in a manner that will prevent breakage of containers and damage to products.
D. Products should not be stored in areas with temperatures over than + 30 ºC or below + 10ºC.

1.7. PROJECT CONDITIONS

A. Install materials in accordance with safety and weather conditions required by the manufacturer or as modified by applicable rules and regulations of local, state and federal authorities having jurisdiction.
B. Seal doors, windows, air intakes, elevators and other openings that could allow vapors to migrate into occupied spaces.
C. Ventilate interior and exterior application areas, and all occupied spaces adjacent to application areas, during the application of resin.
D. Remove open fires and spark producing equipment from the application area until vapors have dissipated.
E. Curing conditions for water reactive resin:
   1. Cracks/Joints must be wet or the materials will not properly react and cure.
   2. Do not apply if the air and/or substrate temperatures are lower than + 5°C or if temperatures are expected to drop below + 5°C within 24 hours of application; or higher that 30°C).

3. Cure times are affected by water temperature. Lower temperatures and/or lack of water can extend or prevent curing.

1.8. WARRANTY

A. Installer of waterproofing system (concrete crack and/or joint repair) shall provide standard installation warranty for workmanship.

PART 2 PRODUCTS

2.1. MANUFACTURER

A. Acceptable Manufacturer: KÖSTER BAUCHEMIE AG • Dieselstraße 1-10 • D-26607 Aurich • Tel. 04941/9709-0 • Fax -40 • info@koester.eu • www.koester.eu
B. Substitutions: Not permitted.
C. Requests for substitutions will be considered in accordance with provisions section.
D. Provide the materials of one manufacturer throughout the project

2.2. MATERIALS

Water reactive elastomeric chemical resins meeting or exceeding the following typical physical and performance properties: **KOSTER IN 1, KOSTER IN 7, KOSTER 2 IN 1.**

A. Koster IN 1- Water activated hydrophobic, rigid closed cell PU injection foam for rapid reaction with flowing water. The material only reacts when it comes in contact with water and immediately forms a stiff, waterproof polyurethane foam.
B. Koster IN 7- Viscoplastic, water activated PU injection foam. Reacts only when in contact with water and spontaneously forms a compact, viscoplastic, waterproof polyurethane foam which is able to follow crack movements.
C. Koster 2IN1- Solvent-free PU injection resin for dry and water bearing cracks. Material forms an elastic foam when coming into contact with water which pushes the water out of the crack. If no water is present the material forms an elastic solid body resin and permanently seals the crack.

Table 1 - Typical physical properties for urethane resins

Property	Measuring standards and conditions	Results
Appearance	Visual	Pale yellow
Viscosity	ISO 2555 (at +25°C)	250-300 mPa.s
Density of the mixture	DIN 53479	1,1 kg/litre
Flash point		107°C
Corrosiveness		Non-corrosive

Table 2 - Typical performance properties for urethane resins / foams

Property	Measuring standards and sonditions	Results
Volume expansion		1:20 – 1:30
Density of the fully cured foam		0,05-0,1 g/cm3
Tensile strength	ASTM D 3574-86	0,55 – 0,62 MPa
Elongation	ASTM D 3574-86	30 - 800 %
Shrinkage	ASTM D 756 Procedure D, ASTM D 1042	<10 % linear shrinkage
Toxicity		Non-toxic in cured form, contact manufacturer for more information

2.3. ACCESSORIES

A. Additives and cleaners as recommended by manufacturer.
B. Oil-free oakum or open cell urethane backer rod.
C. Koster PUR Cleaner, or other suitable solvent as recommended by the manufacturer.

2.4. EQUIPMENT

A. Two electrical injection membrane pumps are required, one for pumping water and one for pumping reactive resin. Pumps have to be suited for low and high pressure injection of liquid media (without the addition of compressed air). Pumps must have a maximum pressure capacity of 0 – 200 bars and a volume capacity of 2,2 litre/minute at full pressure.

Example: (supplied by KÖSTER BAUCHEMIE AG)

1. Koster 1C Injection Pump

B. Solvent and moisture resistant high pressure hose d=6mm, with a minimum length of 5 m.
C. Two application control valves with fluid filled gauges, and dampeners, 0-250 bars, that are compatible with pumps.

D. Superpacker or One-Day-Site Packer with cone or pan head fittings, usually 10 or 13 mm diameter, supplied by KÖSTER BAUCHEMIE AG. Packers should have a cone shaped flange in the gasket section that ensures that the pressure is exerted deep in the drill hole, providing an excellent seal and ensuring a permanent fixation in the drill hole.
E. Hammer drill, air powered or electric. Example: Hilti, Bosch, Black and Decker or similar.
F. Concrete drill bits various lengths and proper diameter to match injectors.
G. Generator and/or compressor.

PART 3. EXECUTION

3.1. PREPARATION

A. Clean mineral deposits (if present) from the crack face. This should help the applicator inspect the cracks, to understand crack location and size. Precise crack location is required to determine location of the holes for injectors. Crack size determination is required to decide injector spacing.
B. Crack cleaning may be done by one or all the following methods: high pressure water, wire brush, light duty chipping hammer, grinding wheel.
C. Remove any and all materials that are in the joint area. Clean out the joint completely if possible. Joint cleaning can be done by the same methods listed in “B”.

3.2. EXAMINATION

A. Inspect the areas to be sealed with resin to assure that the surfaces are clean and wet. Materials will not properly cure if pumped into a dry crack/joint.
B. Assure that the injectors are properly seated, to avoid leaking material, and a loss of pumping pressure.

3.3. APPLICATION – DRILLING HOLES FOR INJECTORS

A. Do NOT drill directly into a crack unless concrete is less than 15 cm thick, or if offset drilling is not possible.
B. Injection Test Holes: Drill one or two injection holes on the right or left side of the crack. These first injection holes are test holes to determine which side of the crack should be sealed first and how far materials will travel along the crack. Only the water pump should be charged and ready to pump for test holes. If something goes wrong during test hole pumping, it is very easy to clean a water pump.
C. **Do not fill the material pump, or open pails of resin, until AFTER the test hole pumping**.
D. For a vertical wall, always begin drilling at the lowest point of a crack and work up. Drill the first injection hole at the lowest point on the crack possible. Drill the second injection hole on the same side of the crack, approximately 30 cm up the crack from the first injection hole. Remember that injection holes are drilled at a 45-degree angle to intersect the crack halfway into the concrete.
E. Drilling injection holes in concrete less than 15 cm thick:
    1. Concrete 15 cm thick or less may require drilling the injection holes directly into the cracks to properly seal them.
    2. Drill the injection holes deeper than 5 cm, but not more than 12 cm deep, to expose a larger area of crack surface to the materials. This will allow deeper penetration and better pressure relief. More crack surface area exposed in the injection hole equals lower pump pressure required to seal the crack. Surface sealing the crack may be required.
F. Drilling injection holes in concrete 15 cm – 90 cm thick:
    1. Determine injection hole position. This is one of the most important phases of the sealing process. Correct injection hole position allows proper injector installation and adequate material pumping. Incorrect injection hole position may prevent resin flow into the crack.
    2. A simple rule of thumb for injection hole location is: the distance from the crack to the injection hole origin, equals one-half of the concrete thickness. For example, drill injection holes for 30 cm thick concrete 15 cm from the crack.
    3. Drill injection holes at 45 degree angle to intersect the crack halfway through the concrete. At a 45 degree, angle, the injection hole depth equals the hypotenuse of a right triangle.
    4. Drill injection holes deep enough to assure intersection with the crack. Drill hole depth is unpredictable because crack direction is irregular. Drill an injection hole and test for crack

intersection by pumping water into the hole. (Note: a 40 cm deep 45 degree angle injection hole can be drilled into 30 cm thick concrete without drilling through the concrete. If the injection holes are not properly drilled, the materials may not be evenly pumped into cracks, and may not completely seal the entire crack depth. Consequently, water may penetrate into sealed cracks behind the material. If fissures and honeycombs in the concrete exist behind the sealed cracks, small amounts of water may move around the sealed crack. Evidence of this will appear as damp or wet spots along the crack.

G. Drilling injection holes in concrete greater than 90 cm thick:
   1. Determine injection hole origin and drill injection holes in concrete greater than 90 cm the same as concrete 90 cm thick or less. Therefore, injection hole origin is 46 cm from the crack. Injection hole depth is 71 cm – 76 cm minimum, intersecting the crack 46 cm deep in the concrete. Surface damming techniques using activated oakum or foam backer rod will help force the resin further back into the crack, when wider cracks are encountered.

H. Holes are generally drilled with 10 – 15 cm spacing, depending on the substrate thickness and crack geometry. The spacing between the holes is critical, and is a function of crack width. The tighter the crack, the closer the holes. Typically, holes will be spaced 1½ times the distance that the test water travels. With very wide cracks that have a surface dam over them, the spacing may be quite large.

3.4. APPLICATION – INSTALLING PACKERS

A. Insert the Packer in the hole.
B. Lightly tap on the socket (possibly reversed) or installation tool with a rubber mallet to ensure a snug fit, and insertion to the proper depth. Do not strike the cone or pan head fitting with the hammer.
C. Tighten the Packer using a deep socket and a ratchet. Tighten until snug.
D. To test, pump water into the packer, beginning with low pressure.
E. Increase pressure slowly and incrementally. Sudden surges of pressure can cause the packer to shoot out of the hole, in a very dangerous manner.
F. Check for leaking water as pressure is increased.
G. If water is leaking around the Packer, stop pumping water and slowly tighten.
H. Resume pumping water, incrementally increasing pressure.
I. Continue to increase the pressure and watch for leaking water. Slowly tighten 1 to 2 turns each time leaks are observed, until the pressure required to pump the material is reached, but the injector is not leaking. CAUTION! DO NOT TEST PUMP WITH RESIN. USE WATER. DO NOT OVER-TIGHTEN PACKERS. Tightening packers until resistance or friction is felt may cause spalling or additional cracks in the concrete, before resistance is felt. Also, injection holes drilled too close to the crack may cause spalling between the crack and the injection hole.

NOTE: Water injection is as important as resin injection itself. Therefore, proper equipment is critical. Some applicators may attempt to use the same pump and control valve (gun) for both the water and resin injection, flushing the pump with solvent after each use of the water or resin. The pump will ultimately become clogged with activated foam resin. Some applicators may even try to skip water injection. This may cause the material not to cure, if the crack is dry, and sufficient moisture to react with the resin is not present. Uncured resin in cracks will eventually migrate out of the crack and create and unacceptable situation.

3.5. APPLICATION – INSTALLING PACKERS

A. **Clean, potable water must be used to flush cracks.** Water must be injected into a crack prior to the injection of resin, for the following reasons:
   1. Water exiting the crack indicates the injection hole has crossed the crack. If water is not observed exiting the crack, and the pressure gauge reading is at, or near the maximum pressure output of the pump (170 – 200 bars), the injection hole may not have crossed the crack. Even though the injection hole was drilled several cm past the hypothetical location of the crack, it may be necessary to drill deeper or drill another injection hole on the opposite side of the crack. This is one reason that one or two test injection holes are used, to start.
   2. Water is pumped to flush out debris, organic matter, sand, silt, and anything else that will restrict the flow of resin through the crack. Flush each injector for 3 to 5 minutes minimum with water to ensure the crack is clean. The time will vary due to thickness of the concrete, and the amount of contamination in the crack. Clean potable water must be used to flush cracks.
   3. Water is pumped to sufficiently wet the crack, so the resin will catalyze. Even if the crack is already wet, it must be flushed with clean water so a proper and predictable reaction occurs. Contaminated water may not allow the resin to react or cure properly.
   4. Water is sometimes used as a carrier medium for the accelerator. When used, accelerators can be added to the water injection side, or the resin side, depending on which resin is used.
   5. Monitoring the pressure gauge on the injection control valve will indicate, to a trained operator, the volume of water being pumped into a crack at any given time. This will help him anticipate the volume of resin that will be pumped into the crack.
   6. Water is pumped to determine the distance water or resin will travel, in each direction, from the injector. This distance is needed to determine the spacing of injectors. A good rule of thumb: allow approximately 30% - 50% overlap between injectors.

B. When pumping water or resin into an injector use care to increase the pressure very slowly. Sudden pressure increases can blow out the injector or crack the concrete. Use the proper injection control gun to avoid accidents.

3.6. APPLICATION – DRILL REMAINING INJECTION HOLES

A. Using spacing determined by 3.5., drill the remaining holes required.
B. Install injectors per 3.5.

3.7. APPLICATION – RESIN INJECTION

A. Begin injecting resin immediately after the cracks have been flushed with fresh water. Do not flush cracks, then wait until the next day to begin resin injection. If resin injection has not begun 30 minutes after water injection, or if cracks appear dry, re-inject water into the cracks. Re-tightening injectors may also be required. The rubber gasket on the injector will relax over time. Use caution and water test the injectors, slowly building pressure. Further, if an accelerator is used in the injection water, the resin injection must begin immediately, because accelerator can evaporate from the water.
B. Begin injecting the resin slowly, building pressure on the injector. If recommended equipment is used, the applicator will have control of pressures. Pump resin at the lowest possible pressure with the application control valve fully open. Refer to the schedules for a pressure guide that may be associated with varying crack sizes. Sealing fine cracks at high pressures, with the application control valve in the full open position, may cause cracking, spalling or other damage, to weak concrete. Build pressure very slowly for fine cracks. Pump pressure should be 204 bars maximum

and the control valve should not be fully open. This should slowly allow efficient volumes to be pumped into the crack.

C. When resin injection begins, water is displaced from the crack and injection hole. Water may continue to run from the crack for several minutes before resin appears. The first sign of resin is a very light foamy substance, which thickens over time to look like shaving cream. Continue injecting resin until pure resin flows from the crack and until resin has traveled the desired distance between the injectors. Varying resin pump pressure will help the resin travel as far as possible. If resin does not travel the required distance between injectors, it may be necessary to drill an injection hole between existing injectors.

D. **Always re-inject a small amount of water into the injection hole after injecting resin. This assures that the remaining material in the hole will be reacted.**

3.8. APPLICATION – LARGE CRACKS

A. Large crack (70 microns or larger) injection techniques vary slightly from the fine crack injection. However, the same equipment is required for both applications.

B. First, clean concrete surface a minimum of 5 cm out on each side of the crack. Second, if the crack is not leaking at the time of resin injection, and the concrete is dry, apply a surface seal over the face of the crack to restrict the flow of water and resin. This will contain resin and water in the crack. If a surface seal is not installed over a large crack, resin may run from the crack before reacting and curing. Leave a 1,5-2,0 mm inspection hole every 30 cm in the seal. Inspection holes will allow visual inspection of resin travel. Inspection holes may be plugged with a small piece of wood as the resin begins to flow.

Some surface sealing materials are:

Dry Concrete	**Wet Concrete**
Koster KB-Fix 5	Koster KB-Fix 5
Epoxy Mortar	Oakum
Polymer concrete	

C. Drill 45 degree angle injection holes approximately 45 cm apart beginning at the lowest point of the crack on a vertical surface. This spacing may be increased or decreased depending on the flow of material from hole to hole.

D. Install and seat injectors. Pump water and resin according to procedures described previously. As water is pumped onto each injector, confirm travel distance between inspection holes. After thoroughly flushing with water, begin resin injection. Pump resin mixture until pure resin, not foam, exits the inspection holes.

E. As a steady resin flow begins to exit each inspection hole, a small wood plug should be wedged tightly in the hole creating a dam. Continue pumping each injector, plugging the nearest inspection hole as pure resin begins to exit.

F. Using Water diversion holes:

1. A large crack with running water requires a different technique for proper sealing. The surface of the crack is generally thoroughly saturated, which makes it impossible to use some kinds of sealing compounds. The pressure of the running water will generally blow off any surface seal, as well as any material wedged into the crack (oakum). To make a surface seal effective, leaking water and the pressure must be diverted.
2. Drill the injection holes and install the injectors previously described. After the injectors are thoroughly tested for proper seating, remove the cone or pan head fitting from the head of each injector. Water should flow from the hollow injector, sometimes in a fast stream.

Install all injectors and remove all cone or pan head fittings. After a few minutes the water flowing from the face of the crack may slow as water is diverted through the injectors. If water continues to flow from the crack, as well as the injectors, more water must be diverted. Drill more injection holes and install injectors on the opposite side of the crack. Stagger new holes between previously drilled holes. Water flow from crack should be adequately diverted. Install surface seal.

3.9. APPLICATION – GENERAL

A. Once the crack is sealed, and each injector has been pumped with resin, inject a small quantity of water into each injector. This will help materials in drill holes to cure.
B. Allow adequate time (approximately 24 hours) for materials to fully cure.
C. Reinject areas that still appear wet, and allow to cure.
D. Remove injectors.
E. Scraping, or an electric, angle grinder (with a cupped wire wheel) can remove excess cured material, so that the repair is flush with the adjacent surface.
F. A surface sealer can be applied to cover injection holes and sealed crack, for aesthetics, if required.