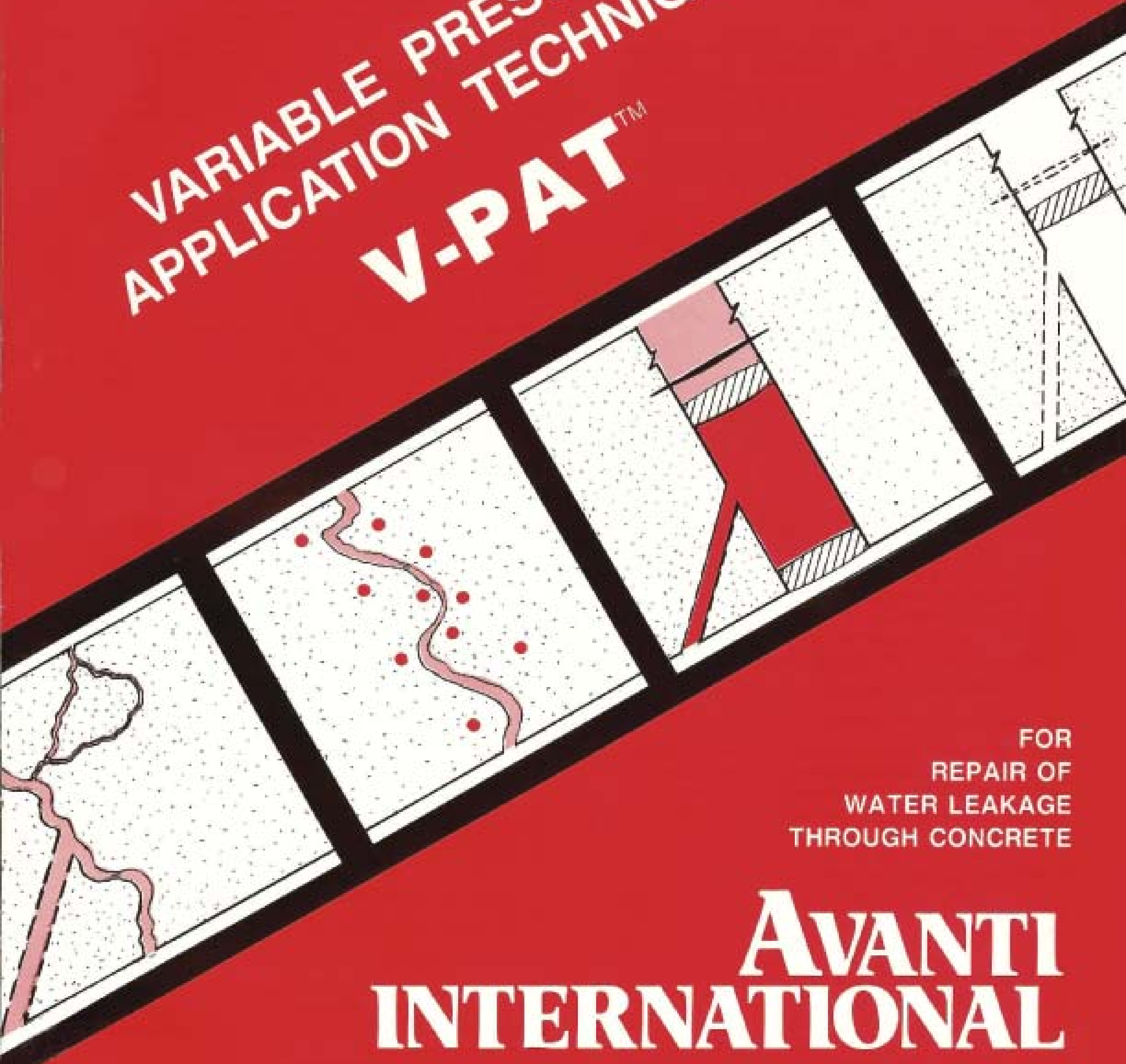
VARIABLE PRESSURE APPLICATION TECHNIQUE

V-PAT™



FOR
REPAIR OF
WATER LEAKAGE
THROUGH CONCRETE

AVANTI INTERNATIONAL

BACKGROUND

Water leakage through cracks or joints in concrete is nothing new. When concrete moves, it often cracks. The size of the crack depends on the amount of movement; the problem caused by water leaking through the crack, however, can be much larger than the crack itself.

Freeze-thaw damage, corrosion, structural weakness, and even failure can all be traced to cracks and water. Cold weather may bring hazardous ice formations underfoot or overhead. And, certainly, the contents of the structure always experience difficulty when water appears uninvited.

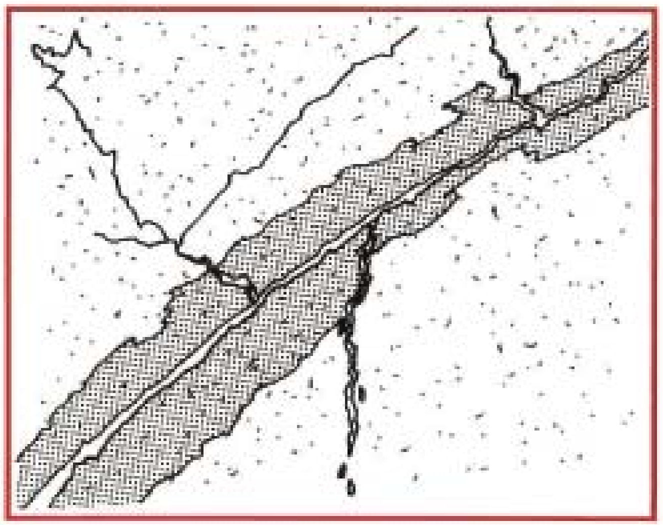


Figure 1

Thus, in spite of the best efforts of the architect, engineer, and contractor, structures will sometimes move in unanticipated places, and cracks will appear. The injection of resin into concrete is then performed to accomplish one of two purposes:

1. Restore design strength
2. Stop water leakage

Structural members, such as load-bearing walls, beams, or columns, may be weakened by cracking. For such cases, the injection of high-strength epoxy resins may restore design strength or prevent future problems. When structural strength is not the prime concern, water entering through the crack will frequently be the biggest headache.

Many epoxy injection resins have difficulty in stopping active water leakage because they do not bond well to wet surfaces. Even the newest epoxy resins have tough substrate preparation requirements for wet applications. If the crack movement later approaches the elongative limits of the material, release may occur. Since 5% maximum elongation is common among epoxies, a 10 mil crack could experience failure with only five ten-thousandths (0.0005) of an inch of movement.

Active leakage from the crack also causes other difficulties for many epoxies. The set-time or "pot life" of an epoxy is partly a function of the hardener used, but set time is also a function of mass. Thus, even a very fast set time of a few minutes becomes much longer in a small crack. Prior to set, water pushes against the liquid epoxy and may extrude it from the crack, separate it from one wall of the crack, or both. Either way the leak continues.

Obviously, every crack (or every leak through a crack) must have a reason - a cause for its occurrence. If the movement which caused the crack stops, the crack plane becomes stable. Most cracks, however, continue to "work" throughout their life due to thermally induced forces in the structure or due to soil moisture changes. Such cracks are sometimes said to "breathe;" that is, to become wider or narrower at various times throughout the year. Where water is successfully stopped at first, this "breathing" is often the cause of later failure. Since the structure "wants to move" at the crack, and since available forces are quite large, rigid materials either fail or cause other cracks in nearby areas.

In water control work the side of the structure where the hydrostatic load originates is called the positive side. In most cases this positive side will also be the soil side. Any water control material has a much higher probability of success when placed on the positive side because it then has the original structure for support.

Almost all access to a water leakage problem, however, will be from the negative side. Water control materials which are surface-applied on the negative side have a strong potential for failure, and some invariably fail soon after application. Their effectiveness depends mostly on their bond strength to the substrate and their tensile and elongation capability. Primary mechanisms for their failure are bond release, breach by elongation-to-break due to structure movement, or "cold-flow" of the coating under hydrostatic load.

Resin injection procedures, then, arise from the need to work on the negative side and yet place water-stop materials on the positive side.

With the problem of small size, movement, active leakage, dampness, and debris in the crack to be sealed, an engineer or contractor might well pause to consider the characteristics he should expect in the sealant he chooses. To function as a water-stop material, an ideal injection would:

1. Be thin enough to penetrate small cracks
2. Set quickly
3. Bond to wet surfaces
4. Work in and under water
5. Possess good elastic strength
6. Tolerate unavoidable debris

The material would be all the better if it were:

7. Easy to handle
8. Inert after cure
9. Approved for contact with potable water
10. Tolerant of mix variations and field conditions

If the product actually expanded to fill the available space and was activated by the water leak itself, then it might well be outstanding - even unique - in its ability to stop water leaks.

PREPOLYMER URETHANE RESIN (hereafter referred to as PUR) Grouting Compounds from AVANTI were designed specifically for sealing leaks in concrete. Uncured PUR grouts are viscous liquids that look much like honey or medium-weight motor oil. When mixed with an equal quantity of water, the grout expands and quickly cures to a tough, flexible rubber.

THE V-PAT PROCESS

The VARIABLE PRESSURE APPLICATION TECHNIQUE (V-PAT) can be used to apply PUR grout in both cracks and expansion joints. The methods used for these two problems are somewhat different, but the basic steps are the same. The procedure for cracks will be examined first.

V-PAT crack sealing follows this simple sequence:

1. Scrape or brush debris from crack surface
2. Drill injection holes
3. Set injectors
4. Flush the crack
5. Inject PUR grout

Step 1: Clean the Surface

Examination of the crack after cleaning tells the technician where the crack goes and how wide it is. The first good impressions of how the crack will behave when pumped begin forming during this cleaning and examination. The crack must also be seen clearly in order to lay out the drilling pattern for the injection holes.

Step 2: Drill Injection Holes

The diameter, angle and depth of injection holes (or ports) can largely be predetermined and specified. A 5/8" diameter hole is standard. The angle of drilling is approximately 45° to the surface and the depth of the hole will be 1/2 the thickness of the concrete up to about 18 inches. See Figure 2. Ports deeper than 18" are usually not required even if the concrete being repaired is more than 36 inches thick as long as adequate pumping pressure is available.

If the concrete thickness is six inches or less, however, do not attempt angle drilling; set these ports straight into the face of the crack. This procedure will help minimize spalling in this concrete sections.

Experience helps in deciding how far apart to drill the injection ports. Of course, as the crack gets wider, the space between holes can increase. Generally, a minimum of 8 inches and a maximum of 24 inches will be most common. Holes should always be staggered from one side of the crack to the other. This assures crack intercept by at least 50% of the holes even if the angle of the crack within the concrete (Figure 3) is not perpendicular to the surface. No two cracks behave just alike. In some instances a crack will fill from just a few injection ports.

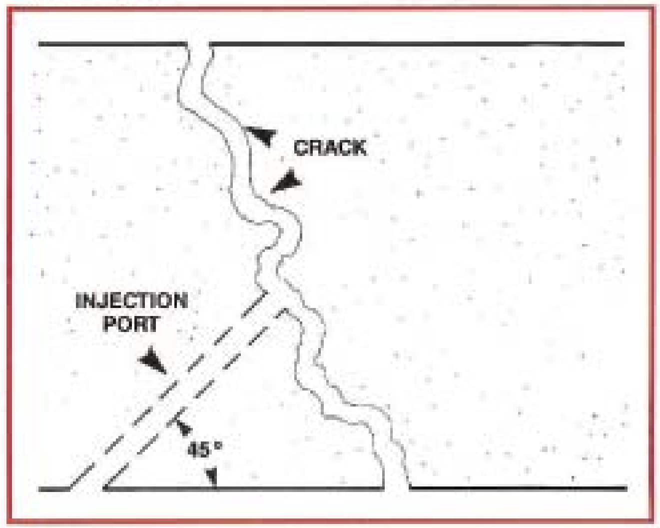


Figure 2
Injection port drilling. Note angle of hole to intersect crack.

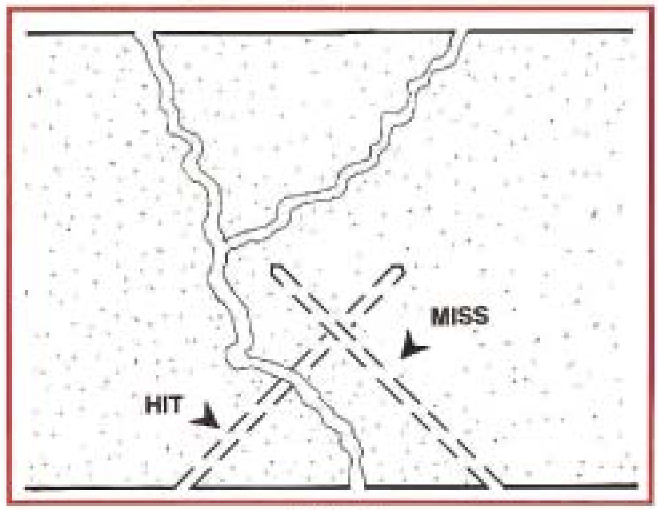


Figure 3

Step 3: Set Resin Injectors

Place the injector in the drilled hole so that the top of the sleeve is just below the concrete surface. Tighten by hand until snug. Then tighten further with a ratchet and socket or open end wrench as tightly as possible.

Step 4: Flush the Crack

Flushing the crack with water prior to resin injection is very important. The water flush removes drilling dust and debris and improves subsequent penetration of PUR grout. Water left in concrete pores will catalyze the PUR grout - especially if cracks are not leaking at the time. The flushing operation also tells the technician how the crack will behave during resin injection. Blind drill holes may be exposed, and voids, cavities, or honeycomb may be pinpointed for special treatment.

In some circumstances tracer dye in the flushwater may be helpful. The addition of dye will often pinpoint small, unseen cracks prior to injections of resin. Dye

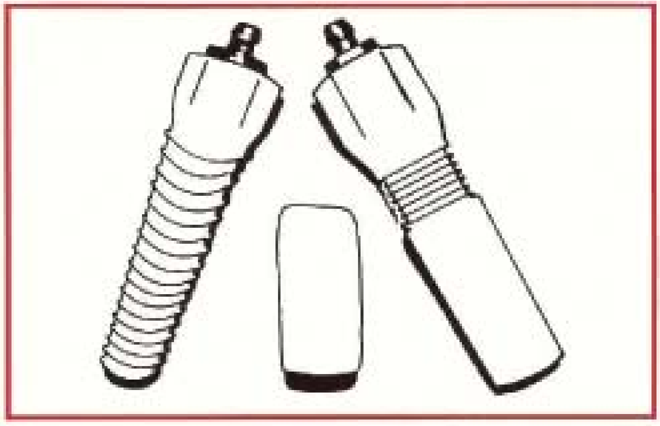


Figure 4

Figure 5

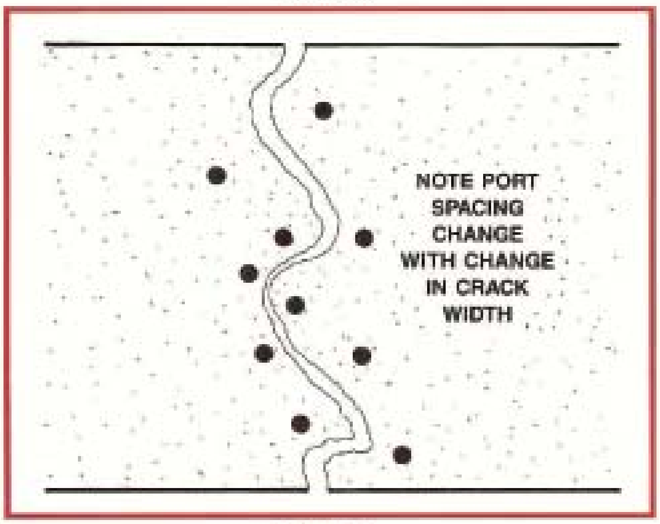


Figure 6

Figure 4 shows standard injectors, although other types are sometimes preferred (Figure 5). Contact Avanti for a wide selection of injectors for every application need. Figure 6 shows the hole pattern on a typical crack.

also exposes loss of flush water and enables the technician to distinguish between his flush water and formation water. The use of dye should be considered helpful but not necessary. Also, use care in selecting a dye if staining or other cosmetic considerations are present.

Sometimes, the same kind of pump (or even the same pump) which will be used for the resin is also used to flush the crack. Special caution is required if the same unit is used for both flushing and resin injection; *ALL WATER MUST BE COMPLETELY REMOVED* from the pump before charging with resin. The penalty for failure to remove the water before pumping resin is paid in downtime while the technician cleans out reacted resin.

The pump may not be permanently damaged, but the occurrence can spoil an otherwise perfectly good day. On large jobs, a separate pump should be used for each operation. Clean-up (and the possibility for mistakes) are then minimized.

Flushing starts at the lowest injector on a vertical crack (or at the narrowest part of the crack on a horizontal surface) and proceeds from one port to the next in sequence. Flush water should flow from the crack face. Flow of flush water into an injector is critical in that a hole is presumed blind if flow does not occur. The injector should be removed from each such location and the blind holes plugged with quick-setting cement. Do not try to pump resin in a blind hole.

200 to 300 psi will be required to open most injectors. Common sense says a wide crack will accept more volume at a lower pressure than a narrow crack will. Raise pressure and volume levels slowly. Flush the crack with the highest flow volume practical without exceeding the permissible pressure.

In cold weather (32˚ to 55˚F), accelerator may be added to the flush water. Accelerator is not normally required, but its use will aid in achieving faster set times in cold conditions. Accelerator should not be used in temperatures above 60˚F.

Epoxy resin injections sometimes call for the use of muriatic or hydrochloric acid as flushing agents. Do not use these materials. Such agents are difficult to completely remove from the crack and are not needed by the PUR system.

After completing the entire flushing sequence for all ports in the series, prepare for resin injection. The first port flushed will normally be the first port injected.

Step 5: PUR Grout Injection

When all preparation work is completed, load the pump resin hopper and charge the pump, hose, and gun. Pull the trigger on the gun and allow all solvent to pass while watching for the PUR grout to appear. Keep the hopper covered in very wet environments, especially if water is dripping from overhead. A cover that you can see through is best. Begin the injection of PUR grout at the lowest injector on a vertical crack or at the first injector flushed for a horizontal surface.

Patience is important in resin injection work. If experience says that a crack is wide enough to accept resin at 400 psi but it does not immediately do so, WAIT.

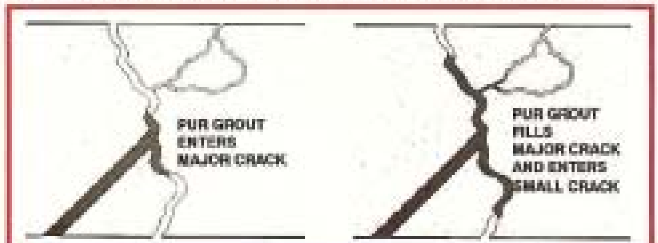


Figure 7

PUR does not have a "pot life." Thus, PUR grout in the machine, hoses and gun may sit for long periods - possibly even overnight under the right conditions - without setting up. Hold pressure constant for awhile. If flow still does not occur, raise the pressure slowly in 100 psi increments. Perhaps that extra minute or two will make the difference between 95% and 100% crack filling (see Figures 7 & 8). Also, sudden applications of high pressure may help propagate the crack. If in doubt, SLOWER is BETTER. As soon as flow is established, decrease pressure as much as possible consistent with desired flow rate.

Figure 8

As grout begins to flow, the technician should be carefully watching three points of reference:

1. The crack - for PUR grout flowing out of the work face
2. The whip line - for pump pulsations indicating resin flow
3. The gauge - for actual pressure in the crack

Holding the whip line allows the operator to feel the pump pulsations. A common pump for PUR applications is a diaphragm-type used in airless paint-spraying work. As resistance increases against the fluctuating diaphragm in the pump head, the rate of fluctuation will decrease proportionately. Thus, the technician may tell from hose vibration how well material is flowing into the crack. If the crack surface exhibits immediate free flow of PUR while working the first injector, pause for a few minutes. In many cases the PUR will unite with the flush water and expand rapidly. The resulting "foam rubber" product will heal the crack and provide a surface seal to contain the material to follow. In five minutes or so, pump again.

If resin still flows freely out of the crack, stop again. Immediately apply a surface seal over the crack with rapid-setting cement. Allow a few minutes for cure and pump again. Resin may still flow from pin-holes in the cement patch, but do not be concerned as long as the majority of the PUR is contained. A small amount of leakage is beneficial because it shows the extent of resin travel.

Under proper pumping conditions, the following signs will be observed in the order listed:

1. Water displaced from the crack by the resin
2. Water and resin mix (foamy) appearing at the crack
3. Pure resin from the crack

Stop the pump when pure resin reaches the portion of the crack adjacent to the next injector, move up, and begin pumping again. Continue in this fashion until the crack is completely filled.

Injection of PUR grout into floor slab crack. Note disposable coveralls and protective equipment.

Occasionally someone will object to the loss of some resin from the crack as an unnecessary expense. Remember, however, the PUR grout will accept up to 100% of its volume in water. The ratio of the water combining with the PUR grout is the primary factor influencing end-product density. Since only one or two percent water is required for cure, greatest density is achieved by displacing as much foam as practical. The cost of the resin is a very small part of the total job cost, and best results are obtained when relatively pure resin is placed in the crack. A little resin lost is good insurance that the crack is well filled.

The initial set of PUR is rapid, and final cure follows in 12 to 24 hours.

V-PAT AND EXPANSION JOINTS

PUR grout is an excellent repair material for failed waterstops and leaking expansion joints. In the past, repairing leaking expansion joints has been difficult because, by definition, an expansion joint is designed to move. Many products used for stopping water, however, are rigid and hard-setting; such materials either break up and fall out over time, or else they bond solidly and kill the designed movement within the joint - thereby defeating its purpose.

Most flexible sealants, on the other hand, require a clean, dry surface (or special surface preparation) to obtain a bond. These materials can stretch, but often fail to stick because of imperfect conditions during their installation.

Expansion joints must be allowed to expand, but clean, dry surfaces are hard to find below the water table.

Expansion joint repair with PUR takes the full advantage of the resin's ability to expand in confined spaces. The concrete surfaces of the joint provide confinement on two sides. The back confinement surface may be soil, but, in most cases, will be either the waterstop or a layer of lead wool, FIBROTITE, or activated oakum. Containment on the outer surface is provided temporarily by hydraulic cement. If desired, this temporary surface may be removed after resin injection.

Though the repair technique for expansion joints using PUR grout follows the same basic sequence as for cracks, a few extra steps are required. The actual sequence is:

1. Remove debris from joint surface
2. Remove old or failed sealant
3. Drill injection holes and set injectors
4. Flush injection holes and joint
5. Apply joint seal backing if required
6. Apply temporary outer joint surface seal
7. Inject PUR grout
8. Finishing cosmetics

Step 1: Remove Debris from Joint Surface

Clean away surface deposits and debris just as you would for crack sealing work. With the smallest amount of extra effort, the end result can be not only the most effective seal possible, but also the best-looking as well.

Step 2: Remove Old or Failed Sealant

Old cement patches in expansion joints defeat the purpose of the joint and should be removed. Complete removal, however, is usually difficult and may not be practical. All loose mortar, at least, must be removed to allow enough room in the joint for the PUR grout to be placed in sufficient quantity. Expansion joints are designed to move. At 50% elongation, one tenth of an inch can only become .015" while one-half inch can become 3/4". Loose beads of polysulfide or polyurethane sealants should be completely removed. Fiber or cork fillers may not require complete removal, but should usually be cleaned out at least to a depth of six inches. If a waterstop is present, and its depth is less than 8 inches, remove everything down to it.

Step 3: Drill Injection Holes and Set Injectors

Injection holes for expansion joints should be drilled in the same manner as for a crack. However, if a waterstop is present, best results are usually obtained by incorporating whatever is left of it into the new seal. Thus, injection ports should not pierce the waterstop if full-depth penetration is not required; each hole should be angled to end just short of the waterstop material. See Figure 9. When water is already flowing from the joint, removal of the failed joint filler material will sometimes allow the flow to increase. Small seepages or even light flows can be ignored, because they will be overcome by reaction and combination with the HYDRACURE resin.

Step 4: Flush Injection Holes and Joint

Joint flush procedures for expansion joints are the same as outlined previously for cracks.

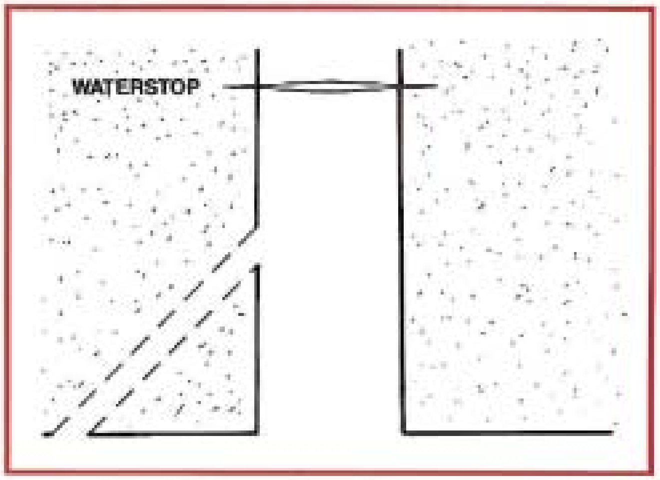


Figure 9

Step 5: Apply Joint Seal Backing

Large volumes or heavy flows of water must be controlled during resin injection and cure. One of several materials and methods to control such flows may be selected. Some of the common choices are:

1. Oakum (AV-219 Fibrotite)
2. Expanded gaskets (E.G.P.)
3. Diversion nipples
4. Resin rod (AV-215)

A thin layer of lead wool or oakum placed over the water-stop will temporarily cut off flowing water. See Figure 10. Strips of dry, unoiled jute such as Fibrotite, may be soaked in PUR grout and packed into the joint recess. Foam rubber or strips of other absorbent materials may also be soaked in PUR grout and used for packing. Such strips of PUR materials are sometimes called "expanding gaskets," and the process is called Expanded Gasket Placement - E.G.P. for short. The PUR combines with water to expand and cure rapidly, thus forming a quick "molded-in-place" gasket seal.

If leak flows are very great, one or more pieces of small diameter pipe can be imbedded in the packing material. These nipples serve to relieve pressure and divert flow while the packing seal solidifies. Once the seal has cured, a small amount of PUR grout, injected through the nipples, will rapidly complete the seal. The pipe nipples can then be removed.

Step 6: Apply Outer Joint Seal

With the inner seal in place and flow temporarily controlled, proceed to installation of the temporary outer seal. See Figure 11. Here, again, several materials may be used, but hydraulic cement has been used successfully and economically. Remember that PUR develops expansion pressures as it cures. If the outer seal is not secure, you may "spring a leak" during injection. Such

Flushing the joint prior to injecting PUR in tunnel joint with active water leakage.

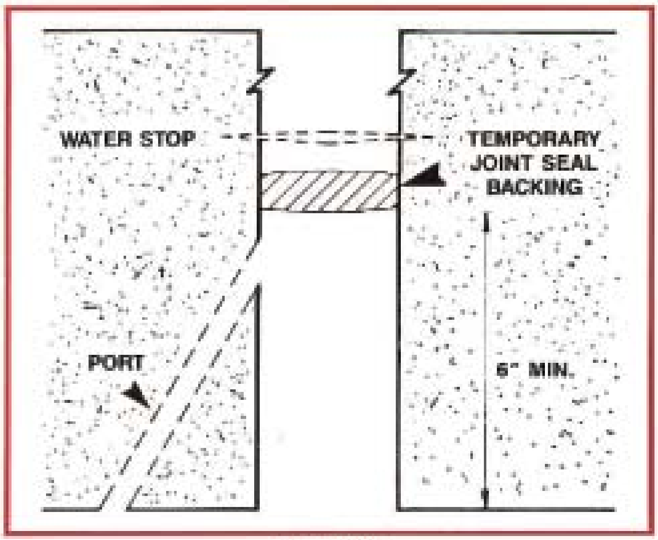


Figure 10

a leak is inconvenient at best, and wastes time and resin while you clean up and start over.

Step 7: PUR Grout Injection

Resin injection for the expansion joint proceeds just as outlined for crack sealing. However, any pressures much above the minimums required to open injector ports will seldom be needed. In fact, special care should be taken so as not to rupture the outer seal. Begin at the lowest injector and work your way up as before. Once pumping starts, best results are obtained by methodically proceeding to the end of the joint without stopping. Continuity helps assure uniform density of the PUR by achieving total joint filling (thus material containment and compression) as rapidly as practical. Continue to pump each injector until relatively pure resin flows from the next port before moving up.

When the last injector has been pumped, go back to the first port and work through the series again adding a *small amount* of resin at each. Watch your outer seal

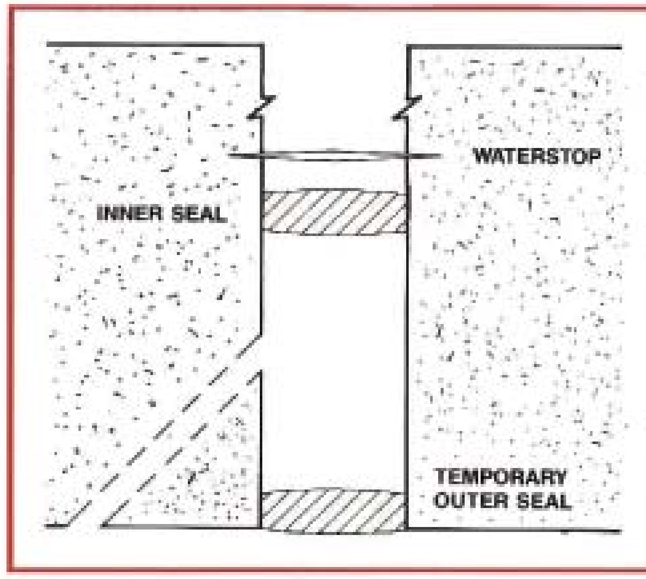


Figure 11

carefully. A little resin is usually enough. After curing overnight, the expansion joint is "better than new" (see Figure 12) and is ready for a long life of full service.

Step 8: Finishing Cosmetics

Once injectors are removed, the injection holes are patched with a quick-setting hydraulic cement. However, for best results we recommend using the AV-500 high mod gel or the AV-510 low mod gel for injector holes. These gels can be smoothed by using a wet sponge immediately after application to provide a smooth surface that can be painted.

NOTE: Stainless steel needles are available from Avanti for reinjection of any E.G.P., resin rod, or double-dam method seals which may need additional grout (Figure 11).

Basic Equipment for Sealing Fine Cracks

1. Chemical grout (PUR)
2. Accelerator (sometimes necessary)

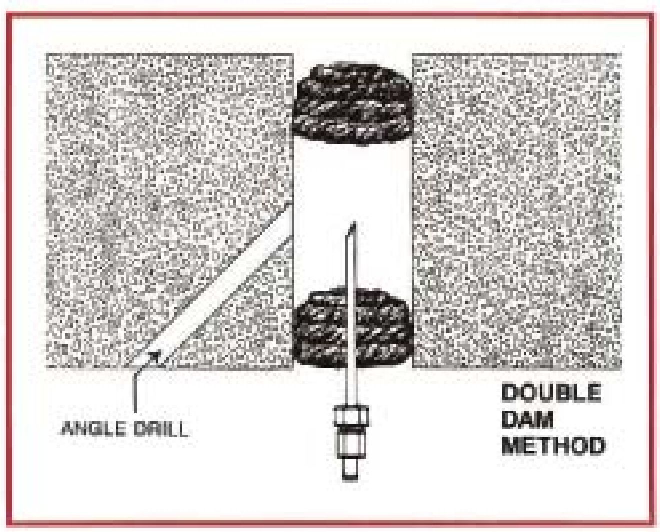


Figure 12

3. Pneumatic or electric drill with 5/8" drill bits long enough to intersect crack
4. Injectors (plastic or mechanical)
5. High pressure pump capable of a pressure range of 200-3000 psi, preferably a positive displacement design. The pump also must have a capacity of 1/2 to 2 gpm. It can be powered by either electric, air or hydraulics. All internal seals must be resistant to solvents such as acetone. There are a wide variety of pumps to choose from. Call Avanti for assistance in choosing the pump to fit your application.
6. Hoses used in conjunction with your pump must be resistant to water permeation from the outside in.
7. Injection gun should be capable of 3000 psi and have the capability of metering the PUR through the injectors to achieve variable rates of flow (not just on or off).

SAFETY PROCEDURES

Exposure

PUR grout in liquid form may cause skin and eye irritation following direct contact. If PUR grout comes in contact with skin, it should be washed off with soap and water. Material getting into the eyes must be flushed out immediately with plenty of water for at least ten minutes and a physician should be consulted. PUR grout should not be ingested.

Before eating, smoking or drinking liquids, remove protective clothing such as gloves and coveralls, wash hands with soap and water and stand away from the immediate work site. DO NOT SMOKE while working with PUR grout. If respiratory difficulties are encountered when working with PUR grout, obtain medical attention.

Users should avoid excessive exposure to vapors and keep the work area sufficiently ventilated to avoid exceeding the toluene diisocyanate Threshold Limit Value (TLV). Gloves, goggles, respirator and protective clothing are recommended when working with this product.

Ventilation

Ventilation is an important aspect of project planning. Small amounts of toluene diisocyanate (TDI) may be present. A small segment of the population may be more sensitive to TDI than the norm. A respirator equipped with an organic vapor cartridge should always be available and ventilation augmented by blowers or fans when appropriate.

Summary of Handling Precautions

1. Wear goggles and rubber gloves in handling and application operations.
2. Keep away from heat and open flame during storage and use.
3. Ventilate sufficiently and use respirator, especially for operations in a closed space.
4. If skin or mucous membrane is contaminated with PUR grout or its solutions, wash thoroughly with plenty of water. In case of eye contact, wash immediately with plenty of water and boric acid solution, and seek medical attention.

WARRANTY STATEMENT

The data, information and statements contained herein are believed to be reliable, but are not construed as a warranty or representation for which AVANTI INTERNATIONAL assumes any legal responsibility. Since field conditions vary widely, users must undertake sufficient verification and testing to determine the suitability of any product or process mentioned in this or any other written material from AVANTI for their own particular use.

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