# Repair of Active Cracks of Concrete Structures with a Flexible Polyurethane Sealant for Controlled Movement

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Abstract: *Repair of active cracks are most difficult because of the continued movement of such cracks and is still further difficult if the cracks are in wet condition. Any rigid repair material at such locations will harden at the interface between old and new surfaces and promoting to develop another crack at some other location. It is better to treat such cracks as joints if the movement is within the limits, otherwise it should be treated as expansion joints. With the controlled movement repair of such active cracks with a flexible polyurethane (PU) sealant is most suitable than other methods. The present paper focuses the application and suitability of PU sealant for active crack repair.*

Keywords: *Active cracks, Flexible sealing, Movement accommodation factor, Polyurethane sealant,*

## I. Introduction

Live cracks are those cracks which undergo some movement in direction, width or depth over a measured period of time. Such cracks should be inspected periodically for longer period to asses any further increase of depth, width and nature of cracking before going for any type of repair. Cracks due to overloading and thermal expansion (freeze-thaw) are the examples of active cracks.

Live cracks, on the other hand, are usually formed in response to a continuing movement or to present overload; they open and close as a result of external forces. Repairing active cracks is difficult. While it might seem a good idea to repair them to prevent their uncontrolled propagation, this is easier said than done. If the underlying cause is not fixed, a new crack will form next to the “repaired” one.

To determine whether a crack is active or dormant, one simple way is to bridge the surface of the crack with a rigid but non-shrink material, such as plaster or even paint, and inspect the patch periodically. Depending on the circumstances, the measurements can be taken daily, weekly, or monthly. The longer the waiting period, the more chances there are to detect an infrequent movement. An active crack will, of course, reflect through the coating and become visible, a dormant one will not. The actual magnitude of the movement can be determined, if that is needed, by periodically measuring the crack width in a few places.

It’s a little more difficult to know how much a crack is moving. For an approximate evaluation, two pencil marks (parallel lines or a “+”) on both sides of the crack to be marked and measurement between them at regular intervals to be made. However, to be more precise a crack monitor should be used.

## II. Repair of Live Cracks

Cracks subjected to movement should be treated carefully. Small movements up to 35% of crack width can be tolerated with a flexible sealant. For large cracks and where rapid cyclic movement is anticipated, the cracks should be treated as movement joints. The movement of such cracks has to be established before sealing with a suitable sealant. For active cracks a flexible joint sealant can be used with the help of a bond breaker (Fig: 1).

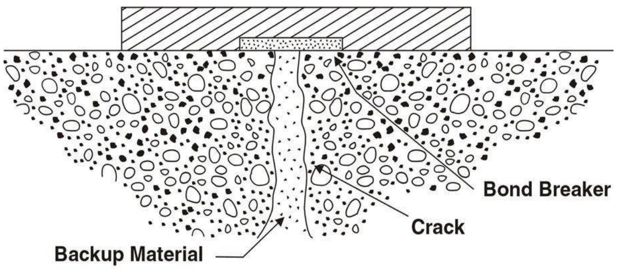


**Fig: 1 Details of flexible sealing**

Live or active cracks must be treated as if they were control joints. It must be determined if it is necessary to restore the tensile or flexural strength across the crack. If the strength must be restored, it is best to install an expansion joint nearby prior to bonding the crack. If the crack is simply bonded, a new crack will occur adjacent to the old one. The active crack that is leaking and must be bonded is the most difficult problem. In such cases the following precautions should be taken.

- First the leakage must be stopped and the crack dried. If the crack can not be dried prior to injection, other methods of strengthening should be considered, such as stitching or external stressing.
- Active cracks that must be made watertight cannot be easily repaired, because they change in width in response to changes in temperature or humidity. The required seal must have the proper elongation and shape factor.
- To provide a watertight seal in a crack, the crack must be routed out to a width of at least 10 mm to provide some stretching length.
- In addition, bond must be prevented to the bottom of the routed area to achieve an un-bonded length.

The various methods for treating live cracks are discussed below.

The various low coat sealants like mastics such as non-drying oils, butyl rubber, or low melting asphalts, with added fillers or fibres can be used where movement will not 15% of the width of the groove and non-cyclic. They are used for vertical and no traffic structures. The other thermoplastic such as asphalts, rubber-modified asphalts, bitumen, rubber-modified bitumen, pitches and coal tar are used where movement of crack is about 25% of the groove width. Although these materials soften much less than mastic, they expand at high temperature and degraded by ultra-violet rays. Elastomeric sealants like poly-sulphides, epoxy poly sulphides, polyurethanes, silicones and acrylic are widely used because of their higher elongation [1].

## III. Material Properties for Crack Repair

The use of polymeric materials or sealants for repair of active cracks has been widely accepted and most effective. A crack filling material should satisfy the requirements such as good workability, mix stability, ageing resistance, strength, compatibility with substrate, adequate adhesion and low volatile content.

## IV. Polyurethane Sealant

Polyurethane sealants are generally used to seal cracks that are from 2.5 to 25 mm in width. Polyurethane sealants generally provide an excellent bond to clean concrete and masonry surfaces, and usually do not require a primer to obtain this excellent adhesion.

The use of a primer, however, is beneficial in many applications where increased adhesion is needed or in situations where the bonding surfaces are not as well prepared as is desirable. Polyurethane sealants can provide a service life from 3 to 10 years; one reason is their ability to relieve the stress at the bond line, caused by constant elongation of the joint, through controlled internal flow. Very high elongation properties make these materials suitable for active joints. Polyurethane sealants have excellent weathering resistance properties; thus, they will maintain their original material properties over time. Certain formulations of these materials may be placed in submerged environments, such as joints within water tanks and reservoirs, because their physical properties will be unaffected, even under constant immersion.

These materials do not require a high level of skill to apply. Coatings may be applied to some polyurethane sealants for a more uniform appearance, particularly in wall panels of a building.

Sealants are not suitable for structural repairs. While the chemical resistance is generally not as good as an epoxy, some sealants with enhanced resistance are available; sealant manufacturers should be consulted regarding the suitability of specific sealants for specific exposures. Although the performance of the material is not unusually affected by UV light, the surface will tend to form a white, dusty deposit on the sealant surface (known as chalking) under long-term exposure. For optimum performance, polyurethane sealants should have regular inspections and maintenance [2].

Proper design of the joint and sealant profile is critical to ensure the sealant performs as specified. A single direction of joint movement is usually required for good sealant performance, and bond breakers within the joint are frequently used to allow the sealant to contract vertically when stretched horizontally (just as a rubber band gets thinner when stretched). Stress buildup in the sealant is minimized as the width-depth ratio approaches 2:1. The maximum joint width is generally 25 mm; however, some products may be applied up to 50 mm in width. The minimum joint width is 6 mm; therefore, smaller cracks have to be routed to comply with this limitation. The minimum joint depth is generally about 6 mm, and the maximum depth is about 12 mm. These sealants are available in single and two components.

Single-component products are ready to use and do not require mixing; however, the colour selection may be limited, and sufficient humidity must be present for proper curing.

Two-component products should be thoroughly mixed before using; they may cure faster in cold environments, and there is greater diversity in colour choices.

Polyurethane sealants (Fig: 2) come in a variety of consistencies and hardness, making them suitable for vertical and overhead applications.

**Fig: 2 PU sealant at construction joint**

One-part polyurethane sealant is composed of polyurethane polymer, pigments, fillers and additives suitable for filling and sealing joints in building construction. It is elastic, weather-resistant, non-sagging, and water tight with excellent adhesion to practically all surfaces [3].

**A. Features and Benefits**

- The single pack reduces the application failure from heterogeneity by imperfect mixing.
- It saves the trouble of measuring, mixing and de-bubbling and forms a permanent tough elastic rubber seal.
- It has excellent adhesion to a wide range of substrates.
- It can accommodate continuous and pronounced cyclic movements.
- It can be over coated.
- It is resistant to bio-degradation.

**B. Properties**

The standard for testing various properties of the flexible sealant is ASTM C -920: 2001 “Standard Specifications for Elastomeric Joint Sealants” [4].The some of the properties are discussed below:

*B.1 Acceptable Joint Widths*

Most elastomeric sealants are limited to joint widths between 6 mm and 32 mm. However, some polyurethane is designed for wider joints. The problem with narrower joints is that the absolute movement (especially compression) exceeds the capability of the sealant. Some narrow joints have no movement at all.

*B.2 Movement Capability*

This is the gauge of how much extension and compression the sealant can withstand without either pulling away from the sides of the joint or failing in the body of the sealant. It is measured as a plus/minus percentage of the joint width at the time of installation, tested as per ASTM C 719 - "Standard Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement" [5].This test also evaluates adhesion and cohesion as criteria for the movement limits. Movement capability or MAF (Movement Accommodation Factor) over 25 percent is possible with polyurethane sealants.

*B.3 Adhesion*

Suitability for a specific substrate usually comes down to adhesion. Minimum adhesion is usually taken for granted, but there are variations—most of which cannot easily be quantified. Polyurethanes generally have the best adhesion. The adhesion and cohesion under cyclic movement of PU sealant is 5-6 $cm^2$.

*B.4 Hardness*

Hardness is also a measure of vandal resistance, but the harder the material, the lesser the movement capability it has. Hardness (Shore A) of PU sealant varies in between 20-25.

*B.5 Porous Substrate Staining Probability*

Sealants can potentially be made of chemical compounds whose component materials might leach or migrate, especially into a porous substrate. This is a pass - fail judgment for finding out whether the sealant stains or it doesn't.

*B.6 Cure Type*

All the joint sealants cure (change from being of toothpaste consistency to being solid) except those that are intended to never cure for some specific reason.
The other properties of PU Sealant as follows:
Colour : Grey / White
Skinning time: 15 - 20 minutes
Tack free time: 72 hrs
Service temperatures: - 30$^o$C to + 80$^o$C
Specific Gravity : 1.23 + 0.02
Slump at 35 °C : Nil
Elongation at break : 500 - 600%

**C. Joint Design**

For various reasons, the different types of joints are provided with width depth ratios in different proportions. Depending on the horizontal or vertical movements, the cured sealant should retain its original shape after the deformation of expansion-contraction. So width depth ratio is very important.

For 6 to 12 mm joint, width: depth shall be 1:1(equal)

For 12 to 25 mm joint, width: depth shall be 2:1(half)

**D. Method of Application**

*D.1 Surface Preparation*

The joint edges should be sound and free from grease or oil contaminations. If spalled, it should be rectified properly by using polymer mortar or epoxy mortar.

A closed cell polyethylene foam sheet or rod as a back up material should be used. The back up material is used to adjust width to depth ratio and falling of sealant while application. A thermo-cool sheet can be used as a back up material.

A bond breaker tape should be fixed over the backup material to prevent third surface adhesion. Thereafter a masking tape should be fixed on both sides of joint surface to get neat and clean appearance of joints after application of sealant

*D.2 Priming*

The Priming should be done only on two sides of the properly prepared joint surface with a suitable primer by a brush and should be allowed to cure for minimum 20 minutes. Two coats of primer should be applied at an interval of 30 minutes. After priming is over, sealant should be filled after minimum 30 minutes and before 90 minutes. If 90 minutes is exceeded a fresh coat of primer should be applied.

### *D.3 Application*

PU Sealant is available in different volume of sausages. The sausage should be inserted in hand operated application gun and nominal pressure has to be applied over the trigger of the gun so that sealant starts extruding out of the nozzle & filled in the joints(Fig: 3). A slightly excess amount to be applied for tooling and finishing purpose(Fig: 4).

**Fig: 3 Application of PU sealant**

**Fig: 4 Tooling of excess sealant**

### *D.4 Finishing*

The sealant should be tooled immediately with tooling knife by pressing against the joint to remove air pockets and to ensure 100% contact and adhesion with the surface.

### *D.5 Cleaning*

After sealing the joint the tools and equipments should be cleaned immediately with kerosene or any other cleaning solvents.

### E. Areas of Application

- Sealing of expansion and construction joints as well as joints between different construction materials in high rise buildings, basements, floorings etc.
- Sealing joints in between precast concrete panels.
- Sealing joint in between tiles, bricks, marble etc.
- Sealing joints of metal container finishing.
- Repairing of non-moving concrete cracks and control widths.

### F. Precautions and Limitations

- Maximum width for application in a joint is 50 mm.
- Sealant must be stored at a temperature of 5 to 25 °C.
- Sealant must be stored in a dry conditions avoiding direct sunlight.
- PU Sealant is reactive to alcohol and it will not cure if reacted.
- Sealant will not adhere to substrates with contamination and traces of bitumen.
- Adhesion of the sealant must only be on two opposite faces.

## V. Conclusion

Repair of any active crack has to be observed for a longer period before adopting any repair methods. Movement of joint is also another important factor while designing the joint for sealing with any flexible sealant. With the controlled movement repair of any active crack with a flexible polyurethane (PU) sealant is the most suitable method.

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## References

[1] Pattanaik Suresh Chandra, "Cracks & crack repairs" – Guide to Health Construction , A Publication of Dr.Fixit Institute of Structural Protection & Rehabilitation, Mumbai, India, 2010(Unpublished)

[2] Bhedasgaonkar B.V. –"Joints & Sealants" - Health Construction Manual , A Publication of Dr. Fixit Institute of Structural Protection & Rehabilitation, Mumbai, India, 2010

[3] Product data sheet of Dr. Fixit PU Sealant - http://www.doctor-fixit.com/sealant-pro.asp?product=PU%20SEALANT

[4] ASTM C 920: 2001 - "Standard Specifications for Elastomeric Joint Sealants"

[5]. ASTM C719 -93(2010) - "Standard Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants under Cyclic Movement