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Guidelines for the repair of water-leakage cracks in concrete structures

Lignes directrices pour la réparation des fissures dues à l'eau dans les structures en béton

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 16475 was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 7, *Maintenance and repair of concrete structures.*

Introduction

This Technical Report attempts to draw out a successful and effective plan for repairing water-leakage cracks. In general, there are two types of cracks that form within a concrete structure: dry cracks and water-leakage cracks. Dry cracks vary in their depth and width, and are known to cause instability to the foundation and durability of concrete structures. Water-leakage cracks arise from a combination of several environmental factors (chemical and physical or mechanical influences) that surround the buildings or concrete structures. They not only further the negative effects of dry cracks, but also cause additional problems, such as lingering humidity and wetness in building operations, which sometimes renders the buildings and the structures unable to carry out their designated performance, purposes and duties.

It has been assumed that the reason why it is difficult to find a proper method for repairing water leakage cracks is an insufficient knowledge and understanding of the negative factors (i.e. environmental conditions, the influences of various human activities, etc.) that cause the formation of the cracks and also in the selection of the repair materials and methods. Various types of repair techniques have been carried out in order to mend these different types of cracks, mainly the water-leakage types. However, the required conditions for sealing the water-leakage cracks have often proven to be extremely difficult to satisfy due to the wet and humid environment (which in most cases is the initial reason why the cracks have formed in the first place). This lack of a reliable and stable source of information regarding the water leakage cracks has caused unnecessarily high costs of repair in the field of construction and architecture and still continues to be a problem today.

Past records related to remedial action taken for these cracks have shown numerous results; some have shown failure, some have had minor success and some have managed to find an adequate solution that met the structures' needs so that they are able to continue performing their designed purposes. But rarely has a global, standardized and consistent solution been implemented for these problems. When all the aforementioned problems are taken into consideration, it is evident that there is a strong need for a standardized guideline on how to select the appropriate materials and methods in accordance with the different types of environmental conditions and factors that lead to water-leakage cracks. It is highly anticipated that a newly proposed awareness and understanding of these issues will prevent further unnecessary use of high budgets and expensive repair materials that do not serve its intended purpose and additionally will help avoid manual and possibly dangerous repair projects when dealing with water leakage cracks.

This Technical Report attempts to create a reliable consistency for future cases of water-leakage cracks so that there will no longer be a need for obscure and insecure solutions that rarely remedy these types of problems with concrete structures. This Technical Report was developed for countries that do not currently have existing general guidelines on this subject and for local regulatory authorities worldwide. It is eagerly anticipated that there will be further development and cooperation by the authorities in each country for the principle of further augmenting knowledge about concrete and the understanding of concrete structures and architectural construction.

Guidelines for the repair of water-leakage cracks in concrete structures

1 Scope

This Technical Report gives guidelines for the selection of a proper grout material to repair water leakage through cracks and other discontinuities in concrete structures including the following:

- conditions of water-leakage cracks;
- performance requirements for repair materials;
- different types of repair materials (grouts);
- procedures followed to select the appropriate repair materials;
- execution of different types of repair methods;
- performance assessments of applied materials and methods;
- data collection.

This Technical Report does not include a focused section about the repair of dry cracks and the causes or the origins of cracks. The details on dry crack repairs are covered in ISO 16311-4[1)].

A flow chart for maintenance of water-leakage cracks is shown in Figure 1.

1) To be published.

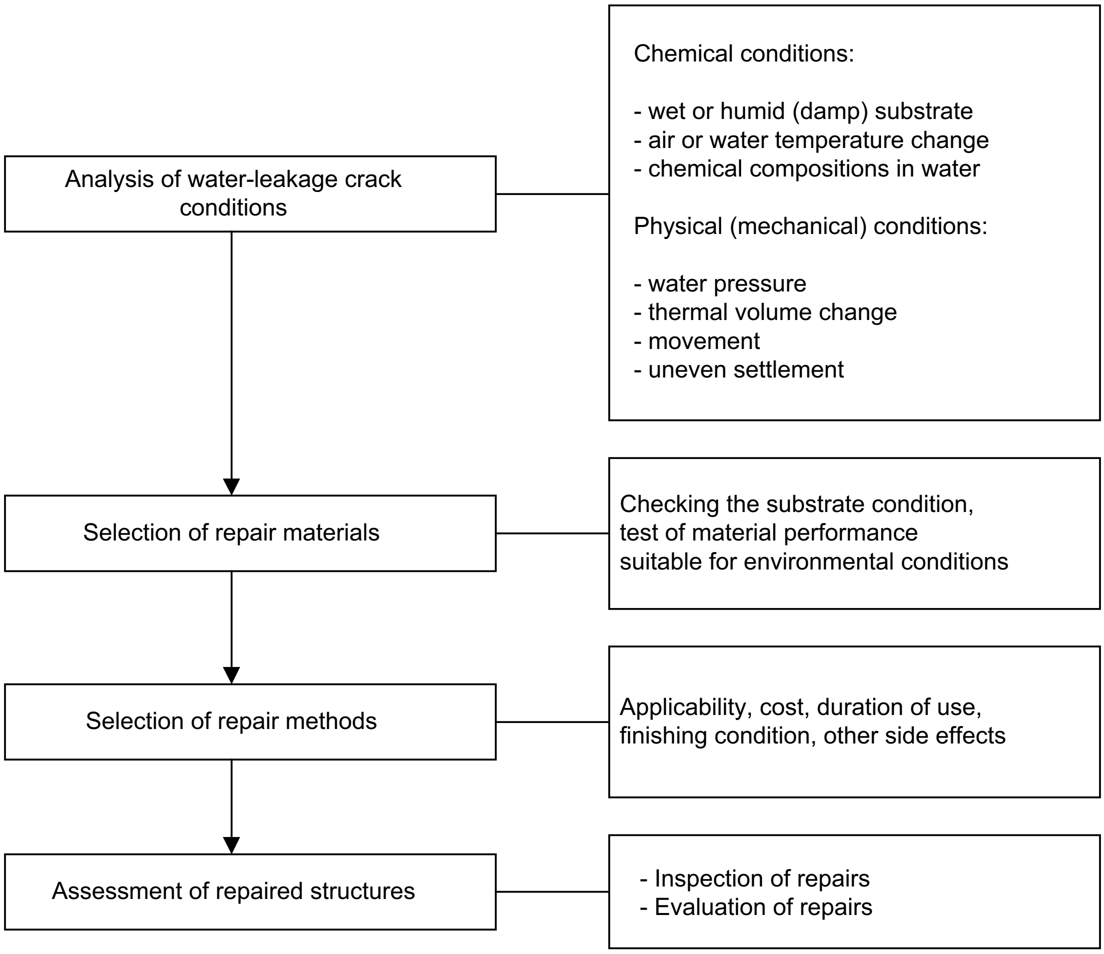


Figure 1 — Flow chart for maintenance of water-leakage cracks

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16311[2)] (all parts), *Maintenance and repair of concrete structures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16311 (all parts) and the following apply.

3.1
water-leakage cracks
concrete fissures that accompany water leakage intermittently or continuously

2) To be published.

3.2
leakage
amount or flowing state of liquid (water) that escapes from inside or outside a concrete substrate by means of a crack, hole, joint or other fault

3.3
thermal compatibility
chemical and physical stability of repair materials in response to temperature fluctuations in the atmosphere or under water

3.4
water resistance
ability to withstand quantitative and qualitative loss of materials produced by the pressure and flow velocity of water

4 Conditions of water-leakage cracks

4.1 Types of water-leakage cracks

Various types of cracks under conditions ranging from dry to flowing water are given in Table 1. This includes both non-moving or static cracks which are stable and moving or dynamic cracks which are not growing. Table 1 also provides information about leakage cracks with varying ranges of width and water flow.

4.2 Environmental conditions of water-leakage cracks

Unlike dry cracks, when water-leakage cracks are exposed to various conditions, there are several environmentally-related (chemical and physical or mechanical) factors which must be taken into consideration, including temperature and humidity in the atmosphere, water pressure, flow velocity, chemical reactions of the water, and the vibration caused by passing vehicles. Such factors have negative effects not only on the water-leakage cracks themselves, but also on the efficiency and effectiveness of repair materials and methods that may be used on the cracks (see Figure 2).

Table 1 — Classification of cracks in relation to repair of water-leakage

<table>
<tr><th>Crack width</th><th>Leakage amount</th></tr>
<tr><td>Stationary or dormant crack</td><td>—</td></tr>
<tr><td rowspan="7">Fine cracks
≤2 mm (≤1/13 in)

Medium cracks
>2 mm to 6 mm (>1/13 in to 1/4 in)

Large cracks
>6 mm to 20 mm (>1/4 in to 10/13 in)</td><td>Damp surface</td></tr>
<tr><td>Light seepage
<1 l/min (<1/4 gal/min)</td></tr>
<tr><td>Medium seepage
>1 l/min to 5 l/min (>1/4 gal/min to 1 1/4 gal/min)</td></tr>
<tr><td>Heavy seepage
>5 l/min to 10 l/min (>1 1/4 gal/min to 2 1/2 gal/min)</td></tr>
<tr><td>Light flow
>10 l/min to 15 l/min (>2 1/2 gal/min to 4 gal/min)</td></tr>
<tr><td>Medium flow
>15 l/min to 25 l/min (>4 gal/min to 6 1/2 gal/min)</td></tr>
<tr><td>Heavy flow
>25 l/min (>6 1/2 gal/min)</td></tr>
<tr><td colspan="2">NOTE Each and every crack width in the left column corresponds to all seven leakage amounts in the right column.</td></tr>
</table>

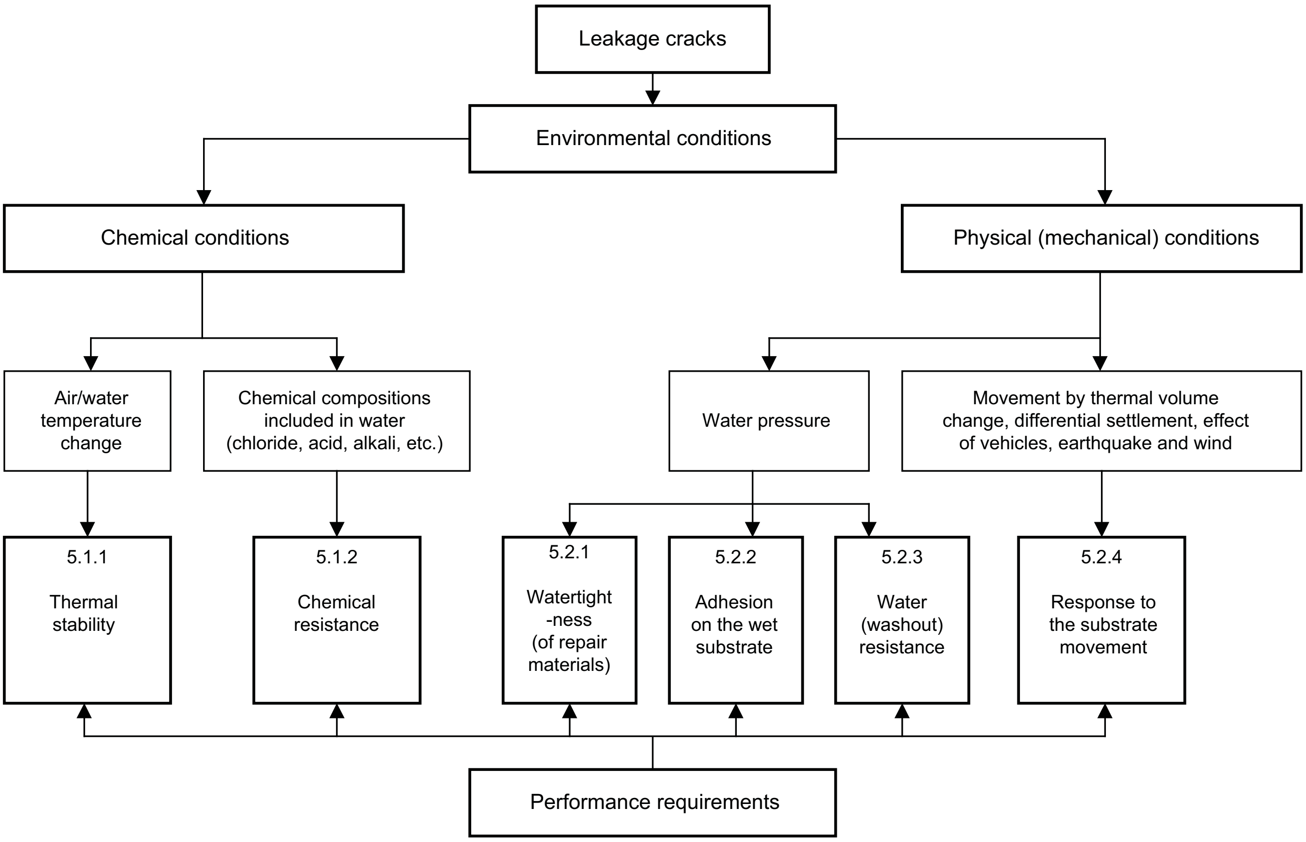


Figure 2 — Environmental conditions and performance requirements for the repair of water-leakage cracks

Because water-leakage cracks are constantly affected by a variety of environmental conditions and factors, repair materials and proper methods must also be designed to address these environmental factors.

An understanding of the environmental conditions pertaining to water-leakage cracks is a priority for remedying them. When selecting the correct repair materials and proper methods, the appropriate response to environmental factors must be considered. Finally, evaluating the appropriate materials and the application method of these materials to determine the response method to environmental factors is obligatory.

Figure 2 categorizes the environmental factors and illustrates the required performance responses to each factor. It also provides evaluation items for each repair material.

4.2.1 Chemical conditions

Chemical factors in the environmental condition that affect the efficiency of repair materials for water-leakage cracks include temperature changes in the air or water surrounding the leakage cracks, and the chemical composition of the water (e.g. underground water, salt water, sewage water, and acid rain).

These factors affect thermal stability, resistance to chemical attack, watertightness, and the adhesion of repair materials on the substrate. The selection of appropriate materials for the given chemical condition is therefore very important.

4.2.2 Physical (mechanical) conditions

The physical (mechanical) factors in the environmental condition that affect the efficiency of repair materials include the movement of volume change by the shrinkage and expansion of concrete due to temperature change, the movement due to unevenness in the settlement of the structure, the vibration movement caused by passing of vehicles, and water pressure surrounding the crack.

These factors affect the adhesion on the substrate, the watertightness, and the responsiveness of repair materials to the substrate movement. The selection of appropriate materials for the given physical (mechanical) condition is very important with regards to these factors as well.

5 Performance requirements for repair materials

Materials used for repairing water-leakage cracks should perform in response to the environmental conditions. The performance requirements can be divided into the categories described in 5.1 and 5.2.

5.1 Performance requirements for chemical conditions

5.1.1 Thermal stability

These repair materials are made up of highly polymerized or inorganic compounds, thus they undergo constant shrinkage and expansion depending on temperature changes. Due to these continuous changes, the performance of injected repair materials can deteriorate.

In other words, repair materials used to seal water-leakage cracks should maintain their thermal dependence, even in the case of repeated temperature change, and should remain intact for a long period of time.

5.1.2 Chemical resistance

Concrete structures are constructed under various chemical environmental conditions. They are often bordered by water or soil in underground structures, and are located near industrial areas or seashores so that chemical corrosion caused by chemical substances (e.g. acid, alkali, salt water or calcium hydroxide, and carbon dioxide) occurs more frequently. In addition, chemical corrosion decreases the performance of the injected repair materials.

Therefore, repair materials should maintain their chemical attack resistance performance, even in the case of chemical corrosion, and satisfy the need to resist chemical attacks over a long period of time.

5.2 Performance requirements for physical (mechanical) conditions

5.2.1 Watertightness

Watertightness of repair material is the ability of a material to block the penetration of water. The watertightness of repair material is a crucial performance factor in environments where the substrate concrete is vulnerable to moisture-related deterioration. It must, therefore, be made certain that injected repair materials have bonded well, so as not to allow water passage.

Therefore, repair materials should be able to maintain their watertightness performance by withstanding constant changes in the surrounding water pressure or water volume and remain permeable to water over a long period of time.

5.2.2 Adhesion on the wet substrate

Water-leakage cracks often occur in wet or underwater conditions. In this case, the injected repair materials should not only be capable of withstanding strong water currents, but should also have strong adhesion to wet concrete substrate and other waterproofing layers. These characteristics can be obtained by maintaining the strong adhesion of repair material in either solid or liquid gel forms that can block water leakage under higher stress (water pressure and substrate movement).

Therefore, repair materials should maintain their adhesion performance even in the case of moist or wet environments, and satisfy the criteria that specify strong adhesion on a wet substrate over the long term.

5.2.3 Water (washout) resistance

The repair material for this condition is injected as a liquid/gel-type substance. The danger of these types of repair materials is that if they are washed away before hardening, it is highly unlikely that they will keep proper form and maintain a sufficient amount of repair material in the crack. Thus, its effect could be lost. Furthermore, when injected repair material is lost due to the water current, it could cause environmental pollution to the surrounding area, e.g. the underground water or the soil under the building foundation.

Therefore, repair materials used for water-leakage cracks should have the appropriate water resistance performance to prevent them from being washed away over a long time period.

5.2.4 Response to the substrate movement

The width of water-leakage cracks constantly shrinks and expands according to the changes in the surrounding temperature, constant vibrations from the motion of vehicles on railways or underground railway structures and bridges, as well as the movement caused by uneven settlement of structures. The repeated movement of concrete substrates with water-leakage cracks increases the load on repair materials injected into the cracks, thus the injected repair materials can be destroyed, which causes a recurrence of water leakage even after the repair.

Therefore, repair materials should maintain their responsiveness performance to substrate or crack movement and satisfy the criterion that their responsiveness to the substrate or crack movement will last for a long time.

6 Grout materials for repair

Many types of repair materials (grouts) are currently being used on site, including acrylic grout, water-based cementitious grout, hydrophilic epoxy resin grout, polyurethane grout, synthetic rubberized gel grout, etc. It is important to note that many products on the market today may not only have disclosed the composition of their products, but also be blends of different types of materials, or contain additives that modify or change their characteristics. There have been numerous attempts to classify grouts according to their appropriate properties, but the simplest division to date is that of “particulate” grouts and “non-particulate” grouts as outlined in Figure 3.

6.1 Acrylic grouts (water-based acrylic gel grout)

Types of acrylic grout material include products such as acrylics, acrylates, acrylamides and acrylate ester. The water-based acrylic gel grout is composed of acrylic acid polymer. Acrylic acid polymer (resin) and hardener should be prepared in accurate proportions and be mixed at the work site immediately before application for ideal performance as repair materials. Due to the chemical reaction that occurs with water, water-based gel grout as an acrylic attains a jelly-like viscosity and blocks water penetration temporarily.

Acrylate gel grout has low tensile capacity and low viscosity because it is water-based. Poor tensile capacity of the gel results in the grout fracturing. Due to its weakness in terms of stability and its lack of adhesion on wet substrates, there is a possibility that injected acrylic grout could be destroyed if the crack width changes too frequently.

Thus, it is advisable to refrain from using this material for water-leakage cracks with severe water leakage or for expansion joints with severe movement on the structure, such as bridges, underground railways, or railways. The use of water-based gel grout as an acrylic is recommended for water-leakage cracks or joints with relatively little movement.

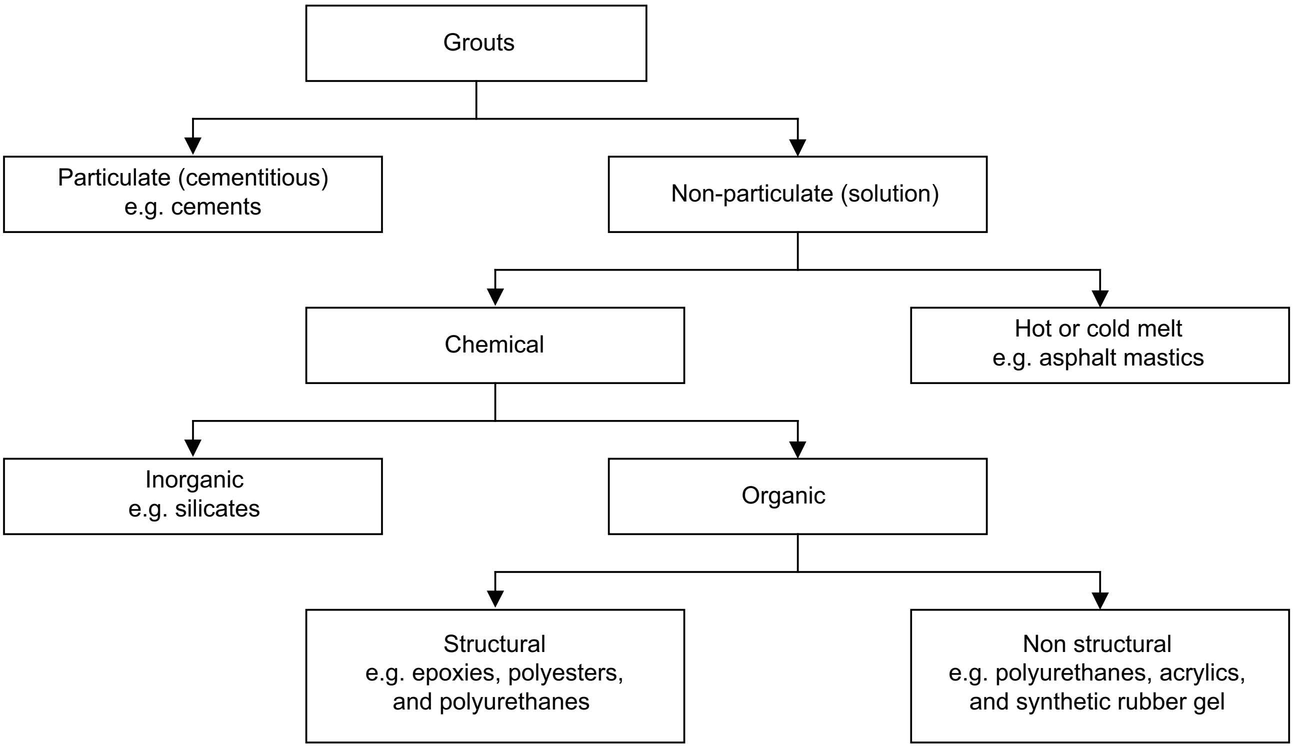


Figure 3 — Classification of grout material types

6.2 Cementitious grouts (water-based mixture of cement grout)

Types of cementitious grout material include products such as cements or a mixture of cement grout and bentonite grout, acrylamide grout, microfine grout, polyurethane grout and silicate grout. The thermal expansion coefficient of cementitious materials tends to be very similar to that of the substrate concrete. They are widely used due to their efficient bond strength to wet substrate concretes.

Polymer-cement slurry, a mixture of super particle cement (maximum grain size less than 16 μm) and inorganic compound, is also often used. Cement, polymer and water should be in accurate proportions and mixed well at the work site to obtain repair material that performs well. When polymer-cement slurries are used, it is possible to inject materials into cracks that are less than 0,05 mm in width.

Generally, the site at which the injection will be applied should be wet. If the crack is dry, then cementitious material may shrink before completely sealing the crack, making it difficult to cover the remainder of the crack. Thus, it is advisable to maintain the crack in a moist environment. When the movements or vibrations of the structure occur, cracks change width and volume, and damage to the injected cementitious material is possible. The use of cementitious material is recommended for water-leakage cracks or joints with little movement.

6.3 Hydrophilic epoxy resin grout

Epoxy always requires thorough mixing with a hardener and a curing compound, such as an amine or a polyamide. Epoxy resin and hardener should be mixed in accurate proportions at the work site right before application to obtain a repair material that performs well. There are two types of epoxy resins: hydrophobic and hydrophilic. Because of their high adhesive strength, hydrophobic epoxies are used for dry crack repairs for widths greater than 0,05 mm. Problems could also arise due to the high thermal expansion modulus of hydrophobic epoxies. The concrete is likely to produce another crack adjacent to the repaired crack when substrate movement occurs. Rigid resign grouts usually fracture at the bond line when subjected to high tensile stress.

Although hydrophobic epoxies have been widely used for structural bonding and waterproofing repairs, most epoxies that were previously used to seal water-leakage cracks have not produced successful results. Therefore, until now, epoxies that are able to maintain highly flexible and strongly adhesive properties in water-leakage cracks were in demand. To meet that demand, hydrophilic epoxies that effectively bond to moist substrates and effectively withstand substrate movement and constant temperature changes are being developed and tested in the market.

When selecting an epoxy resin grout, analysis of environmental conditions of the areas where epoxy resin grouts have previously failed is crucial.

6.4 Polyurethane grouts

Types of polyurethane grout material are products such as polyurethane foam, gels, resins, and solids. Urethane foam grouts consist of a polyurethane resin that reacts with water to form an expansive, closed-cell foam or gel (hydrophilic types). Polyurethane resin and hardener should be prepared in accurate proportion and mixed well at the work site to obtain a repair material that performs well. The reaction time to form the foam may be controlled from a few seconds up to several minutes with the addition of different types of catalysts. Because the desired effect of the materials depends heavily on the interval it takes to form, the importance of proper time management in mixing the components at the site is highlighted.

These grouts are semi-flexible, and thus they may tolerate some changes in crack width. Urethane foam grout expands when placed by the formation of gas bubbles. But when the crack changes width, a defomation of foam grout can occur because the gas bubbles are free to change volume. Poor bond of the grout to the crack surfaces may result in a loss of bond when the grout is placed in tension, and the expanded gas bubbles absorb water.

Urethane foam grouts are mainly used to briefly stop a sudden leakage of water, and constant surveillance of the leakage site is needed. They cannot maintain long-term repair because they absorb moisture.

In this regard, when deciding to select and use urethane foam grout, analysing environmental and mechanical conditions of the water-leakage crack and substrate concrete is necessary.

6.5 Synthetic rubber polymerized gel grout

Synthetic rubber polymerized gel grout is a mixture of a special macromolecule resin, such as a synthetic rubberized gel and asphalt compound, and an inorganic component such as bentonite. This grout can be used directly without mixing it with other components at the work site. It bonds well to wet substrates in water because of the expanding property of the bentonite component and can respond well to the movements of cracks because of the high flexibility of the rubberized gel component. It is also effective in both winter and summer because of the expanding property with high viscosity.

6.6 Other material

The other types of grout material are products such as asphalt emulsion, asphalt and mastics, quick setting mortars, silicate (liquid) and vinylester, etc.

7 Procedures applied to select the appropriate repair materials

7.1 Selection process of repair materials (grouts)

A number of applicable materials are available to the owner, engineer, or contractor. Depending on the varying environmental conditions of the water-leakage cracks, the appropriate selection of repair materials is very important for successful maintenance. Figure 4 provides a selection process of materials that can repair (seal) cracks of varying width and water flow. The cracks that occur in various service and application conditions require an adequate combination of effects from different repair materials, which have their respective capabilities (but also limitations when applied on the crack alone) in order to respond to such requirements. Therefore, well-designed assessments are required in order to select the most appropriate repair materials, and ensure the best resulting performance possible. Economics (cost) and previous experience by engineers may also influence the choice of materials utilized in a specific case or application.

7.2 Test for performance requirements

A number of tests are available for use in comparing the properties of grout itself. But there is no test used for evaluating the required performance (see Clause 5) of grout itself to resist environmental conditions (see Clause 4). The properties of a particular grout material should meet the performance requirements of site conditions. It may be necessary to devise new tests for specific purposes (to evaluate the required performance) in grouting application. The objectives and the contents involved in each test are listed in this clause.

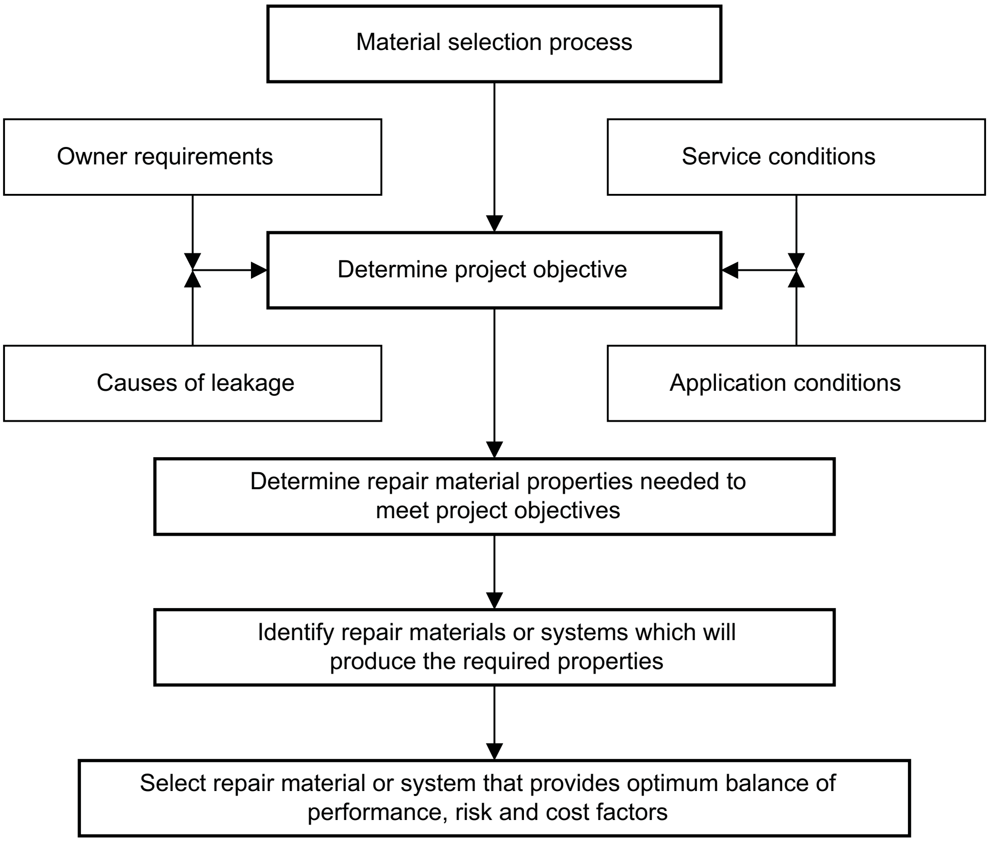


Figure 4 — Process of repair material selection

7.2.1 Test for thermal stability

The test for thermal stability assesses the thermal stability of an injected repair material and the amount of time it can maintain its degree of performance against temperature change in the surrounding environment of leakage cracks or repaired leakage cracks on underground structures or on roof slabs.

One method used to evaluate thermal stability is to observe the water penetration of the repair material immediately after the material is thermally stressed. To perform this evaluation, the repair material to be tested first undergoes several cycles of low and high temperatures (i.e. artificial fluctuations in temperature) in a temperature cycle chamber. Hydraulic pressure is then immediately exerted on the test material for a given interval of time. A material that does not allow water penetration after being affected by thermal change has good thermal stability.

7.2.2 Test for chemical resistance

The test for chemical resistance assesses the chemical resistance of injected repair materials against the corrosion effects of chemical compounds in surrounding water of repaired leakage cracks on underground structures or on roof slabs, and measures how long the repair material maintains its performance for repaired leakage cracks in chemical water.

One method used to evaluate chemical resistance is to measure the rate of the mass change of the repair material. To perform this evaluation, water containing various chemicals (e.g. acid, alkali and sodium chloride, or sea water) is used to exert chemical stress on the material injected into a crack for a given interval of time; a slow rate of mass change implies good resistance.

7.2.3 Test for watertightness

The test for watertightness assesses the watertightness of repair materials against the effect of water pressure on repaired leakage cracks in the surrounding environment of underground structures and on roof slabs, and measures the duration of their performance.

One way to evaluate permeability is to observe the water penetration through the test material, which is injected into an artificially made space between two pieces of wet substrates. Controlled hydraulic pressure is then exerted on the material that was injected into the “crack”; a material that does not allow leakage under applied water pressure implies good watertightness.

7.2.4 Test for adhesion on the wet substrate

The test for adhesion on the wet substrate assesses the adhesion of injected repair materials on the substrate concrete, and measures the duration of the adhesive strength.

To measure the adhesion, the repair material is used like a glue to hold two pieces of mortar (substituting for concrete substrate) with a standardized surface area and weight. The top half of the mortar is then fastened or clamped in mid-air, and the time it takes for the bottom half to fall off is measured. A repair material that holds the two mortar pieces together for a long time has good adhesion.

7.2.5 Test for water (washout) resistance

The test for water resistance assesses the washed-out resistance of injected repair materials against the erosion effect of water flow on repaired leakage cracks of underground structures or on roof slabs and the period during which the material maintains performance.

One method used to evaluate water resistance is to measure the rate of the mass change of the repair material. To perform this evaluation, an artificially created water flow is used to exert stress on the material injected into a crack for a given interval of time; a slow rate of mass change implies good resistance.

7.2.6 Test for response to the substrate movement

An ideal repair material not only must be watertight and resistant to changes but must also be flexible enough to modify its shape slightly in order to respond to moving substrates and avoid damage from the force.

This test assesses the flexibility or the ability of the repair material to respond to substrate movement that is due to cycles of thermal shrinkage and expansion, ground vibrations (from nearby passing vehicles), and uneven settlement in the surrounding environment of repaired leakage cracks on underground structures and roof slabs.

One way to evaluate this response to substrate movement is to determine whether the water penetrates through the test material after having forcefully moved the substrates to which the material was applied. A material that does not leak under stress due to moving substrates has good response to the substrate movement.

8 Execution of different types of repair methods

In order to select the best method for effectively sealing water-leakage cracks, the appropriate applicability, cost, duration of use, finishing condition and other effects related to repair methods must be considered. All methods used to repair cracks should provide effectiveness against water leakage. The effectiveness should be maintained for a long period of time. The methods for sealing water-leakage cracks can be categorized as listed in 8.1 and 8.2.

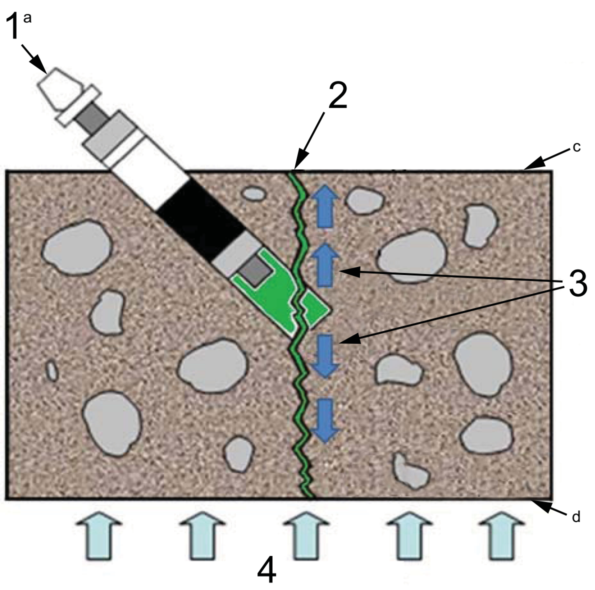
8.1 Grouting injection methods

Figure 5 illustrates the injection repair methods using urethane foam grout, acrylate grout, cementitious grout, and epoxy resin grout. There are three main types of grouting injection methods for water-leakage cracks.

The first method is called intercept injection [Figure 5 a)]. At a certain distance away from the crack, a hole is drilled diagonally through the concrete until it intercepts the crack at its midpoint. An injection nozzle is then inserted through the drilled hole. When the repair materials are transferred through the nozzle, the materials flow through the crack in both negative and positive directions from the midpoint of the crack until the crack is completely sealed up.

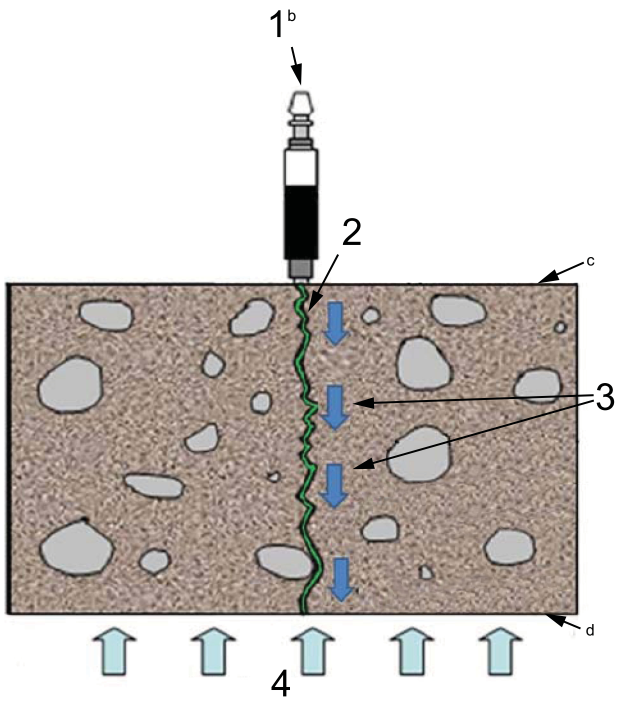
The second method is called negative side injection [Figure 5 b)]. The repair material is directly injected via the mouth of the crack on the negative side, flowing through the crack toward the positive side, filling up the entire inner space.

In the third method, called positive side injection [Figure 5 c)], an injection hole is drilled parallel to the crack at a certain distance away, creating another passage connecting the negative and positive sides. The repair material is then injected into this newly drilled hole, and the material flows from one end to the other. The material then spills out from the hole, later hardening to become a small barrier which blocks the mouth of the crack from the positive side, directly intercepting the water leakage. In order for this method to work, there must be a layer of soil beneath the substrate. Grout flow penetrates the surrounding soil, blocking the flow of fluid into passage. The amount of success depends upon the soil condition. Results may be uncontrollable.

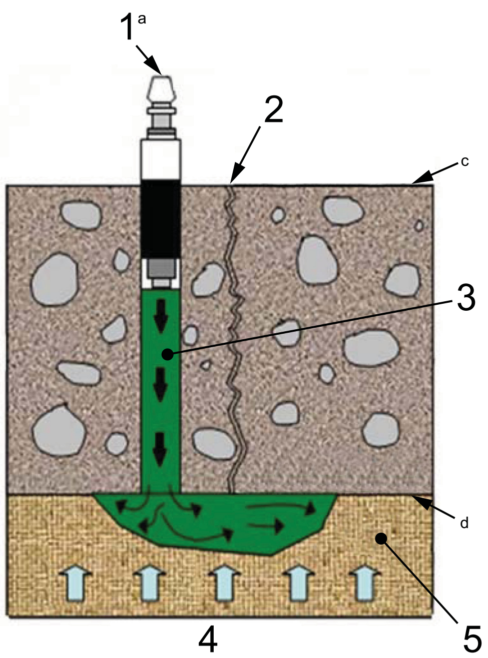


a) Intercept injection

Figure 5 — Grouting injection methods (*continued*)



b) **Negative side injection**



c) **Positive side injection**

Key

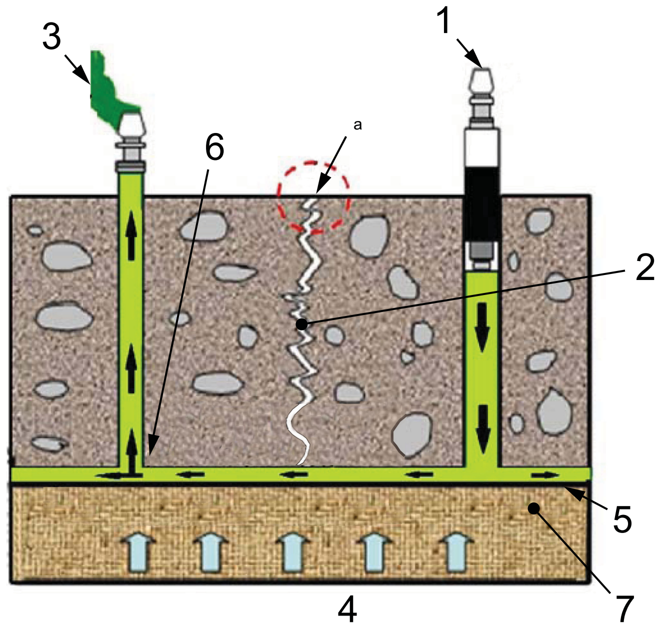
1 grout materials
2 leakage crack
3 grout flow paths
4 water pressure
5 soil

a Urethane foam, acrylate, microfine cement.
b Epoxy.
c Negative side.
d Positive side.

Figure 5 — Grouting injection methods

8.2 Injection method for reforming a waterproofing layer

Figure 6 shows the injection method for reforming a waterproofing layer using synthetic rubber polymerized gel grout, water-based gel acrylic grout, or water-based cementitious grout. This method describes how to reinforce the existing waterproofing membrane by using a drilled hole for injection. By drilling a hole into the substrate concrete (near the crack) through to the other side, a small space between the existing membrane and the substrate becomes accessible. Next, by injecting a sealing material into the drilled hole, the space between the membrane and the substrate is filled with repair materials. The injected material will spread around the space between the membrane and the substrate to create a new waterproofing layer and repair the fractured position of existing waterproofing layer, and prevent further water leakage and flow.



Key

1 grout materials (polymerized gel, acrylate)

2 water crack

3 counter flowing of gel

4 water pressure

5 existing waterproofing layer

6 reforming waterproofing layer

7 soil

a Stop water leakage by injecting polymerized gel in the existing waterproofing layer.

Figure 6 — Injection method for reforming a waterproofing layer

9 Performance assessments of repaired structures

9.1 Inspection of repairs

In order to measure the success of repairs of water-leakage cracks, inspection of each step of the preparation, process and completion is mandatory. An expert should be able to determine whether the application is successful or not after a brief examination.

Theoretically, it is easy to check the repaired crack to determine whether the crack no longer leaks. It is important to check whether the repair material firmly adheres to the cracks for a long period of time. However, in terms of the improvement of durability compared to the materials used before, it is usually difficult to evaluate the overall result. Therefore, the records of the materials used, mixing proportions, application period, quality control and test methods must be checked. Photographs that show the overall finished condition should be kept as a comparative reference. In other cases, inspection using a water leakage examiner with gas pressure is one alternative for evaluating the results of a repair process.

9.2 Evaluation of repairs

After carrying out the water-leakage crack repair, determining whether its result is successful or not is a very important step. In general, the assessment of the effects of the repair on water-leakage cracks should reach an accurate conclusion. If any defects in the initial planning, application or performance are found, and the effects prove to be insufficient, then reapplication should be carried out. Again, failure of reapplication will not only result in significant economic and administrative losses, but will also damage the repair material company and the engineers' reputation.

In order to reduce these types of errors, a systematic evaluation is needed as follows: analysis of the environmental conditions where the substrate structure is located, the nature of the water-leakage crack, the selection of suitable materials and application methods, the application and quality control (test planning included) scheme, and the maintenance management following the repair process.

In addition, various types of documents (such as the recording of results after completing the application, the procedure for selecting repair materials and applications, the list of defect inspection methods, the reason for the defect, the specifications for work, test and assessment, and the report of maintenance management planning) must be maintained for long-term security management of the repaired structures.

10 Data collection (record keeping)

By keeping a thorough record of each case where a water-leakage crack was successfully or unsuccessfully sealed, certain repairing processes can be selectively reused and the percentage of successful repairs for future problems can be increased. For similar cases, the records of the past problems can serve as a useful reference. The following items should be kept for records:

a) repair history (month, date, and year);

b) information on water-leakage crack (width, length, leak point, water leakage situation);

c) information on repair material (materials used);

d) information on application method (execution methods used);

e) information on repair results;

f) information on weather conditions during repair application work;

g) information on quality tests of repair materials (grouts);

h) information on required documentation process (including the detailed reports on repair process and the inspection process) upon completion of repair (refer to ISO 16311-4)[3].

3) To be published.

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