MASTER® BUILDERS SOLUTIONS

bluey

TBM Leak Repair and Maintenance

PROCEDURE

TBM Leak Repair and Maintenance

CONTENTS

TABLE OF CONTENTS

Why Cracks Occur in Concrete Structures	3
Cracking in Tunnel Enviroments	3
Materials - BluRez CSW	4
Materials - BluRez CS150	6
Injection Equipment	8
Set Up	10
Preparation for Injection	10
Injection	10
Cleaning	11
Section 1 - Wet or Weeping Cracks	12
Section 2 - High Flow Water Ingress	13
Section 3 - Leaking Gasket	14
Section 4 - Leaking Grout Socket	15
Section 5 - PUR Contact Grouting	16

TBM Leak Repair and Maintenance

THE IMPORTANCE OF WATER LEAK REPAIRS IN TUNNELS

This procedure details the steps involved in rectifying water leak defects in TBM tunnels. These steps have been developed by Bluey engineers who have successfully completed hundreds of repair projects.

NOTE: If a leak on site requires an alternative procedure to achieve the best results, contractors should follow the recommendations of the project designers.

The repair procedures in this document have been divided into five categories:

- Repair of a wet or weeping crack in a concrete segment lining
- Repair of high flow water or a large void in a concrete segment
- Repair of a leaking gasket in a segment joint
- Repair of a leaking grout socket in a segment.
- PUR Contact grouting of cracks

For each procedure, site trials must be carried out to confirm their effectiveness before widespread repairs can begin.

WHY CRACKS OCCUR IN CONCRETE STRUCTURES

Concrete provides structures with strength, rigidity, and resilience from deformation. These characteristics, however, result in concrete structures lacking the flexibility to move in response to external, environmental or volume changes. When these changes exceed the concrete's maximum tensile strength, cracking occurs.

Once the reason for the crack has been determined, the appropriate action can be taken, whether its leaving the crack alone, injecting the crack with the appropriate material, or applying other suitable repair methods. In this case, we examine leaks in an underground segmentally lined tunnel, with water charged ground pressurising the segments.

CRACKING IN TUNNEL ENVIROMENTS

Cracking in a tunnel environment occurs in the hardened preformed segments due to water pressure, weight loading or settling of the segments into the newly bored tunnel. When leaks are present in a tunnel that has been constructed in water charged ground it is best to redirect and stop the leaks by injecting BluRez CSW polyurethane resin.

This is done with the use of pumps and equipment that injects the resin behind the segments of the tunnel where the leak originates. It is best practice to identify where the water is coming from, nominate a ring around the circumference of the tunnel (between the water source and the leak) and completely encapsulate the ring with BluRez CSW.

TBM Leak Repair and Maintenance

MATERIALS

BLUREZ CSW

BluRez CSW is a two component catalysed polyurethane liquid which requires only mixing with BluRez CSW - X to form a high foaming very fast setting water reactive injection resin.

USES

BluRez CSW is designed for the sealing/grouting and elastic connection of concrete cracks, rock fissures, civil engineering structures, brickwork and natural stone. Application uses include tunnel linings, carpark decks, concrete foundations, subterranean curtains, retaining walls, slab on ground and bridge abutments.

ADVANTAGES

- Ultra low viscosity for fine crack and fissure penetration
- Fast reacting, effective water stopping properties
- Excellent adhesion properties with both mineral and metallic surfaces
- Superb elastic properties that accommodate considerable movement between construction components
- Large volume, no shrinkage, makes it a very cost effective product

PREPARATION

Evaluate joint or rock fissure for injection.
Drill holes either side of the defect, sloping towards the defect at an angle of approximately 45°.
The depth and distance from the crack will vary depending on water flow rates and site conditions.
Insert packer at a depth which will allow resin to enter the defect without impediment. Consult Bluey for additional information.

MIXING

Calculate the required volume of BluRez CSW - X to be combined with BluRez CSW within the range specified on this data sheet. Measure the required quantity and add the two components together. Mix together using a slow speed mixer (400rpm) for at least 3 minutes or until a uniform mixture is achieved.

APPLICATION

Commence from the widest part of the crack or fissure and proceed injecting outwards along the crack or fissure in each direction. Turn on pump and slowly increase pressure to a maximum of 30 bar. Stop pumping for every litre injected and allow 1 - 2 minutes for reaction. Start and stop injection until the packer will no longer accept material or if the specified pressure has been reached. Move to the next packer and repeat injection process.

Continue injection until crack is full and has been adequately sealed. Monitor the effectiveness of the work and allow to settle for 2 - 3 days before returning to site and completing additional injection if required.

TBM Leak Repair and Maintenance

MATERIALS

BLUREZ CSW PRODUCT DATA

Packaging	21kg kit (20kg BluRez CSW and 1kg BluRez CSW - X)
Mix Ratio	0% to 10% BluRez CSW - X addition
Viscosity	@100cps
Colour	Amber
Shelf Life	12 months

REACTION TIMES OF BLUREZ CSW AND BLUREZ CSW - X				
Initial Temperature	5°C	10°C	15°C	25°C
Reaction Times Measured with 5% BluRez CSW - X				
Start of Foaming	10 seconds	9 - 10 seconds	9 - 10 seconds	8 - 9 seconds
End of Foaming	56 seconds	58 seconds	47 seconds	45 seconds
Foaming Factor*	35 - 50	35 - 50	35 - 50	35 - 50
Reaction Times Measured with 10% BluRez CSW - X				
Start of Foaming	10 - 11 seconds	10 - 11 seconds	9 seconds	8 seconds
End of Foaming	47 seconds	45 seconds	38 seconds	32 seconds
Foaming Factor*	35 - 50	35 - 50	35 - 50	35 - 50

TESTED CHARACTERISTIC	STANDARD	RESULT
Density	ASTM D-1622	64kg/m^3
Water Absorption	ASTM D-2127	<1%
Shear Strength	ASTM C-273	135kPa
Tensile Strength	ASTM D-1623	186kPa
Elongation	ASTM D-1623	50%

* The reaction is started by addition of 10% water to the fresh blend

TBM Leak Repair and Maintenance

MATERIALS

BLUREZ C150

BluRez CS150 is a single component polyurethane which reacts with water to form a hydrophilic flexible seal.

USES

BluRez CS150 is designed for the sealing/grouting and elastic connection of fissures and cavities in buildings and other civil engineering structures constructed of concrete, brickwork and natural stone. Application uses such as tunnel linings, concrete foundations, subterranean curtains, retaining walls, slab on ground and bridge abutments. Generally, the BluRez CS150 is most suitable for use in consistently damp or wet environments.

ADVANTAGES

- Potable water use approved in accordance with AS/NZ 4020:2005
- Hydrophilic for high water stopping properties
- Easy to use, single pack
- Highly flexible for live structures
- Compatibility with most surfaces
- Rapid foam and gel times

PREPARATION

Evaluate joint or crack for injection. Drill holes either side of the crack, sloping towards the crack at an angle of approximately 45°, beginning at a distance of 120 - 150 mm from the crack. Insert packer at a depth of approximately 100mm. Pre-injection with water is recommended for priming and facilitation of reaction.

MIXING

BluRez CS150 is supplied in one component packaging ready for application.

APPLICATION

Commence from the widest part of the crack and proceed injecting outwards along the crack in each direction. Turn on pump and slowly increase pressure to a maximum of 30 bar. Stop pumping for every litre injected and allow 1 - 2 minutes for setting. Start and stop injection until the packer will no longer accept material or if the specified pressure has been reached. Move to the next packer and repeat injection process. Continue injection until crack is full and has been adequately sealed. Monitor the effectiveness of the work and allow to settle for 2 - 3 days before returning to site and completing additional injection if required. BluRez CS150 may be injected into the crack with water at a ratio of 1 : 1.

TBM Leak Repair and Maintenance

MATERIALS

BLUREZ C150 PRODUCT DATA

Packaging	20kg kit
Mix Ratio	Single component
Viscosity	800cps @ 25°C
Shelf Life	12 months

TESTED CHARACTERISTIC	STANDARD	RESULT
Tensile Strength		2.55MPa
Elongation @ Break		400%
Foaming Factor		3 - 3.5*
Start of Foaming		45 seconds*
Gel Time		55 seconds*
End of Foaming		200 seconds*
Tack Free Time		230 seconds*

* Laboratory measurements mixed 1 part water to 3 parts BluRez CS150 @ 25°C

TBM Leak Repair and Maintenance
INJECTION EQUIPMENT

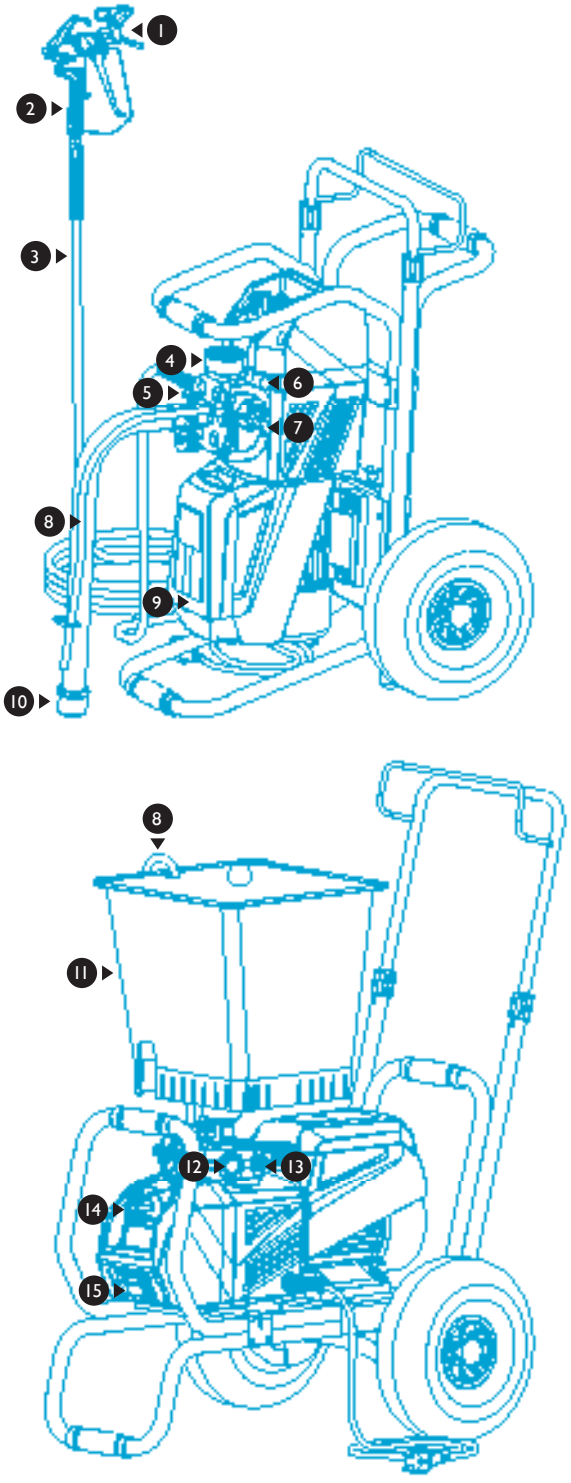
TOOLS AND EQUIPMENT

- Shifters x 2
- Multi grips
- Screwdriver set
- Spanner set
- Hammer
- Teflon tape
- 20 Litre buckets x 3
- Chemical gloves
- Face shield or goggles
- Safety glasses
- Disposable coveralls
- Electric hammer drill
- Battery hammer drill
- Drill bits
- Cordless drill
- Extension lead
- Generator
- Paddle mixer
- Rags x 1 bag
- Timber wedges x packet
- Injection packers
- Clutch heads
- Injection lance
- Quarter inch ball valve
- BluRez CSW kit
  (BluRez CSW and BluRez CSW-X)
- BluRez PU cleaner (polyurethane cleaner)
- Plastic sheet
- Wagner SF33 spray pump

TBM Leak Repair and Maintenance
INJECTION EQUIPMENT

WAGNER SF33
DETAILED DESCRIPTION

1 Tip guard with airless tip
2 Spray gun
3 High-pressure hose
4 Pressure gauge
5 Inlet valve button
6 Oil measuring stick
7 Multifunction switch
Symbols (shown in the recess of the switch):
OFF
ON/Circulation
ON/Spraying
8 Return tube
9 Tool box
10 Suction tube
11 Hopper
12 Outlet valve
13 Connection for high-pressure hose
13 Socket, max. load 1200 Watt
14 Pressure control valve
15 Socket, max. load 1200 Watt



TBM Leak Repair and Maintenance

CRACK REPAIR PROCEDURE

SET UP

1 Place plastic sheeting below the area where the injection works will be performed. Cover the EWP basket in plastic also, ensuring an easier, faster clean up.

2 If possible, have the EWP 'up wind', to eliminate spillage on the base of the EWP.

3 Use rags and timber wedges to plug larger cracks, voids and grout ports.

PREPARATION FOR INJECTION

4 Drill packer holes using an appropriated drill size for the packers angled at 30° to the vertical, and between 100-160mm from the crack on the surface to ensure the hole doesn't penetrate the full depth of the segment.

5 The holes should be a minimum of 80mm from the segment edges and grout sockets.

6 Drill holes should alternate on either side of the crack length, spaced at approximately 200mm along the length of the crack (see Figure 1).

7 The hole spacing will require some judgement by the repair crew and locations/spacing will vary depending on:

- Amount of water leaking
- Size of crack
- Nature of crack.

8 Insert the packers into the holes and embed the black rubber end completely into the lining. Tighten the packer adjustment nut with a shifting spanner so that the end will expand and provide a tight non-return seal.

9 Clean the concrete face to ensure that the surface is free from dust, oils or other contaminants.

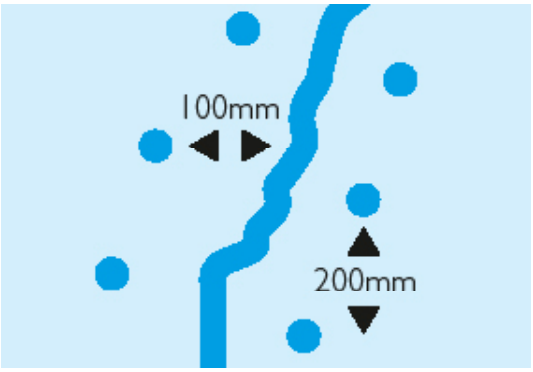


Figure 1: Drill hole spacing for packers

INJECTION

10 BluRez CSW/CS150 will react with any free water or moisture within the pump and the line, so ensure the line/pump is free of any water prior to use. Water should never be used to clean the lines containing resin as it will react. Instead, a polyurethane cleaner should be used.

11 Some larger cracks with greater inflow of water may require an initial injection of BluRez CSW. Reaction time can be adjusted depending on catalyst quantity added. When adding catalyst to BluRez CSW, it should be added slowly whilst continually mixing. Refer to each products' Technical Data Sheet at www.bluey.com.au for more information.

12 Both BluRez CS150 and BluRez CSW are injected using a single component injection pump.

13 The pump line should be stored/filled with oil or cleaner. Ensure the line is clear of any free material.

14 Always make sure that the injection material is homogeneous. Mix the resin using a dry, clean drill with paddle mixer for a minimum of 2 mintues before application.

15 When using BluRez CSW, perform a trial to confirm the activation using a cup and water once mixed. Once activation has been confirmed, injection may commence.

TBM Leak Repair and Maintenance

CRACK REPAIR PROCEDURE

16 Once the injection material is agitated and the pump is connected, prime the line with BluRez CS150/CSW by slowly pumping the material until the existing oil/cleaner is bled from the line. This material should be collected in a waste container to prevent any runoff.

17 Once the pump line is primed, connect the pump nozzle to the end of the packer at the lowest point. Starting on one side of the crack, inject the packers, moving across the length of the crack. Continue pumping from one location until resin comes out of the crack close to the next packer. Alternatively, pump until point of resistance and allow time for the material to react.

18 Release the pump hose and continue to the next packer. If the crack is large enough for the material to leak out of the crack, it will be necessary to patch over the existing crack using BluRez 575 prior to attempting to seal the crack again.

19 In some instances, leaks may require a number of attempts to seal. The reaction may take up to a couple of hours to completely take effect. In some cases, it may be necessary to undertake a round of injection then reinspect the area the following shift.

20 If water slows but does not stop, repeat the injection procedure from existing packers, starting from one side working to the other. It is worth leaving packers in place until water is confirmed to have stopped and the crack area dries. Packers and/or drill holes may have become blocked due to reaction with leaking water. In which case, replace the packer or drill another hole.

21 Once the material has reacted (10-15 mins), the packers can be removed from the lining. Care needs to be taken when removing packers due to the potential pressure remaining in the holes which can cause resin to eject. Hold a rag at the base of the hole to shield the squirting resin. Ensure all PPE is worn during the removal of packers.

22 The adjustment nut on the packer should be loosened, the packer removed and the remaining hole filled in with BluCem HB50.

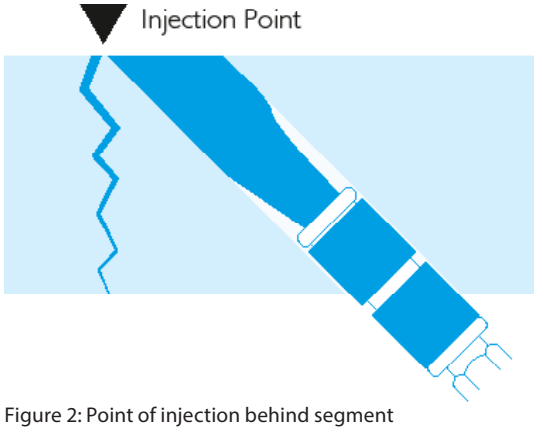


Figure 2: Point of injection behind segment

CLEANING

1 After each round of injection, the pump is required to be cleared to preserve its life.

2 Note that when separate from the presence of water, BluRez CS150/CSW will remain in liquid form. When open to the atmosphere, the moisture found in the air will cause the product to react.

3 Using a Polyurethane Cleaner and a collection container, remove feeder hose from material drum, empty the line and flush thoroughly with cleaner until the fluid coming through contains no trace of BluRez CS150/CSW.

TBM Leak Repair and Maintenance

SECTION 1 - WET OR WEEPING CRACKS

REPAIR OF A WET OR WEEPING CRACK IN A CONCRETE SEGMENT LINING

For wet or weeping cracks BluRez CS150 should be used as it is a water reactive, single component, hydrophilic polyurethane designed to stop the ingress of water. The image (right) shows a typical wet crack in a concrete segment.

1.1 Drill packer holes as described in section 1.0.

1.2 The crack must be intersected to allow the injection material to react with the water behind the segment.

1.3 Clean the concrete face to ensure the surface is free from dust, oils or other contaminants.

1.4 Insert a 13mm x 100mm packer and tighen to seal.

1.5 Pour the BluRez CS150 into the hopper of the drill pump and begin injecting through the first packer.

1.6 Always start from the lowest point of the crack.

1.7 Inject the resin until you see a white or creamy foam weeping from the crack close to the second packer.

1.8 Disconnect the injection hose from the first packer and connect to the second packer.

1.9 Continue this process until the entire crack is filled.

1.10 Trying to clean resin from the crack whilst wet usually results in it being smeared over the surface and making it difficult to clean. Therefore, clean the resin once it has reacted and set.

1.11 Re-inject the BluRez CS150 in all packers a second time to tighten up any problem areas, it is important to do this within 45 minutes of your first packer injection.

1.12 If crack continues to weep after 45 minutes, drill and install extra packers at a point where water is visibly weeping. Inject BluRez CS150 into these packers as previously mentioned.

1.13 Inspect the work the following day to check if any areas require additional injection.

1.14 Once the crack has been inspected and deemed repaired, all packers should be removed.

1.15 The packer hole can then be filled with BluCem HB50.

1.16 A smooth 100mm strip of BluRez 575 is then applied over the length of the crack injected.

TBM Leak Repair and Maintenance

SECTION 2 - HIGH FLOW WATER INGRESS

REPAIR OF HIGH FLOW WATER OR LARGE VOIDS IN CONCRETE SEGMENT LININGS

For high flow water or large voids use BluRez CSW for initial grouting. BluRez CSW is a water reactive, two component, hydrophobic polyurethane designed to stop the ingress of high water flow. The BluRez CSW comes with a catalyst to determine the speed of reaction. It is ideal for cracks up to 10mm thick.

BluRez CSW should be used on cracks where water leaks are large. This product is designed to react with water to form a water tight seal. Only inject enough resin to stem water flow before completing the repair with BluRez CS150.

2.1 Begin by drilling packer holes as described in section 1.0.

2.2 Intersect the crack to allow the injection material to react with the water behind the segment.

2.3 Insert packer and tighten to seal.

2.4 Pour the BluRez CSW into the hopper of the pump and start to inject through the first packer.

2.5 Always start from the lowest point of the crack.

2.6 Inject the BluRez CSW until you see a white or creamy foam weeping from the crack close to the second packer.

2.7 Disconnect the injection hose from the first packer and connect to the second packer.

2.8 Continue this process until the water flow has been reduced to a level where injection can continue with BluRez CS150.

2.9 Trying to clean resin from the crack whilst wet usually results in it being smeared over the surface and making it difficult to clean. Therefore, clean the resin once it has reacted and set.

2.10 If the crack continues to leak, re-inject the BluRez CSW/CS150 in all packers a second time in any problem areas. It is important to do this within 45 minutes of the first packer injection.

2.11 If the crack continues to weep after 45 minutes, drill and install extra packers at a point where water is visibly weeping. Inject BluRez CSW/CS150 into these packers as previously mentioned.

2.12 Inspect the work the following day (if possible) to check if any areas need additional injection.

2.13 Once the crack has been inspected and deemed as repaired, all packers shall be removed.

2.14 The adjustment screw on the packer should be loosened, packer removed and hole filled in with BluCem HB50.

2.15 A smooth 100mm strip of BluRez 575 is then applied over the length of the crack injected.

Note: BluRez CSW is highly water reactive and can block pumps very easily. It is recommended to cycle two lots of 1 litre of fresh cleaner through the pump before pumping through oil to encapsulate the lines. This will not allow any air or moisture to set the resin off that may be left in the lines.

TBM Leak Repair and Maintenance

SECTION 3 - LEAKING GASKET

REPAIR OF A LEAKING GASKET IN A SEGMENT JOINT

Where gasket leakage is identified (resulting from excessive gap/lip/step) in a ring or longitudinal joint, there are two repair options (below). Option 2 shall only be used if Option 1 does not stop the water from leaking in an undesirable location.

The area shall be injected using the same method as described in Sections 1.1 and 1.2 for the wet crack injection. However, for a gasket leak, holes must be drilled straight through to the back of the segment. Drilling on an angle may result in drilling through the gasket which will create additional issues. Note that holes to be drilled a minimum of 80mm from segment edge as shown in Figure 3 bottom right.

Typical gasket leaks

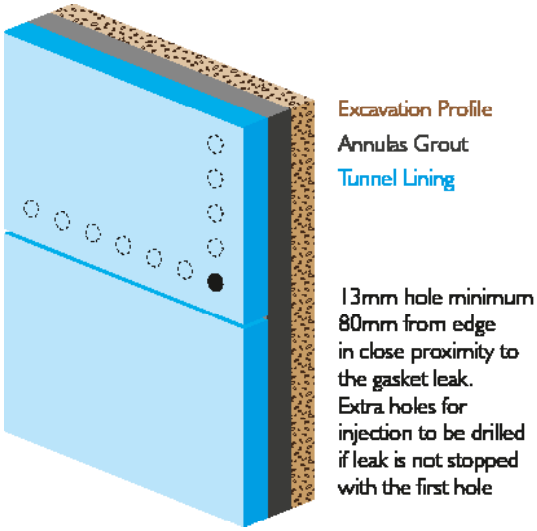


Figure 3: Segment joints

TBM Leak Repair and Maintenance

SECTION 4 - LEAKING GROUT SOCKET

REPAIR OF A LEAKING GROUT SOCKET IN A SEGMENT

If this does not stop the leaking water, the pathway for the water must either be on the outside of the grout socket or the cap area is damaged allowing water to escape around the o-ring. For this situation the following steps should be followed.

4.1 Drill a hole to suit the packer size at about 30-45 degrees through the segment into the socket behind the grout socket cap.

4.2 The hole should be drilled a minimum of 80mm from the grout socket.

4.3 Trying to clean resin from the crack whilst wet usually results in it being smeared over the surface and making it difficult to clean. Therefore, clean the resin once it has reacted and set.

4.4 Insert a packer and tighten to seal.

4.5 Pour the BluRez CS150/CSW (depending on water flow) into the hopper of the drill pump and start to inject through the packer.

4.6 Inject the BluRez CS150/CSW until the whole void behind grout socket cap is filled.

4.7 Inspect the work the following day to check if any areas need topping up.

4.8 If the leak has been successfully repaired then the adjustment screw on the packers should be removed and the hole filled in with BluCem HB50.

Where water is leaking from of a grout socket the first step should be to unscrew the cap and replace the rubber o-ring or cover the old o-ring (only if not damaged) with BluSeal Leakmaster before replacing the cap.

Typical grout socket arrangement

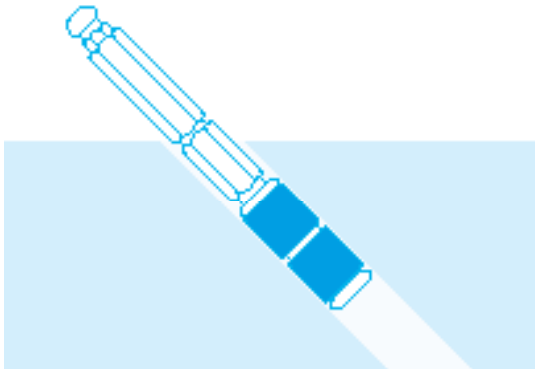
TBM Leak Repair and Maintenance

SECTION 5 - PUR CONTACT GROUTING

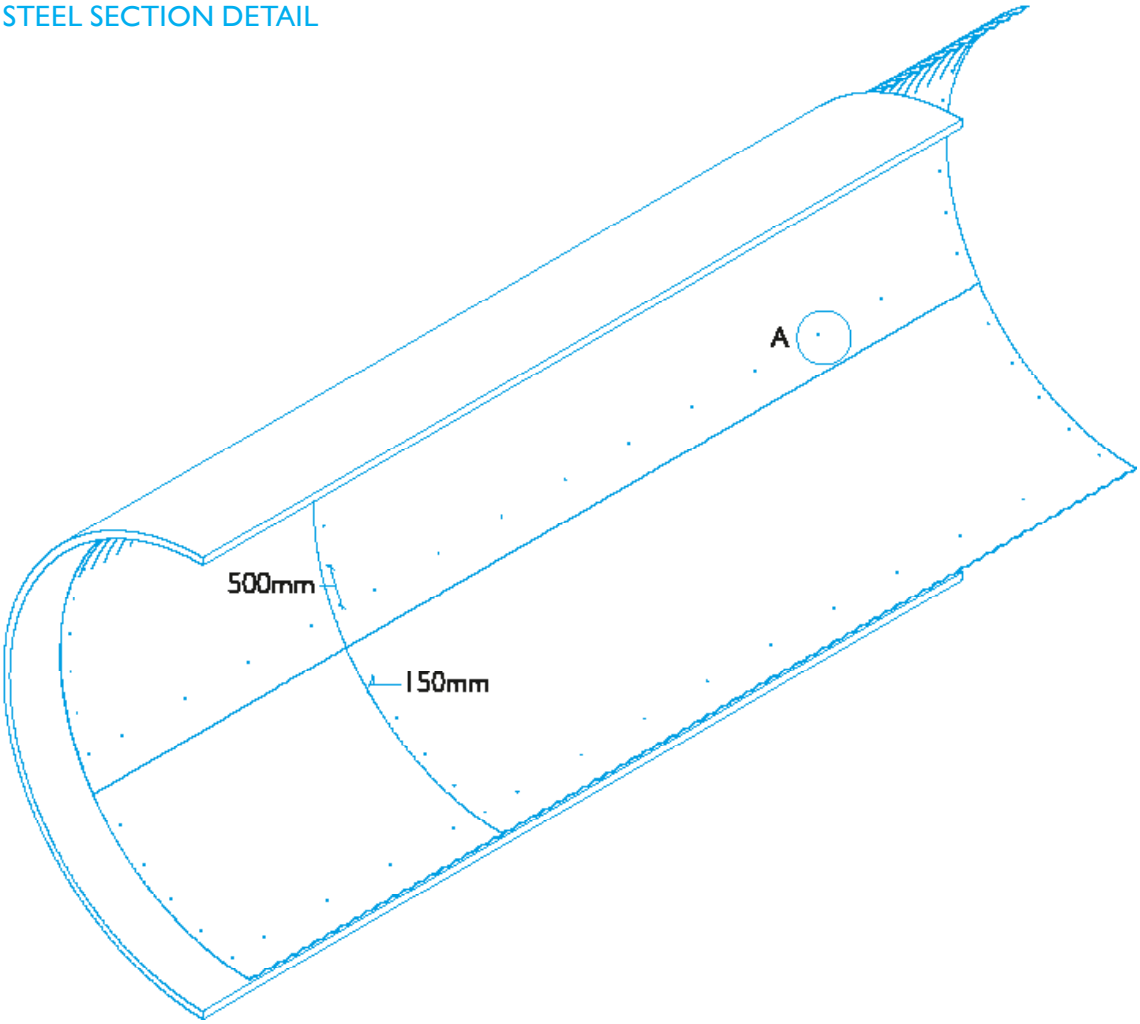
TUNNEL INJECTION PROCESS

To create a tunnel encapsulation ring in the TBM segmentally lined tunnel, holes are drilled every 500mm through the segment and injection packers are then installed. It is important to inspect the surrounding area whist injecting, monitoring any new leaks or loss of product through another problematic area. Continue injecting until the packer will not accept any more product, the leak has stopped or product is being lost to a high flow area. Continue the injection process until each packer has been injected. It is important to clean the pump thoroughly before and after use.

INJECTION PACKER DETAIL



STEEL SECTION DETAIL



TBM Leak Repair and Maintenance

SECTION 5 - PUR CONTACT GROUTING

PUR CONTACT GROUTING PROCEDURE

SET UP

5.1 Begin by selecting a safe and practical area to layout the equipment for the injection works.

5.2 Place plastic sheeting below the area where the injection works will be performed. Cover the EWP basket in plastic also, ensuring an easier, faster clean up.

5.3 If possible, have the EWP 'up wind', to eliminate spillage on the base of the EWP.

5.4 Use rags and timber wedges to plug larger cracks, voids and grout ports.

PREPARATION

5.5 Mark and drill injection packers approximately 500mm apart, installing the packers as you go. (If water is present overhead, use a cordless hammer drill to eliminate risk of electrocution and equipment being damaged).

5.6 Pour 2-4 litres of BluRez PU Cleaner into the hopper of the Wagner SF33 spray pump. Ensure that the pressure relief valve is open and allow the PU Cleaner to circulate for 2-3 minutes. Once finished, turn the pressure relief valve off and open up the ball valve on the lance (hand piece) and spray the contents into a bucket. This will ensure the pump and hoses are clean and working optimally.

5.7 Confirm steps 1 to 6 have been completed and begin mixing BluRez CSW and BluRez CSW-X for 3 minutes using a cordless drill and paint mixer until an even mix of the 2 products is achieved.

5.8 Once mixed, perform a trial to confirm activation using a cup and water. Once activation has been confirmed, injection may commence.

TBM Leak Repair and Maintenance

SECTION 5 - PUR CONTACT GROUTING

INJECTION

5.9 To inject the resin, ensure that the clutch head is locked on to the packer securely with the ball valve turned off to avoid water entering the line and pump.

5.10 Pour BluRez CSW into the pump hopper and prime the lines with the pressure relief valve open. Once the BluRez CSW is continuously circulating turn off the pressure relief valve. Then, turn the lance ball valve on to start injecting.

IMPORTANT: Do not turn on the ball valve first as water may enter the line, and react with BluRez CSW causing a block in the lines and the pump.

Continue injecting until:

a The pump pressurizes and cuts out

b The leak stops

c BluRez CSW retreats out of the leak with the packer (shown right).

d BluRez CSW seeps out of a crack, gap or grout port in the surrounding area.

5.11 Once the packer is no longer taking in resin, ensure that the lance ball valve is turned off, then turn the pressure relief valve off. Allow the BluRez CSW to continue circulating until you are ready to inject the next packer.

5.12 Continue the process until the entire tunnel ring has been encapsulated.

CLEAN UP

5.13 Once the injection work has been completed, ensure the pump is cleaned thoroughly. Use the BluRez PU Cleaner (that is also used to test the pump before starting the injection) to work and flush all contents through the pump and hoses in the same manner as step 6.

5.14 Pour another 2-4 litres of fresh BluRez PU Cleaner into the hopper and perform the rinse again until the system is clean and there is no milky residue in the pump or lines.

Note: Do not let the hopper get below one quarter full as this will potentially allow solids to sit over the suction valve and block the system. Leave the solid crust in the hopper and pour the BluRez CSW through it. If the crust is broken into smaller pieces, it may block the pump resulting in wasted product as the reaction in the hopper will continue until a new crust is formed.

MASTER® BUILDERS SOLUTIONS

bluey®

We deliver...

- Products developed for civil engineering
- Product technical knowledge
- Site application knowhow
- A collaborative approach
- Economical solutions for large projects

1300 0 BLUEY | qld@bluey.com.au

bluey.com.au

NSW
nsw@bluey.com

VIC
vic@bluey.com

SA
sa@bluey.com

WA
wa@bluey.com

TAS
tas@bluey.com

ACT
act@bluey.com

NT
nt@bluey.com

NZ
nz@bluey.com

Exclusive Distributors for

EpiMax JM JENNMAR AKS FiRep SAMWOO Anchor Technology

Our products have Government and Regulatory Authority approvals across Australia and New Zealand.

R01/2023