



quality control requirements for repair systems

TECHNICAL REPORT



TR 5.3

REINFORCED CONCRETE STRUCTURES REHABILITATION
IN MARITIME ENVIRONMENT

QUALITY CONTROL

quality control requirements
TECHNICAL REPORTS

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**REINFORCED CONCRETE STRUCTURES
REHABILITATION IN MARITIME ENVIRONMENT
QUALITY CONTROL**

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NOTE:

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented.

PREFACE

The main subjects concerned in this TR were discussed and a general review was made inside the working group WG A5 – Quality control requirements for repair systems. The WG was created in the DURATINET project with the aim to evaluate the new requirements at the levels of quality control of materials and repair products and execution works during structures repair due to the application of new European standard series EN 1504.

This report contains an example of the type of the quality plan to apply during execution of structures repair, according to EN 1504.

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CONTENTS

1	Introduction	1
2	Quality control of products and systems-evaluation of conformity.....	2
2.1	General considerations	2
2.2	Identification tests	2
2.3	Performance tests.....	2
2.4	Factory production control	2
3	Quality control of the works – tests and observations	3
3.1.	General considerations	3
3.2.	Methods for protection and repair of concrete structures	3
3.3.	Substrate conditions before and/or after preparation	4
3.3.1	Delamination (test)	4
3.3.2	Cleanless (test and observations)	4
3.3.3	Surface Unevenness (observation)	5
3.3.4	Roughness (test and observation).....	5
3.3.5	Surface tensile strength of substrate (test)	6
3.3.6	Crack width and depth (test and observation)	6
3.3.7	Crack movement (observation)	6
3.3.8	Vibration (observation)	7
3.3.9	Moisture Contents of substrate and cracks (tests and observation).....	7
3.3.10	Temperature of substrate (observation)	8
3.3.11	Carbonation (observation).....	8
3.3.12	Chloride content (test).....	8
3.3.13	Penetration of other contaminants and crack contamination (tests).....	8
3.3.14	Electrical resistivity (tests)	9
3.3.15	Cleanliness of existing reinforcement (observation)	9
3.3.16	Size of existing reinforcement (observation).....	9
3.3.17	Degree of corrosion of existing reinforcement (observation).....	9
3.3.18	Cleanliness of reinforcing plates (observation)	9
3.3.19	Compressive strenght (test)	10
4	Acceptance of products and systems	11
5	Condition and requirements before and/or during application	12
5.1.	Ambient temperatures (observation)	12
5.2.	Ambient humidity (observation).....	12
5.3.	Precipitation (observation)	13
5.4.	Wind strength (observation)	13

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

5.5. Dew point (observation)	13
5.6. Wet thickness of coating (test)	14
5.7. Consistency of concrete or mortar (tests).....	14
5.8. Air content of fresh concrete (test)	14
5.9. Thickness of cover or repair materials (test and observation)	14
5.10. Compressive strength (test)	14
5.11. Position of reinforcement (test or observation)	15
6 Final hardened condition	16
6.1. Delamination (test).....	16
6.2. Electrical resistivity (test)	16
6.3. Dry thickness of coating (test).....	16
6.4. Covering of coating (observation)	16
6.5. Penetration of impregnation (test and observation).....	16
6.6. Permeability of coating or repair material or filled cracks to water (tests)	17
6.7. Degree of filling of cracks (test and observation).....	17
6.8. Thickness of cover or repair materials (test and observation)	17
6.9. Adhesion of coatings, adhesive and repair material (test)	18
6.10. Compressive strength (test)	18
6.11. Density of hardened concrete or mortar (test)	18
6.12. Shrinkage cracking in repair material (observation)	18
6.13. Presence of cracks and voids in and behind hardened repair materials (test and observation).....	18
6.14. Position of reinforcement (test and observation)	18
6.15. Bond of reinforcement (test).....	19
6.16. Presence of voids between bonded plates and substrate (test)	19
6.17. Structural performance - load tests	19
6.18. Adhesion of crack filling material to substrate (test and observation)	19
6.19. Colour and texture of finished surfaces (observation)	19

1 Introduction

This document concerns the quality control of products, systems and works of rehabilitation of reinforced concrete structures in maritime environment.

The quality control and the evaluation of conformity of the products and systems used in the rehabilitation works are mentioned in Technical Report 5.1, referring mainly to the requirements of EN 1504.

The quality control of the execution of the rehabilitation works is described in Technical Report 5.2, mentioning the required tests and/or observations to be carried out for the several methods for protection and repair of concrete structures.

The execution of the rehabilitation works is described in four phases for quality control, namely the substrate conditions before and/or after specific preparation, the acceptance of products and systems to be applied, the condition and requirements before and/or during application and the final hardened condition of the rehabilitation work.

For each phase of the rehabilitation work, a list of tests and/or observations is presented, associated to the referred methods of protection and repair.

2 Quality control of products and systems-evaluation of conformity

2.1 General considerations

The rehabilitation products and systems applied shall satisfy the requirements in EN 1504 – Parts 2 to 7 and Part 8. The storage conditions and the periods of use of these products and systems shall comply with clause 5 of EN 1504- Part 10 and the specification.

2.2 Identification tests

The initial identification tests of the products and systems shall be undertaken as mentioned by the materials specification Part of EN 1504, in Table 2 of Parts 2 to 7. These tests may be used to confirm the composition of the product at any time and they are to be carried out when mentioned in Clause 7 of the material specification (Parts 2 to 7 of EN 1504). The manufacturer shall hold the records of these tests, as part of the product technical file and keep it available for future inspection. Also in Table 2 (EN 1504) the material specification are given the tolerances for the specified identification characteristics to be considered and that shall be maintained by the manufacturer.

2.3 Performance tests

The performance tests of the products and systems shall be executed to verify the conformity of these products and systems to the requirements of the relevant Part of EN 1504. These tests are to be carried out when mentioned in Clause 5.2 of the material specification (Parts 2 to 7 of EN 1504). The records of these tests shall be held in the product technical file and kept available for future inspection.

2.4 Factory production control

The factory production control consists of procedures to provide the internal control of production, ensuring that all the batches of products satisfy the requirements of the relevant materials specification Part of EN 1504. The factory production control system shall include the following:

- inspection, sampling frequencies and testing of raw materials, master batches, production equipment and process;
- inspection, sampling frequencies and testing of finished products.

For the factory production control, the manufacturer may select representative identification or performance tests, or other test methods correlated to them, in order to confirm the conformity of the product to the requirements of EN 1504. The records of the inspections, tests, assessments and any actions taken (e.g. in the event of non-conformity) shall be retained for at least five years.

3 Quality control of the works – tests and observations

3.1. General considerations

The execution of the rehabilitation works shall be carried out in accordance with a Quality Plan and be carried out by suitably experienced personnel, with written evidence of their competence.

3.2. Methods for protection and repair of concrete structures

Methods involving hydrophobic impregnation and impregnation:

- Hydrophobic impregnation for protection against ingress of adverse agents;
- Impregnation for protection against ingress of adverse agents;
- Hydrophobic impregnation for moisture control;
- Impregnation for increasing physical and mechanical resistance;
- Hydrophobic impregnation for increasing resistivity of concrete.

Methods involving surface coating:

- Surface coating with and without crack bridging ability;
- Surface coating for moisture control;
- Overlays or surface coatings for increasing physical and mechanical resistance;
- Overlays or surface coatings for increasing resistance to chemicals;
- Increasing cover to reinforcement with additional cementitious mortar or concrete or surface coating;
- Limiting moisture content by surface coatings or sheltering;
- Limiting oxygen content (at the cathode) by saturation or surface coating.

Methods involving filling cracks, voids or interstices:

- Filling cracks for protection against ingress of adverse agents;
- Injecting cracks, voids and interstices;
- Filling cracks, voids or interstices for structural strengthening.

Methods involving locally bandaged cracks, consisting in sealing the cracks in the concrete to prevent the passage of adverse agents.

Methods involving the application of mortar and concrete:

- Applying mortar by hand;
- Recasting with concrete;
- Spraying concrete or mortar;
- Adding mortar or concrete;
- Overlays or surface coatings for increasing physical and mechanical resistance;
- Overlays or surface coatings for increasing resistance to chemicals;
- Increasing cover to reinforcement with additional cementitious mortar or concrete or surface coating;

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

- Replacing contaminated or carbonated concrete;
- Re-alkalisation of carbonated concrete by diffusion.

Methods for adding reinforcing steel bars: specifically adding or replacing embedded or external reinforcing steel bars.

Methods for installing bonded rebars in preformed holes: specifically installing bonded rebars in preformed or drilled holes in the concrete.

Methods for plate bonding, for structural strengthening.

Methods involving reinforcement coating:

- Painting reinforcement with coatings containing active pigments;
- Painting reinforcement with barrier coatings.

The quality control of methods involving electrochemical re-alkalisation of carbonated concrete and electrochemical chloride extraction must be as mentioned in the specific Standard EN 14038.

The quality control of methods involving applying electrical potential must be as specified in EN 12696.

3.3. Substrate conditions before and/or after preparation

The aim of these controls is to prepare the best substrate conditions, and to confirm the most accurate and relevant product and applying method.

3.3.1 Delamination (test)

Delamination Test, carried out once before application, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- involving the application of mortar and concrete;
- for plate bonding.

To detect delaminated areas of the concrete structure or loose single aggregates in the surface of the substrate, the Delamination Test is carried out by tapping or sounding on a surface with a light hammer or other impact echo equipment.

3.3.2 Cleanless (test and observations)

Cleanliness Test and Observation, carried out after preparation and immediately before application, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- involving filling cracks, voids or interstices;
- involving locally bandaged cracks;
- involving the application of mortar and concrete;
- for installing bonded rebars in preformed holes
- for plate bonding;

- involving reinforcement coating.

The Cleanliness Observation should check the surface of the substrate for the presence of:

- hardened cement and spray fog;
- flaws, such as gravel pockets;
- efflorescence;
- powdering and sanding;
- loose particles such as dust or concrete spalling;
- organic growths;
- contaminants such as oil, grease or paraffin;
- debonding agents, curing agents or residues of old coatings;
- debonding of mortar.

To detect the presence of dust or contaminants on the surface of the substrate, the Cleanliness Observation can be carried out by wiping or scratching the concrete surface.

The use of an adhesive strip applied to the surface is a method that indicates the presence of dust when the strip is removed.

3.3.3 Surface Unevenness (observation)

Surface Unevenness Observation, carried out before application, for quality control of the following methods:

- involving surface coating;
- for plate bonding.

To detect the presence of cavities pores and pits on the surface of the substrate, which would cause an interruption of an even thickness of a bonding or coating film, the Unevenness Observation can be carried out by visual inspection.

The unevenness of the substrate can be verified using a steel straight edge.

The existing irregularities and defects in concrete can be remedied as specified in EN 1504 – Part 10.

3.3.4 Roughness (test and observation)

Roughness Test and Observation for quality control of the following methods:

- involving surface coating;
- involving the application of mortar and concrete;
- for installing bonded rebars in preformed holes
- for plate bonding.

The determination of the roughness of the surface may be carried out by visual observation, with the use of a profile meter, using the Sand Area Method as specified in EN 1766 (Clause 7.2) or using the Surface Texture Profile Method as described in EN ISO 3274 and EN ISO 4288.

3.3.5 Surface tensile strength of substrate (test)

Surface Tensile Strength of Substrate Test for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving locally bandaged cracks;
- involving surface coating;
- involving the application of mortar and concrete;
- for plate bonding.

The determination of the surface tensile strength may be carried out on site by using Pull-off Test analogous to EN 1542 or as described in BS 1881 Parts 201 and 207.

The test equipment can be used directly on the surface or, if strength at a specified depth beneath the surface is required, at a position surface which has been partially cored.

To provide a set of tests that is properly representative it is very important to execute the correct surface preparation and the necessary number and position of pull-off tests.

3.3.6 Crack width and depth (test and observation)

Crack Width and Depth Test and Observation for quality control of methods involving filling cracks, voids or interstices and locally bandaged cracks;

The measurement of crack width on exposed structures may be carried out by electrical or mechanical gauge.

The characteristics of the crack should be recorded with the following additional data:

- date, time;
- weather conditions, such as temperature, cloud cover/rain, etc (including on preceding days);
- surface temperature of the component in the crack relevant zones and, in special cases, also in the interior of the component.

The type, size and state of the crack and crack edges and any remedial previous measures can be determined by using drilled cores, as described in EN 12504-1.

This method should only be used in restricted cases because of the disturbance caused by the core drilling.

Ultrasonic Tests may also be used to obtain crack characteristics, as specified on EN 12504-4 and ISO 8047, only by experienced personnel properly trained.

3.3.7 Crack movement (observation)

Crack Movement Observation for quality control of the following methods:

- involving filling cracks, voids or interstices;
- involving locally bandaged cracks;
- for plate bonding.

And for special applications, of the following methods:

- involving surface coating;
- involving the application of mortar and concrete.

The measurement of crack width may be carried out by electrical or mechanical gauges, with an accuracy of at least 0.1 mm.

The methods that can be used to measure, with different sensitivity, the changes in distance associated with changes in crack width are:

- using line-width rule, comparing the crack width visually with a calibrated line on a line-width rule;
- using glass plates or strain gauges, fixed over the crack, as described in BS 1881-206;
- using crack magnifier;
- using thin plaster markers, applied by brush to the concrete surface.

The selected measuring periods should be such that adequate conclusions on short-term and daily changes in crack width at the planned filling time can be drawn from the results.

3.3.8 Vibration (observation)

Observation of vibration for quality control of the following methods:

- for plate bonding
- involving locally bandaged cracks
- involving the application of mortar and concrete.

To observe and register the vibration, due to traffic, equipment, wind or other causes, it can be used vibration measurement equipment such as an accelerometer. If the vibration values are within the values for dynamic loads accepted by the product or systems during the application, then there is no need to restrict the causes of vibration.

3.3.9 Moisture Contents of substrate and cracks (tests and observation)

Moisture Contents Test and Observation, carried out before and during application, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- involving filling cracks, voids or interstices;
- involving locally bandaged cracks;
- for installing bonded rebars in preformed holes
- for plate bonding.

The evaluation of the moisture contents can be carried out by the following tests and observations:

- visual observation;
- use of Relative Humidity Probes;
- measuring the electrical resistivity by the Wenner Probe Test, relating the measurements to absolute moisture content as measured in the laboratory; a two pin conductivity test may also be related to absolute moisture content;
- taking site samples and testing in the laboratory.

The moisture content in cracks can be observed by taking samples or cores and by visual observation.

3.3.10 Temperature of substrate (observation)

Temperature Observation, carried out throughout application, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- involving filling cracks, voids or interstices;
- involving locally bandaged cracks;
- involving the application of mortar and concrete;
- for plate bonding;
- involving reinforcement coating.

The temperature measurement should be carried out with a thermometer made for measuring surface temperature (steel or concrete surfaces).

3.3.11 Carbonation (observation)

Carbonation Test for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- for plate bonding.
- for special applications of methods involving the application of mortar and concrete.

The Carbonation Test should be carried out using the Phenolphthalein Test as described in EN 14630 Part 3 – Products and Systems for the Protection and Repair of Concrete Structures – Test Methods – Determination of Carbonation Depth in Hardened Concrete by the Phenolphthalein Method.

3.3.12 Chloride content (test)

Chloride Content Test for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- for plate bonding.
- for special applications, of methods involving the application of mortar and concrete.

The Chloride Content Test may be carried out by obtaining dust samples on site and by testing them in laboratory by the method described in EN 14629 Part 3 – Products and Systems for the Protection and Repair of Concrete Structures – Test Methods – Determination of Chloride Content in Hardened Concrete.

3.3.13 Penetration of other contaminants and crack contamination (tests)

Penetration of other Contaminants Test for quality control of methods involving:

- surface coating
- for special applications, of methods involving the application of mortar and concrete.

Crack Contamination Test for quality control of methods involving filling cracks, voids or interstices.

The contamination of concrete substrate or cracks, by agents that cause deterioration and corrosion, may be detected taking samples on site by drilling or coring and testing them in the laboratory for chemical analysis.

Important indications of possible contamination are the structure's history and environment.

3.3.14 Electrical resistivity (tests)

Electrical Resistivity Test for quality control of methods involving the application of mortar and concrete, for special applications.

To measure the electrical resistivity of substrate it may be used the Wenner Probe.

3.3.15 Cleanliness of existing reinforcement (observation)

Cleanliness of Existing Reinforcement Observation, carried out once before application, for quality control of methods for adding reinforcing steel bars.

Depending on the repair method to be executed, it is required a different degree of cleanliness for the existing steel reinforcement.

This cleanliness can be evaluated by visual observation and by comparing the appearance of the cleaned steel with the defined in ISO 8501 Part 1.3.5 Cleaning of the surfaces with water and sand jets.

3.3.16 Size of existing reinforcement (observation)

Size of Existing Reinforcement Observation for quality control of the following methods:

- for adding reinforcing steel bars;
- for installing bonded rebars in preformed holes.

The size of the steel reinforcement, namely the cross section dimensions, should be measured mechanically (visual observation), specially at positions where the corrosion products have been removed, to obtain the minimum cross sectional area, for further structural calculations and considerations.

3.3.17 Degree of corrosion of existing reinforcement (observation)

Degree of Corrosion of Existing Reinforcement Test and Observation for quality control of the following methods:

- for adding reinforcing steel bars;
- for installing bonded rebars in preformed holes;
- for plate bonding.

There must be inspected the loss of steel area on reinforcement due to corrosion and the presence of corrosion pits on the steel.

This inspection can be carried out by visual observation, mechanical measurement and/or by Half-Cell Potential Tests, according to the ASTM C-876:91 standard, or RILEM TC 154-EMC recommendations.

3.3.18 Cleanliness of reinforcing plates (observation)

Cleanliness of Reinforcing Plates Observation, carried out once before application, for quality control of the following methods:

- for installing bonded rebars in preformed holes;

- for plate bonding.

To ensure the required degree of cleanliness of the steel plates it should be evaluated as defined in ISO 8501 Part 1.

The reinforcing steel plates should be free of mill scale, rust, grease and other contaminants.

3.3.19 Compressive strength (test)

Compressive Strength Test for quality control of the following methods:

- involving the application of mortar and concrete, for special applications;
- for plate bonding.

The compressive strength of the concrete or mortar can be evaluated by taking cores and crushing them as described in EN 12504-1 (obtaining absolute values) or by using a rebound hammer according to EN 12504-2 (obtaining indications of comparative surface strength).

The strength of concrete can be established according to EN 12390 1-3, using cube and crushing tests.

For polymer mortars and concretes, polymer hydraulic cement mortars and concretes and hydraulic mortars and concretes it can be tested according to EN 12190.

4 Acceptance of products and systems

Identity Observation and Test, carried out before use of the products and systems, for quality control of the following methods involving:

- hydrophobic impregnation and impregnation;
- surface coating;
- filling cracks, voids or interstices;
- locally bandaged cracks;
- the application of mortar and concrete;
- adding reinforcing steel bars;
- installing bonded rebars in preformed holes;
- plate bonding;
- reinforcement coating.

The identity of all the applied products and systems may be established by means of marking and labelling according to EN 1504 Part 8 or by written certificate. Specifically, the purity of water can be evaluated as specified in EN 1008.

5 Condition and requirements before and/or during application

The controls are full part of process of product application, peculiarly to ensure getting necessary conditions just before and during work, suiting with the product according to its «product technical file» and also with the mother structure.

These controls within the works are in a way, the binded twin of providing products factory quality controls themselves.

5.1. Ambient temperatures (observation)

Ambient Temperatures Observation, carried out throughout application, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- involving filling cracks, voids or interstices;
- involving locally bandaged cracks;
- involving the application of mortar and concrete;
- for installing bonded rebars in preformed holes;
- for plate bonding;
- involving reinforcement coating.

The measurement of ambient temperatures can be done by using thermometers and with an accuracy of, at least, plus or minus 1°C.

The measurements should be made sufficiently often to enable recording temperature movement and changes of 2°C.

All the ambient temperature measurements must be made in the immediate vicinity of the works and the temperature sensor should not be directly exposed to solar radiation.

5.2. Ambient humidity (observation)

Ambient Humidity Observation, carried out throughout application, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- involving filling cracks, voids or interstices;
- involving locally bandaged cracks;
- for installing bonded rebars in preformed holes;
- for plate bonding;
- involving reinforcement coating.

The measurement of ambient humidity may be done by using the methods described in ISO 4677 Parts 1 and 2, normally using a hygrometer.

5.3. Precipitation (observation)

Precipitation Observation carried out daily, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- involving filling cracks, voids or interstices;
- involving locally bandaged cracks;
- involving the application of mortar and concrete;
- for adding reinforcing steel bars;
- for installing bonded rebars in preformed holes;
- for plate bonding;
- involving reinforcement coating.

The precipitation can be observed visually and it may include rain, snow, dew and spray.

In certain cases, if it is relevant, the precipitation observation may be recorded using a gauge.

5.4. Wind strength (observation)

Wind Strength Observation, carried out before use, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating.

The measurement of the wind velocity should be carried out using an anemometer.

The maximum values during application can be measured and the works suspended if so required.

5.5. Dew point (observation)

Dew Point Observation, carried out throughout application, if product requires it, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- for plate bonding;
- involving reinforcement coating;
- involving locally bandaged cracks.

The dew point depends directly on the ambient relative atmospheric humidity and on the ambient temperature. It occurs only when the substrate temperature is equal or lower than the dew point temperature.

The air temperature and the surface of the substrate temperature may be measured with the use of thermometers, with a required accuracy of $\pm 5^{\circ}\text{C}$.

The air humidity may be evaluated by using the methods described in ISO 4677 Parts 1 and 2, normally using a hygrometer.

A table given in ISO 4677 1-2 indicates the temperatures of dew points, knowing the ambient dry temperature and the ambient relative atmospheric humidity.

Usually, depending on the material, the repair or protection products can not be applied when the ambient dry temperature is less than 3°C above the dew point.

5.6. Wet thickness of coating (test)

Wet Thickness of Coating Test, carried out after application, for quality control of methods involving surface coating.

For measuring a wet thickness there are two methods given by ISO 2808 – Method No.1: comb gauge and wheel gauge.

To obtain representative results, usually a minimum of three reading is taken in different places in a similar manner, over the repaired area.

5.7. Consistency of concrete or mortar (tests)

Consistency Test, carried out daily or for each batch, for quality control of the following methods:

- involving the application of mortar and concrete;
- for installing bonded rebars in preformed holes.

To test the consistency of flowing concrete there may be used the Slump Test, Vebe Test and Flow Table Test, as given in EN 12350 Parts 1 to 5 and, in addition, a test using a trough.

To test the consistency of mortars and grouts it can be according to EN 13395 Parts 1 to 4.

5.8. Air content of fresh concrete (test)

Air Content Test is used for quality control of methods involving the application of mortar and concrete.

This test is carried out by using the pressure method according to EN 12350 Part 7.

5.9. Thickness of cover or repair materials (test and observation)

Thickness Observation or Cover Test, carried out once after repair, for quality control of methods involving the application of mortar and concrete.

The cover of concrete over the reinforcement can be measured using a cover meter (electromagnetic device), in accordance with the test methods described in BS 1881 Part 204.

In average site conditions, the accuracy should be within $\pm 15\%$ and 5 mm, whichever is the greater, for reinforcement covers less than 100 mm.

The concrete cover may be as well evaluated by taking cores and by removing repair material.

5.10. Compressive strength (test)

Compressive Strength Test, carried out once after repair, for quality control of methods involving the application of mortar and concrete.

The compressive strength of the concrete or mortar can be evaluated by taking cores and crushing them as described in EN 12504-1 (obtaining absolute values) or by using a rebound hammer according to EN 12504-2 (obtaining indications of comparative surface strength).

The strength of concrete can be established according to EN 12390 1-3, using cube and crushing tests.

For polymer mortars and concretes, polymer hydraulic cement mortars and concretes and hydraulic mortars and concretes it can be tested according to EN 12190.

5.11. Position of reinforcement (test or observation)

Position of Reinforcement Observation or Test, carried out once before application, for quality control of the following methods:

- for adding reinforcing steel bars;
- for installing bonded rebars in preformed holes.

The position of the steel reinforcement may be evaluated mechanically, when concrete has been previously removed, or detected by a cover meter as described in BS 1881-204, when reinforcement is not visible.

6 Final hardened condition

The aim of these controls is to get insurance for conformity and reliability of the final repair.

6.1. Delamination (test)

Delamination Test, carried out once per element type to judge efficiency of repair, for quality control of methods involving the application of mortar and concrete.

To detect delaminated areas or loose single aggregates, the Delamination Test is carried out by tapping or sounding on a surface with a light hammer or other impact echo equipment.

6.2. Electrical resistivity (test)

Electrical Resistivity Test for quality control of methods involving the application of mortar and concrete, for special applications.

To measure the electrical resistivity of repair material it may be used the Wenner Probe Test.

Resistivity should be measured on the site applied material or on prepared specimens.

6.3. Dry thickness of coating (test)

Dry Thickness of Coating Test, carried out once to judge the efficiency, for quality control of the following methods:

- involving surface coatings;
- for plate bonding;
- involving reinforcement coating.

The measurement of the dry thickness of the surface coating may be given by knowing the quantity of product applied, using ISO 2808 – Method No.2.

The dry thickness may also be evaluated using destructive methods, such as:

- profilometer method, as specified in ISO 2808;
- wedge cut method, as given in ISO 2808 – Method 5B;
- drilling of core samples and measurement of the film thickness.

6.4. Covering of coating (observation)

Covering of Coating Observation, carried out once to judge the efficiency, for quality control of the following methods:

- involving surface coatings;
- involving reinforcement coating.

Possible gaps, holes and defects in the coating can be detected by visual observation and as described in ISO 4628 Parts 1 to 6.

6.5. Penetration of impregnation (test and observation)

Penetration of impregnation (test and observation) is carried out for quality control of methods involving hydrophobic impregnation and impregnation.

The penetration of the impregnation depends on the substrate porosity and on the product's penetration ability. This penetration can be estimated by knowing the quantity of product that was used, in accordance with EN ISO 2808 – Method No.2. This penetration can also be determined by observation of cores..

6.6. Permeability of coating or repair material or filled cracks to water (tests)

Permeability to Water Tests, carried out once to judge the efficiency, for quality control of the following methods:

- involving hydrophobic impregnation and impregnation;
- involving surface coating;
- involving filling cracks, voids or interstices;
- involving the application of mortar and concrete.

The results to obtain are:

- quantity of penetrating water during the time of the test;
- temperature conditions;
- moisture content of the test area.

There can be used the German Karsten Test or French tests, as in NF P 84-402 or NF T 30-801, based on the same principle.

Cracks filled to at least 80% by volume and with a firm bond between concrete and sealing material, may be visually taken as impermeable to water.

In doubtful cases, it may be carried out penetration tests in concrete cores, as specified in EN 12390 Part 8 and ISO 7031.

6.7. Degree of filling of cracks (test and observation)

Filling of Cracks (test and observation) is carried out for quality control of methods involving filling cracks, voids or interstices.

To evaluate the degree of filling there may be taken drilled cores from representative sections of the filled cracks. The cracks must be filled completely and this is defined if the visible cracks on the surface of the drilled core are filled to at least 80% by volume. The state of filling may also be assessed by ultrasonic test methods given in EN 12504 Part 4 and ISO 8047.

6.8. Thickness of cover or repair materials (test and observation)

Thickness of Cover or Repair Material (test and observation) is carried out once per element type, for quality control of methods involving the application of mortar and concrete.

The cover of concrete over the reinforcement can be measured using a cover meter (electromagnetic device), in accordance with the test methods described in BS 1881 Part 204. In average site conditions, the accuracy should be within $\pm 15\%$ and 5 mm, whichever is the greater, for reinforcement covers less than 100 mm. The concrete cover may be as well evaluated by taking cores and by removing repair material.

6.9. Adhesion of coatings, adhesive and repair material (test)

Adhesion Test are carried out once for each type of surface or member, for quality control of the following methods:

- involving surface coating;
- involving the application of mortar and concrete
- involving locally bandaged cracks.

Using the Cross Cut Test, as specified in EN ISO 2409 Part 6, can be tested the adhesion of coatings, for layers less than 0.5 mm thick. For adhesion of repair materials a Pull-off Test can be used, for thicker layers, as described in ISO 4624 and in BS 1881 Parts 201 and 207 or analogous to the laboratory tests given in EN 1542.

6.10. Compressive strength (test)

Compressive Strength Test, carried out once per element type, for quality control of methods involving the application of mortar and concrete.

The compressive strength of the concrete or mortar can be evaluated by taking cores and crushing them as described in EN 12504-1 (obtaining absolute values) or by using a rebound hammer according to EN 12504-2 (obtaining indications of comparative surface strength). The strength of concrete can be established according to EN 12390 1-3, using cube and crushing tests. For polymer mortars and concretes, polymer hydraulic cement mortars and concretes and hydraulic mortars and concretes it can be tested according to EN 12190.

6.11. Density of hardened concrete or mortar (test)

Density Test, carried out once after repair, for quality control of methods involving the application of mortar and concrete.

By using the tests described in EN 12390 Part 7 (Oven Dry Method) can be established the density of hardened repair mortar or concrete.

6.12. Shrinkage cracking in repair material (observation)

Shrinkage Observation, carried out once to judge the efficiency, for quality control of methods involving the application of mortar and concrete. This shrinkage cracking may be visually observed and measured with a gauge. Cracking may be detected by wetting the surface and allowing it to dry, so, as it dries, the existing cracks can be seen as they retain water for a longer period of time than the uncracked surface.

6.13. Presence of cracks and voids in and behind hardened repair materials (test and observation)

Cracks and Voids test is carried out for quality control of methods involving the application of mortar and concrete.

Cracks and voids can be detected by using radiography reference given in BS 1881 Part 205, by using radar or ultrasonic pulse velocity measurement reference given in EN 12504 Part 4 and ISO 8047. This observation may also be made by visual examination of previously drilled cores.

6.14. Position of reinforcement (test and observation)

Position of Reinforcement is carried out for quality control of the following methods:

- for adding reinforcing steel bars;
- for installing bonded rebars in preformed holes.

The position of the steel reinforcement may be evaluated mechanically, when concrete has been previously removed, or detected by a cover meter as described in BS 1881-204, when reinforcement is not visible.

6.15. Bond of reinforcement (test)

Bond of Reinforcement test, carried out as required, for quality control of the following methods:

- for adding reinforcing steel bars;
- for installing bonded rebars in preformed holes.

The bond strength of reinforcement embedded in repair mortar or concrete can be evaluated by using the specified in EN 1881, ASTM A 944-599 or equivalent. Samples of steel reinforcement embedded in repair material may be tested this way, by Pull-out Test.

6.16. Presence of voids between bonded plates and substrate (test)

Presence of Voids Test, carried out once to judge the efficiency, for quality control of methods for plate bonding.

The presence of voids may be detected by tapping, by using impact echo methods, hammer sounding, or by using ultrasonic testing as in EN 12504-4.

6.17. Structural performance - load tests

Structural Tests, carried out as required, for quality control of methods for plate bonding. After repair and/or strengthening works, to establish the bearing capacity and structural performance of an element or structure, site load tests may be required.

6.18. Adhesion of crack filling material to substrate (test and observation)

Adhesion Test and Observation is carried out for quality control of methods involving filling cracks, voids or interstices, for special applications. To evaluate the adhesion of crack filling material, there may be taken cores and inspected and these cores may be tested to failure as specified in EN 12504-1.

6.19. Colour and texture of finished surfaces (observation)

Colour and Texture Observation for quality control of methods involving the application of mortar and concrete. By visual observation, it must be evaluated if the colour and texture of the finished surfaces of repair works match, as far as possible, the original.

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