quality control requirements for repair systems

TECHNICAL REPORT

TR 5.2

EXECUTION OF REPAIR WORKS

ATLANTIC AREA
Transnational Programme

investing in our common future

European Union

European Regional Development Fund

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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 requirements established by a contractor for the execution of concrete repair works, to comply with EN 1504. The quality of the repair process reported to different repair methods.

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CONTENTS

1 Common requirements for all the works

It is recommended that all the works to be executed should be accompanied by quality control documents.

The works shall be executed in accordance with the National Standards in affect.

Since various European Standards are currently being introduced, some still as pre-standards and, therefore, simultaneously applicable with the European and National Standards, it is understood that, if should there be two Standards, the works shall comply with the strictest specification.

The works to be carried out to execute the structures rehabilitation systems established in this Project Design should fulfil the requirements in EN 1504-9:2008 (Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control, and evaluation of conformity. Part 9: General principles for the use of products and systems), particularly, point 7.3.

To comply with standards EN 1504, it should be provided and maintained the following records updated, as work progresses:

a) Mapping, through separate blueprints, elevations and a photo record, of all the markings for the areas in which work is to take place, for all the structural elements;

b) Detailed mapping of the areas that have been object of the rehabilitation works, identifying the tasks which took place, the materials applied, and the implanted quality control system (including an analysis of that system's effectiveness);

c) Detailed instructions as to future periodic inspection and maintenance tasks to be carried out during the rehabilitated structure's entire useful life;

d) In none of the work's elements shall begin without having been provided with duly authenticated plans, profiles, elevations, sections, benchmarks and other necessary indications to perfectly identify and execute the works in accordance with the Project Design or its changes, and to precisely measure the works, when they are to be paid based on measurements.

It should be placed in a timely manner at the site, in the appropriate quantities and in good state, the necessary materials and machines, tools and other necessary utensils for the good execution of the works, for it to be carried out within the set time period.

The particularity of the tasks specified in the Project Design, requiring execution of works on an existing construction and the importance of paying strict attention to the details for execution of the works, require to always work with the support of the Project Designer/Supervision.

2 Preparation of repair materials

2.1 Cement Grout

2.1.1 Injection of prestress cable sheats

Colloidal mixture or cement paste with the ratio determined during testing, with the necessary adjustments also determined during testing, for the amount of water and plasticizer, given the temperature and length of the cables to be injected.

After carrying out detailed studies, it should be submitted the nominal composition of the mix for approval, indicating:

- the nature, quality and origin of the constituents;
- the dosage of each constituent expressed in weight, with the admissible tolerances;
- the order of introduction of the constituents in the mixer.

In any case, the water/cement ratio shall be as low as possible, compatible with the appropriate workability, and should not be more than 0.40.

Besides the applicable standards, the cements should respect the following:

- not show false setting;
- have a chlorine ion content of less than 0.05 %;
- not contain either sulfur ions or any another element that can cause corrosion in the steel.

It should be proposed the brand of the adjuvant intended for use, including a certificate of origin indicating the limit date beyond which the product should not be used, with the proposal. It is as of now established that that adjuvant should not include any product that is corrosive to steel, such as, for example, chlorides or aluminium.

Besides others standards specifications as LNEC E 372 (Portuguese case) the water shall also respect the following specifications:

- chlorides per Cl^- ion ≤ 500 mg/l;
- sulphates per SO_4^{2-} ion ≤ 400 mg/l;
- absence of detergents.

For the set of constituents (cement, water and adjuvant), the aggressive ion content shall be, overall, less than:

- 0.1 % of the cement mass in Cl^- ions;
- 0.1 % of the cement mass in SO_4^{2-} ions;
- traces $S^{2-}$of ions.

The tolerances of the dosages shall be as follows:

- ± 2 % of the cement mass;
- ± 1 % of the water mass;
- ± 2 % of the adjuvant mass.

Tests shall be carried out in accordance with the specification in EN 445, with the results of those tests fulfilling the specifications in EN 447.

- The mixture shall be studied given the local and actual injection conditions in order to attain a good workability, which should always be tested with a Marsh cone. The flow time through the lower tube of the cone should be twenty-five seconds until at least thirty minutes after manufacturing the grout or the end of the injection period.
- Grout bleeding, measured over the air-tight cylindrical test pieces should not be greater than 2 % at three hours, nor 3 % as an absolute maximum, and the laitance should absorb all the water penetration within twenty-four hours.
- The variation in grout volume, measured on cylindrical test pieces, should be between -1 % and +5 %. If expanding agents are used, the volume cannot be reduced.

At 30 ºC, the initial setting time should, under all temperatures, be more than 3 hours.

Systematic strength tests shall be carried out at 3, 7, and 28 days to guarantee the required strength and to adjust the composition of the grout. Each of these tests shall be carried out, for each kneader-mixer-mixer, on at least one sample of three test pieces. Its compression strength at 28 days cannot be below 35 MPa.

2.1.2 Filling voids

The mix shall be studied according to local and actual injection conditions, in order to attain good workability, which shall always be tested with a Marsh cone. The flow time through the lower pipe of the cone should be less than twenty-five seconds until at least thirty minutes after manufacturing the grout or at the end of the injection period.

3 hours after mixing the water/cement, the cement grout shall not present more than 0.5 % bleeding per volume, nor 1 % as an absolute maximum, when measured at 20 ºC, in a grout thickness of around 100 mm placed in an air-tight glass or metal cylinder, with an internal diameter of 100 mm. The laitance should absorb all water penetration within the following 24 hours.

In preparing the mix, the dosage of solids should be ascertained by weighing. The amount of water should be measured through a duly calibrated counter or a measuring container.

The procedure to obtain the mix to produce the grout should be: first, pour around 2/3 of the cement in the water; second, place the adjuvant, if there is any; and, finally, pour the remaining third of the cement. The grout should be mixed in a high speed mixer, working at, at least, 1000 r.p.m. during enough time to obtain a grout that has a uniform consistence, but never for a period of more than 15 minutes.

After mixing, the grout should be continuously shaken. The cement grout should be passed through a sieve with a mesh opening of 1.2 mm prior to injection. It should be injected as soon as possible after mixing and within a maximum of 30 minutes, except when using delaying agents.

The cement grout injections to fill voids mentioned in these Technical Conditions should be carried out using an appropriate injector, coupled with the grout producing equipment.

The injection pressure to be applied should not cause any damage.

Prior to injection, a sample of the grout shall be collected, from which 100 mm grout cubes shall be prepared. These cubes should be cured and tested according to the European standards (EN 12390-2/3) or national standards, as LNEC E 226:1968 specification (Concrete. Compression test), is an example.

9 cubes shall be prepared for each injection operation to determine compression strength.

Systematic strength tests should be carried out at 3, 7, and 28 days, to guarantee the strength required and adjust the composition of the grout. Each of these tests should be carried out for each kneader-mixer on, at least, one three test piece sample. Supervision shall be responsible for increasing the number of samples per kneader-mixer. Its compression strength at 28 days shall not be less than 25 MPa.

2.2 Mortars

The mortars to be used shall be as follows:

TYPE I - Cement and sand mortar with a ratio of:

- 600 kg of Type I Class 32.5 cement;
- 1000 l of sand;

to be used to set metal rails, curbs, border beams and wherever Supervision authorizes.

TYPE II - Repair mortar, to be used in the repair works, in the sealing of pre-stress anchorage boxes, and possibly, in the placing of bearings and expansion joints and in other situations required.

TYPE III - Sealing mortar, to be used to seal cracks and in other situations required.

2.3 Hydraulic binder concretes

The concretes to be used shall be of the exposure classes and types, strength classes, and quality which follow:

Exposure classes

a) Areas subject to tides and spatter:

- EN 206-1:2000 XS3
- LNEC E 378 (Portuguese case) ECl3

b) Remaining areas

- EN 206-1:2000 XS1
- LNEC E 378 (Portuguese case) ECl1 / ECl4

Types of Concrete:

I. C20/25 sprayed concrete manufactured with CEM IV/A Type (reference, all except CEM I and II/1), 42.5 R Class cement to be used in repair works on abutments.

II. C20/25 Concrete manufactured with CEM IV/A Type (reference, all except CEM I and II/1), 42.5 R Class cement to be used in the works to strengthen the abutments.

III. C30/37 Form-worked concrete manufactured with CEM IV/A Type (reference, all except CEM I and II/1), 42.5 R Class cement to be used in repair and strengthen works on the deck and columns;

IV. C30/37 sprayed concrete manufactured with CEM IV/A Type (reference, all except CEM I and II/1), 42.5 R Class cement to be used in repair and strengthen works on the deck and columns;

V. Light aggregates concrete manufactured with CEM IV/A Type (reference, all except CEM I and II/1), 32.5 R Class cement to be used to fill service bridges.

VI. Fluid concrete to be used to fill voids, for instance in foundation piers.

Note: When the thickness of the repair or strengthening element is less then 100 mm then should be use self compacting concrete, with maximum aggregate size of 10mm.

The concretes to be used in the works, except for those used in the prefabricated parts and to fill the sidewalks shall be shrinkage-controlled concretes, with a maximum stabilized value of 100 ± 10^{-6} at 28 days and 150 ± 10^{-6} at 90 days.

The shrinkage value shall be obtained by measuring the variation of the length between references located on the faces of the test pieces (the test piece shall be a 20 x 20 x 60 cm^3 prism) kept at 20 ºC and 50 % HR.

The concrete for this test shall be of industrial manufacture, with the prisms being moulded at the concrete unloading location or after a time period equivalent to the path between the production location and the unloading location.

To obtain adequate behaviour for these connections it is necessary to guarantee the perfect adhesion of the new concrete to the existing one and very low shrinkage. Therefore, aggregates and their dimensions, as well as the adjuvants and other admixtures, should be carefully chosen, as should the concrete's placement on site and its curing. The rules set forth in EN 206-1:2000 (Concrete - Part 1: Specification, performance, production and conformity) and, the EN 1992-1-1:2004 (Design of concrete structures. General rules and rules for buildings), the as well as in these Technical Conditions shall be followed in everything related to the composition, manufacturing, reception and placement on site of the concretes and to the remaining complementary operations.

NOTE: When the thickness of the repair or strengthening element is less then 15 mm, then should be used self compacting concrete, with maximum aggregate size of 10 mm.

2.4 Sprayed concrete

2.4.1 Concrete composition

The composition of the concrete should be selected so as to comply with the behaviour criteria for fresh concrete and for hardened concrete, as set forth in Chapter 5 of EN 206-1:2000. The study of the concrete's composition should take into account that the execution of the works has as crucial objectives to guarantee the concrete's durability and mechanical strength, which shall be in contact with an aggressive environment. Thus, it is important to guarantee high chemical strength, high compactness and low porosity and permeability, reducing, as much as possible, the effects of differential shrinkage, as well as creep.

Concrete composition studies based of tests on the material that makes up its composition, measuring compression strength, instantaneous elasticity module, shrinkage, creep to various stress levels, consistency, porosity, permeability and the rebound index of the material, shall be done. These studies and tests shall be the basis for the proposal as to the composition of each of the concretes.

For the-dry-sprayed concrete process, preliminary studies should be carried out on concrete to control its manufacture, keeping mainly in mind the accidental corrections to be made as a result of variations of moisture, grading and other causes.

Samples of the same aggregates used in the concrete should be taken in order to confirm that they have maintained their characteristics.

In no case whatsoever shall a water/cement ratio equal to or greater than 0.40 be allowed.

The cement used should also be systematically tested at the same laboratory, according to a plan to be established, rejecting all the cement that does not possess the regulatory characteristics or that does not allow attaining the characteristics required for the site's

concretes. The origin of the cements should not be changed during the execution of the works.

The last layer to be applied should be a mortar, whose composition shall be studied for the same components as the sprayed concrete, except for the absence of coarse aggregates (gravel).

Complementary tests could be carried out at the laboratory, for confirmation purposes.

2.4.2 Mixing plan

The fresh concrete's properties comply with the indications in Article 5.4 of EN 206-1:2000.

In order to attain the consolidation and final strength requirements, the sprayed concrete mix shall be determined by laboratory tests and on-site trials, as indicated below.

The following factors must be taken into account:

a) Amount of cement;

b) Water/cement ratio;

c) Consolidation and strength;

d) Mixture temperature.

The amount of silica fume to be added to the concrete should be between 15 to 30 kg per m^3 of concrete.

The distances between the location of the mixers and the placement of the concrete on-site should be studied, through a specialized technician.

The normal consistency of the concrete masses, to be checked through an Abrams cone or mobile stand, should be appropriate for spraying.

For the dry-sprayed concrete process, the amount of cement shall not be below 380 kg/m3 of dry mixture. The amount of cement must be determined to obtain the strength requirements of the concrete to be applied on-site.

For the dry-sprayed concrete process, the amount of water should be controlled by the nozzle operator, taking into account the surface conditions and the location where they are to be applied.

For the dry-sprayed concrete process, the amount of water should be frequently corrected, according to the variations in the moisture of the aggregates, so that the water/cement ratio is what was recommended in the concrete quality studies.

2.4.3 Concrete preparation, mixing and transport

The concrete should be manufactured by mechanical means, in the appropriate mixers, in accordance with the legal dispositions in affect and carefully fulfilling Article 9.6, 9.7 and 9.8 of EN 206-1:2000.

The cement and the aggregates should be prepared in the specified and planned proportions. Measurement should be in weight. At the time of the preparation, all the aggregates should be dry or sufficiently drained to provide a stable mix that does not exceed 7 %.

For the dry-sprayed concrete process, powder admixtures should be added to the dry mix, immediately prior to placing them in the concrete mixer, through a mechanical device (doser).

For the dry-sprayed concrete process, liquid admixtures should be placed through a special pump and be added to the dry mix at the nozzle or next to it.

For the dry-sprayed concrete process, sprayed concrete cannot be used if its placement could not be concluded within 60 minutes after mixing. This time period should be kept as short as possible, especially during times of high temperatures and moisture.

Also for the dry-sprayed concrete process, he mixing time should be long enough to obtain a homogenous mix.

A delivery notice system should be created to record the mix date, time, mix plan number, amount, delivery location, delivery time, and application.

For the dry-sprayed concrete process, the use of a counter that enables controlling the amount of water introduced in the sprayer shall be required, as shall the necessary equipment, such as manometers.

2.4.4 Concreting

Sprayed concrete shall comply with the requirements given in the EN 14487- Part 1 and 2.

Concrete spraying shall not be allowed if the temperature at the site is below zero degrees Celsius or if it is foreseen to be so within the next 5 days. For temperatures between zero and plus five degrees Celsius, this operation can only take place, as long as the measures indicated in Articles 5.2.8 of EN 206-1:2000 and NP ENV 13670-1:2007, are observed. If the temperature on-site is above thirty degrees Celsius, spraying should not be allowed unless fulfilling the conditions set forth in Articles 5.2.8 of EN 206-1:2000 and NP ENV 13670-1:2007.

The concrete's temperature should be controlled so that, when placed, the concrete temperature is not below 5 ºC or above 30 ºC.

To fulfil what was stipulated in the previous point, it should be used duly calibrated thermometer at the yard, with automatic recording, to register the temperatures on the operation dates mentioned in these points, as well as on the five days which follow.

For the dry-sprayed concrete process, at the beginning of the works, only air should be introduced through the hose. After confirming the correct path until exiting the nozzle, information which shall be provided by the operator, and also after confirming the control of the pressure introduced, a task which responsibility falls upon the machine operator/Contractor, the mix should be gradually introduced, to enable the correct balance between mixture and material, in an uninterrupted flow up to the nozzle.

Next, also for the dry-sprayed concrete process, the counter should control the amount of water to be introduced into the spray gun, with the pressure being indicated by the Contractor, until it is certain that spraying is being carried out in the best possible manner.

Concrete spraying should also not be allowed during periods of heavy rain or strong winds.

Concreting with sprayed concrete should be done in layers of around 25 to 40 mm, until reaching the thickness defined in the Project Design. Each section to be executed should be continuously concreted. The exception shall be the locations where there is a need to congrue repair works with reinforcement works by introducing CFRP laminates.

The spray should be applied in a uniform sequence of ovals and circles, in the same direction, at each passage. The entire thickness of the section should be covered by applying only one layer, thus reducing the possibility of forming cold joints, without the operator retreating or advancing in relation to the concrete surface.

Placement of the concrete should be followed by blowing of the surfaces that shall then be concreted, with a fine nozzle compressed air jet, in order to guarantee that all rebound non-

adhering particles and other dirt that hinders the best adhesion of the sprayed concrete to the surface is removed.

When there is the need to apply more than one layer in the same section, enough time should have passed to allow the applied layer to have already begun to set, assuring that it is free from dirt or any loose and rebound material. If necessary, it shall be cleaned by using pressure sand, water and air jets.

The horizontal and/or vertical corners should be the first to be filled, in order to avoid possible accumulation areas of undesirable material. Thus, the nozzle should be pointed towards the bisector of the formed angle.

When concreting thick vertical areas or concreting joints, a slope of sprayed concrete should be created at approximately 45º from the application surface, in order to more easily avoid rebound.

The use of sprayed concrete to repair the columns, particularly when there is a need to rebuild the entire transversal section, should be followed by the necessary formworks, which shall work as a guide for concreting, as well as to guarantee compliance with the coat thicknesses of the reinforcements and the dimensions of the transversal section set forth in the Project Design.

The optimal distance between the nozzle and the application surface should be 1.0 to 1.5 meters. The angle of incidence should be next to zero degrees, what means that spraying should always be perpendicular to the surface to be concreted.

Immediately prior to applying the sprayed concrete, the surface should be cleaned by compressed air blowing carried out by an operator's assistant, in order to guarantee that the spraying of the concrete does not include loose material and to reduce the possibility of forming a wall effect (creation of segregated spaces or voids behind the reinforcement).

After spraying concrete, a last layer of 5 to 10 mm of sprayed mortar should be applied, with the nozzle at a distance from the application surface of around 50 cm more than the one of the sprayed concrete.

This additional layer shall be manually finished, by an experienced mason, using a trowel.

As soon as spraying ends, the concrete works should be inspected for flawed areas, with segregated concrete, nests, delaminations, voids, sand pockets, etc. When such anomalies are detected, they should be immediately repaired before the concrete begins to set. The defective material should be removed and sprayed concrete should once again be applied.

In the areas strengthened through gluing of the CFRP laminates, 10 mm-thick sprayed mortar layers will enable gluing the laminates over them, which shall be incorporated in the replacement mass, thus making a regime of superior work possible, in terms of stress, adhesion, and weather, high temperatures and ultraviolet-ray protection, in particular.

For the dry-sprayed concrete process, an interruption in the spraying process necessarily requires ejecting all the material from within the machine, followed by ejecting the water and, finally, the accumulated air.

Each construction element should be continuously concreted, what means without greater interruptions than those foreseen for the resting periods, entirely dependent on following the various construction phases, always seeking to reduce the shrinkage stresses between each layers of concrete with different ages.

There should only be concrete joints in accordance with the approved concreting plan. Before concreting begins, the concrete surfaces should be conveniently treated in principle, with the following treatment: tines and protruding aggregates shall be left on the surface; if

there is setting of the concrete in the joints, the surfaces should be washed with an air and water jet and the “cream” that is disaggregated should be removed in order to obtain a good adhering surface. It is absolutely forbidden to use metal brushes to treat the concrete surfaces.

The concrete joints should be washed with a water-jet, removing any stone that is loose.

The operator should be a specialized worker, with experience in the technique being used and with the sensitivity to execute the work.

2.4.5 Control of the concrete’s mechanical characteristics

Controlling the strength of the concrete involves executing 60 cm x 60 cm x 12 cm square panels, from which 5 to 9 samples per panel, with 10 cm in diameter and 10 cm in height, should be extracted.

A 60 cm x 60 cm x 12 cm panel should be prepared for each concreting phase.

The execution of these moulds should fulfil, in terms of spraying angle and distance from the spray gun, the specifications for sprayed concrete included in these Technical Conditions.

These panels should be numbered in the normal sequence of whole numbers, with their number being recorded by engraving in the concrete.

The panels and samples should be transported, cured and preserved in accordance with Specification LNEC E 255:1971 (Portuguese case) and EN 12390-2, keeping in mind existing weather conditions.

For each group of 3 samples, compression strength, diameter compression tensile strength and elasticity module tests should be carried out.

The record book should indicate the following information:

a) Number;
b) Concrete type, class, and quality;
c) Composition;
d) Manufacturing Date;
e) Sample Extraction Date;
f) Sample Test Date;
g) Results obtained in the samples tests.

2.4.6 Control of the concrete’s durability and adhesion features

Control of the concrete’s durability characteristics should include the following tests:

a) Water permeability tests;
b) Water absorption tests;
c) Porosity tests.

The tests should be carried out at 28 days.

The water permeability tests to be carried out in the laboratory should take place according to one of the following methodologies:

a) Tests that involve measuring the depth of water penetration. These tests should be carried out in accordance with Standard ISO 7031 (Hardened concrete. Determination of the depth of water penetration under pressure). The values of the

average and maximum depth of water penetration should be less than 20 mm and 50 mm, respectively.

b) Tests that involve measuring the water flow that crosses the test piece. The methodology to carry out these tests should be proposed to Supervision, which shall decide as to its approval. The measured permeability coefficient should be less than 1×10-12 m/s.

The type of water absorption tests to be carried out in the laboratory should be water absorption by capillarity. The methodology to be applied to carry out these tests should be as follows:

a) The test pieces should be constituted by cores of between 80 and 100 mm diameters and height equal to the diameter. The test pieces should be obtained through core drilling of an element executed with the concrete to be tested, which dimension should enable obtaining at least 5 cores with a minimum distance of 5 cm from the contour surface.

b) After being cut with a diamond disk in order to obtain flat surfaces at the top, the test pieces should be dried in a ventilated oven at a temperature of 60 ºC during 7 days. After the test pieces are dry, they should be cooled down in a drying range for 24 hours.

c) After the abovementioned operations, the test pieces should be placed on a stand, made up by two Perspex straps, on a tray with water. The amount of water in the tray should be 1 to 2 mm above the lower face of the test piece.

d) In consecutive intervals, they should be measured, by weighing, for the amount of water absorbed and height of capillary ascension. The duration of the test is 4 hours and the measurements should be carried out at 5, 10, 30, 60, 120 and 240 minutes. The capillary absorption results should be expressed in terms of the amount of water absorbed per surface unit in contact with the water, in relation to the time, according to the following formula: $i = a\ t^{1/2}$

Whereas:

i - amount of water absorbed per surface unit (mm^3/mm^2)

a - capillary absorption coefficient (mm/min 0.5)

t - time (minutes)

The measured absorption coefficient should be less than 0.1 mm/min 0.5 and the height of capillary ascension should be below 10 mm at the end of 4 hours.

The porosity tests (porosity accessible to the water) should be carried out (Portuguese case) in accordance with Specification LNEC E 395:1993 (Concrete. Determination of water absorption by immersion. Vacuum Test). The value of the measured porosity should be below 14 %.

Considering the adhesion between concrete of different ages:

- The composition, placement and compacting of the concrete to be used to repair and prepare the existing concrete surface should take into account that it is important to assure the perfect gluing of the old and new concrete.
- The strength of the connection should guarantee tensile strength stress of at least 1 MPa in the pull-off test, to be carried out at 28 days.

2.4.7 Rejection of the concrete

It should be determined the immediate rejection of the concretes, both insofar as strength and as durability features that do not comply with what was stipulated, the methodology to be adopted should be as set forth in chapter 8 of EN 206-1:2000, in the following conditions:

a) Non-destructive or normal test piece tests collected in areas that do not affect in a sensitive manner the pieces strength capacity should be carried out. If the results obtained are unquestionably satisfactory, the part of the works to which they respect should be accepted.

b) If the results of these tests, as well as the control tests, demonstrate that the concrete's characteristics are below the requirements, it must be consider the demolish and rebuilt of the flawed parts.

2.4.8 Safety criteria

In concrete spraying operations, precautions should be taken to prevent danger to the operators and to the equipment, such as those next indicated:

a) The operator should permanently maintain control of the concrete spray in order to prevent misfiring on others;

b) All the elements involved in the concrete spraying operations should use protection equipment, including weatherproof gloves and boots, protection glasses, and dust masks. This protection equipment should be washed frequently and should be replaced whenever there is wearing;

c) Whenever the hose is clogged, the spraying machine's feeding operation should be slowed down or stopped, with the compressed air supply being cut off, so that it can be unclogged;

d) Should the hose rupture, feeding of the machine and the air supply should immediately cut off;

e) The connections between the hoses and the machines should be constantly and skilfully inspected;

f) The workers who are working with silica fume should use appropriate masks to prevent dust inhalation;

2.5 Formed microconcrete

2.5.1 Microconcrete composition

The composition of the microconcrete should be selected so as to satisfy the behaviour criteria for fresh concrete and hardened concrete, as indicated in Chapter 5.2 of EN 206-1:2000.

The laboratory in charge of the study on the characteristics and composition of the concrete should carry out the necessary tests for the mentioned study. It should particularly determine, besides compression strength, the instantaneous elasticity module, shrinkage (which should necessarily be low and, therefore, very well controlled), creep for various stress levels, consistency, porosity, and permeability.

It should be provided samples of the same aggregates used in the concrete studies, in order to give evidence that it maintained its characteristics.

Ii should be ensured that the same laboratory that executes the preliminary studies on the concrete shall control its manufacturing, mainly keeping in mind accidental corrections to be carried out as a result of variations in moisture, grading, and other causes.

The cement used shall also be systematically tested in the same laboratory, according to a plan to be established. All that cement that does not possess the regulatory characteristics or that does not enable attaining the characteristics required for the works' concrete shall be rejected. The origin of the cements should not be changed during the works.

The microconcrete's composition may use adjuvants whose necessity is justified, according to EN 934-2:2009 (Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures - Definitions, requirements, conformity, marking and labelling)

It is as of now forbidden to use chloride-based adjuvant or those which contain any corrosive elements.

A microconcrete composition study shall always be required.

The microconcrete to be adopted should respect the following requirements:

a) The maximum dimension of the aggregates to be adopted is 10 mm;

b) The water/cement ratio shall not surpass 0.45;

c) The dosage of cement should oscillate between 340 to 400 kg per m³ of concrete;

d) The concrete should incorporate 15 to 30 kg of silica fume per m^3 of concrete;

e) The concrete should be subject to moist curing, immediately following initial setting, for a minimum of 7 days;

f) Adhesion to existing concrete should be at least 1 MPa (pull-off test) at 28 days;

g) The quality of the concrete shall be ascertained by two minimum parameters:

- Permeability coefficient: < 1 x 10^{-12} m/s (ISO 7031 - Hardened concrete. Determination of the depth of water penetration under pressure);
- Accelerated chloride penetration test: < 1000 Coulombs (ASTM C 1202-94 - Standard test method for electrical indication of concrete's ability to resist chloride ion penetration);

h) Slump 55, Self-compacting concrete.

2.5.2 Preparation of the concrete

The concrete shall be manufactured by mechanical means, in an automatic plant, with the materials that are part of its composition fulfilling the abovementioned conditions, in accordance with the legal dispositions in affect, and carefully respecting Article 9 of EN 206-1:2000.

The aggregates and cement should be dosed in weight for all concretes.

The plant should have its water counters duly calibrated, so that the amount of water introduced in each kneader-mixer is exactly the same as the one the official laboratory indicated in its study.

The amount of water should be frequently corrected, in accordance with variations in the aggregate's moisture, so that the water/cement ratio is as recommended in the concrete composition studies.

The moisture of the aggregates should be periodically determined, both when new batches of aggregates are introduced, and every time there are changes in weather conditions that so

justify, so that the previously mentioned corrections can be carried out in a timely manner, with great rigour.

The distances between the plant location and the location where the concrete is to be applied on site should be as little as possible, with the means of transport and paths used from the plant to the concrete application site, as well as the times foreseen for their transport. The concrete should be transported to the different application areas through processes that do not lead to its segregation, always following what is set forth in EN 206-1:2000.

2.5.3 Fresh concrete properties

The properties of fresh concrete should follow what is set forth in Article 5.4 of EN 206-1:2000.

The normal consistency of the molded concrete masses, to be checked through a slump or spread test, should be specified and the necessary amount of water should be determined in previous tests, in order to obtain workability compatible with the desired strength, safeguarding the mentioned water/cement ratio limit.

2.5.4 Concreting and demolding

The concreting should comply with the standards set forth in the EN 1992-1-1:2004 (Design of concrete structures. General rules and rules for buildings) and in EN 206-1:2000, also taking into account these Technical Conditions and the Project Design.

The concrete should be used right after being manufactured, except for the delays inherent to transport within the installations.

The period from manufacturing the concrete to the end of its placement should not exceed half an hour during hot weather and one hour during cold weather. These time periods should be reduced if the circumstances so advise.

If the temperature on-site is below zero degrees Celsius or if this is foreseen to happen within the next five days, concreting should not be allowed. For temperatures between zero and five degrees or above thirty degrees Celsius, concreting should only take place if Supervision so allows and as long as the measures indicated in EN 206-1:2000 are observed.

If the temperature, on-site is above 35 ºC, concreting should not be allowed without authorization and rigorously fulfilling the conditions set in EN 206-1:2000.

To comply with what is stipulated in the previous article, it should be provided, to maintain at the yard, a thermometer that records maximums and minimums and is duly calibrated in order to permanently maintain a record of the ambient temperature.

In order to guarantee the quality foreseen for the concrete, the concreting areas should be protected from intense sun and rain.

If, for any reason, these means are not in the appropriate conditions, it may, as per its criterion and whenever it ascertains that weather conditions are not advisable (extreme solar radiation or intense rain that may change the concrete’s water/cement ratio and/or cause the dragging of fines), prohibit concreting.

Concreting should not take place during periods of intense rain.

Each construction element, unless express in the Project Design, must be continuously concreted, that is, without any gaps of time, always attempting to reduce the shrinkage stress between layers of concrete with different ages.

There shall only be concrete joints in sections in accordance with the approved concreting plan. Before initiating the concreting, the joint's concrete surfaces should be conveniently treated. In principle, the following treatment shall be accepted: tines and protruding aggregates shall be left on the surface; if there is setting of the concrete at the joints, the surfaces should be washed with a water and air jet, removing the "cream" that is disaggregated in order to allow for good surface adhesion. It is absolutely forbidden to use metal brushes to treat the concreting surface.

In the joints where elements to be executed later overlap in elevation, after 2 to 5 hours, the areas to be occupied by those elements should be cleaned, being treated as previously indicated.

In the visible faces of the elements in elevation, joints should only be allowed in the sections where they can strictly be confused with formworks joints. Run-offs or differences in section shall not be tolerated, so the formworks joints should be conveniently sealed and the formworks carefully tightened against the parts that are concreted. For this purpose, soft rubber profiles should be used as sealants.

Where deemed advisable, an appropriate glue or mortar should be used on the concrete joints.

If an interruption in concreting leads to a poorly-directed joint, the concrete should be demolished in the necessary extension in order to obtain a duly guided joint; however, prior to reinitiating concreting, if the previous concrete has already begun to set, the joint's surface should be carefully treated and cleaned, so that there are no aggregates that may detach themselves. Next, the surface should be wet so that the concrete is conveniently moist. Concreting should not recommence while the water is running or accumulated.

Next, the concrete surface should be corrected with an abrasive disk to improve the final aspect of the concrete surface.

The demolding of the bottom of the structural elements should only take place when the concrete presents strength of, at least, 2/3 of the characteristic value, and never before 3 days after the last placement of concrete.

After concreting and vibration, the concrete shall necessarily be protected against water losses by evaporation, and extreme temperatures.

2.5.5 Control of the concrete's mechanical characteristics

During concreting, control tests on the concrete's mechanical characteristics should be carried out on a minimum of three cubes for each element concreted at once or per panel; in case of continuous concreting, cubes for control testing should be manufactured at least three times a week.

The cubes should be in concrete, made from a kneader-mixer to be applied in the works and may only be manufactured in the Supervision's presence, be carried out in metal moulds, and should have aligned faces.

A record compiling all the cube tests should be organized so that, at any point, compliance with the set characteristics can be checked.

All the cubes should be numbered in the normal sequence of the whole numbers, starting with 1. The cube should include not only its number but also the type, class and the respective quality of the concrete, the site, and manufacturing date.

The compiled record should include the following information:

a) Cube Number;

b) Manufacturing Date;

c) Test Date;

d) Age;

e) Type, class and quality;

f) Dosage;

g) Amount of kneading water;

h) Location where the concrete is to be applied from which the mass that made the cube was removed;

i) Strength obtained during testing;

j) Average strength of the three cubes that form the test set;

k) Cube Weight.

Preservation of the cubes during hardening should considerate existing weather conditions.

Whenever cubes are manufactured, for each series of three, a “test record sheet” should be filled out on-site. This record shall include the cube numbers, manufacturing date, cement brand, dosage, grading, kneading water, manufacturing process, and other indications deemed convenient.

The cubes should be transported to the testing laboratory and should be duly packaged so that they do not deteriorate.

Based on the “test record sheet”, the cubes will be sent to the laboratory that shall carry out the respective tests.

2.5.6 Control of the concrete’s durability characteristics

Control of the concrete’s durability and adhesion features should include the following tests:

a) Water permeability tests;

b) Water absorption tests;

c) Porosity tests.

The tests should be carried out at 28 days.

The water permeability tests to be carried out at the laboratory should take place according to one of the following methodologies:

a) Tests that involve measuring the depth of water penetration. These tests should be carried out in accordance with Standard ISO 7031 (Hardened concrete. Determination of the depth of water penetration under pressure). The values of the average and maximum depth of water penetration should be less than 20 mm and 50 mm, respectively.

b) Tests that involve measuring the water flow that crosses the test piece. The methodology to carry out these tests should be proposed to Supervision, which shall decide as to its approval. The measured permeability coefficient should be less than 1×10^{-12} m/s. The type of water absorption tests to be carried out in the laboratory should be water absorption by capillarity.

The methodology to be applied to carry out these tests should be as follows:

a) The test pieces should be constituted by cores with between 80 and 100 mm diameters and with equal height to the diameter. The test pieces should be obtained

through core drilling of an element executed with the concrete to be tested, whose dimension should enable obtaining at least 5 cores with a minimum distance of 5 cm from the contour surface.

b) After being cut with a diamond disk in order to obtain flat surfaces at the top, the test pieces should be dried in a ventilated oven at a temperature of 60 ºC during 7 days. After the test pieces are dry, they should be cooled down in a drying range for 24 hours.

c) After the abovementioned operations, the test pieces should be placed on a stand, made up by two Perspex straps, on a tray with water. The amount of water in the tray should be 1 to 2 mm above the lower face of the test piece.

d) In consecutive intervals, they should be measured, by weighing, for the amount of water absorbed and the height of capillary ascension. The duration of the test is 4 hours and the measurements should be carried out at 5, 10, 30, 60, 120 and 240 minutes.

e) The capillary absorption results should be expressed in terms of the amount of water absorbed per surface unit in contact with the water given the time, according to the following formula: $i = a\ t^{1/2}$

Whereas:

i - amount of water absorbed per surface unit (mm3/mm2)

a - capillary absorption coefficient (mm/min0.5)

t - time (minutes)

The measured absorption coefficient should be less than 0.1 mm/min 0.5 and the height of capillary ascension should be below 10 mm at the end of 4 hours.

The porosity tests (porosity accessible to the water) should be carried out (Portuguese case) in accordance with Specification LNEC E 395:1993 (Concrete. Determination of water absorption by immersion. Vacuum Test).

The value of the measured porosity should be below 14 %.

Adhesion between concrete of different ages

- ✓ The composition, placement and compacting of the concrete to be used to repair and prepare the existing concrete surface should take into account that it is important to assure the perfect gluing of the old and new concrete.
- ✓ The strength of the connection should guarantee a tensile strength stress of at least 1 MPa in the pull-off test, to be carried out at 28 days.

2.5.7 Criteria for conformity and rejection of the concretes

The criteria for conformity and sampling plans meant to ascertain compliance with the specifications are defined in Article 8 of EN 206-1:2000.

It should be determined the immediate rejection of the concrete, both insofar as strength, and as durability features that do not satisfy what was stipulated, the methodology to be adopted should be as set forth in Article 8.2 of EN 206-1:2000, in the following conditions:

a) Non-destructive or normal test piece tests collected in areas that do not affect in a sensitive manner the pieces strength capacity should be carried out at the. If the results obtained are unquestionably satisfactory, the part of the works to which they respect should be accepted.

b) If the results of these tests, as well as the control tests, demonstrate that the concrete's characteristics are below the requirements, two cases shall be considered:
   - If the characteristics attained (in particular, stress strength) are 80 % above those required, the load and behaviour tests shall proceed. If the results of these tests are satisfactory, the part in doubt shall be accepted.
   - If the determined characteristics are below 80 % of those required, the demolishing and rebuilding the flawed parts, must be considered.

c) When there is a situation that corresponds to that defined in point b), or the execution was not carried out within the set or normally acceptable tolerances, load tests may be carried out.

The conditions established for load tests, the duration of the tests, successive loading and unloading cycles and measurements to be carried out should be object of a detailed program.

The overloads to be applied shall not exceed the characteristic overloads adopted in the Project Design.

The test shall be considered satisfactory for the tested element when two of the following conditions are ascertained:

- The measured arc heights shall not exceed the calculated values based on the results obtained for the concretes' elasticity modules;
- Residual arc heights should be sufficiently low, taking into account the duration of the load application so that behaviour is considered elastic. This condition should be fulfilled both for the first load, and for those which follow, should there be any.

2.6 Passive reinforcement

The steel reinforcements to be used in the different concrete elements shall have the sections foreseen in the Project Design and shall be strictly placed as per the drawings, being efficiently tied. If these ties are at the concrete surface, it shall be required to prick the surface to cut them and reclose it with repair mortar. Small prefabricated shims in mortar or microconcrete shall be used to keep the reinforcements away from the moulds. Those shims shall include fixing wire.

The reinforcements shall be cold bent with the appropriate machines, complying with what is set forth in the EN 1992-1-1:2004 (Design of concrete structures. General rules and rules for buildings (EC 2).

When the bars are to be welded, this shall be done without reducing, for purposes of calculation, the useful section, and only after complying with what is set forth in these Technical Conditions and after confirming the efficiency of the machines and the competence of the welders. In any case, the welding should guarantee over 90 % resistant capacity of the bars that it joins. Welding is not authorized in bending areas or to connect crossed reinforcements.

2.7 Stainless steel reinforcement

To preserve the full corrosion resistance of stainless steel, the surface of the bars should be clean at the time of installation and must be free from mill scale and from the presence of scale or oxides.

Stainless steel reinforcements can be bent to shape using the same methods as for carbon steel. However, more force is required to bend stainless steel than carbon steel bars.

For repairing and strengthening of existing reinforced concrete structures, the stainless steel should not be in contact with carbon steel in areas where the existing concrete has high chloride levels.

In accordance with the Standards in affect, the use of stainless steel reinforcements allows the durability requirements developed for carbon steel to be relaxed, namely concerning the reduction of of the concrete cover (maintaining the quality of the cover concrete).

If the stainless steel reinforcement is used in a highly corrosive environment, it is recommended that the minimum concrete cover should still be at least 40 mm.

2.8 Concrete formworks

2.8.1 General specifications

Moulds should be designed and built to comply with the conditions set forth in EN 13670:2009 Execution of concrete structures), EN 1992-1-1:2004 (Design of concrete structures. General rules and rules for buildings (EC 2) and EN 206-1:2000 (Concrete - Part 1: Specification, performance, production and conformity) and in these Technical Conditions.

It should be done and presented a study of the layout of the boards of the surface's moulds in plain sight.

The mentioned study should be executed in accordance with the specifications to be opportunely indicated, keeping as of now in mind that the layout of the boards, joints, patches, nails, etc., should be duly set, so that the surfaces of the moulding in plain view enable checking for their safety.

It may be required the presentation of the moulds to be used and to check their safety.

For purpose of measurement, the work shall be evaluated through the actual measurement of the apparent faces of the moulded parts.

The use of sliding moulds shall not be allowed.

2.8.2 Preparation of the moulds. Moulding and demoulding

Molding and demolding shall comply with what is set forth in EN 13670:2009 Execution of concrete structures), EN 1992-1-1:2004 (Design of concrete structures. General rules and rules for buildings (EC 2) and EN 206-1:2000 (Concrete - Part 1: Specification, performance, production and conformity) and in these Technical Conditions.

The moulds for the different parts of the works should be solidly and perfectly assembled so that they are firm during concreting, and should be easily disassembled without tapping or vibrations.

The moulds' inner surfaces should be painted or protected, with an appropriate product previously approved by Supervision, to avoid concrete adhesion.

Before concreting, all the moulds should be free of debris and wet with water for a few hours.

If the wet surfaces are not perfect, they may be exceptionally corrected as long as there is no danger to their strength (with the flaw being easily corrected by non-retractable mortar plaster followed by painting or other process).

2.8.3 Dimensional tolerances and finishing classes

The tolerance limits for implantation of the moulds are as follows:

a) One centimeter, in relative value, measured between any two points of the formworks of the different parts of one same support;

b) Two centimeters, in relative value, measured between any two points of the formworks of different supports;

c) Three centimeters, in absolute value, measured in relation to general pegging.

The moulds should be levelled at all the points with a tolerance of more or less one centimetre. The widths or thicknesses between the moulds contiguous walls should not present shortcomings of more than five millimetres.

The finishing class required for each of the moulded concrete surfaces is indicated in these Technical Conditions or in the Drawings. Should this indication be lacking, the rules defined in these Technical Conditions shall be applied.

For purposes of applying these conditions, irregularities of the concrete surfaces are classified as coarse and smooth. The protrusions and burrs caused by the displacement or poor placement of the formworks' elements, due to flaws in its connections or any other local defects of the formworks shall be considered smooth and shall be measured through a gauge, which shall be a flat ruler, in the case of straight surfaces or its equivalent, for curved surfaces. The gauge shall be one meter long.

Four finishing classes - A1, A2, A3 and A4 - are considered, in accordance with the following:

a) A1 class: Irregular finishing, without any limit for protrusions. Depressions, coarse or smooth, shall be below 2.5 cm.

b) A2 class: Coarse irregularities should not exceed 0.5 cm and the smooth ones, 1.0 cm.

c) A3 class: Coarse irregularities should not exceed 0.2 cm and smooth ones, 0.5 cm.

d) A4 class: Coarse irregularities should not exceed 0.2 cm and smooth ones, 0.3 cm.

It shall have a uniform color and texture and shall be spot-free.

2.9 Concrete and mortar curing and protection

To obtain the expected properties for the concrete and mortar, particularly in the surface area, appropriate curing and protection for a convenient period of time is necessary, as indicated in Article 5 of EN 206-1:2000 and EN 13670:2009 (Execution of concrete structures)

Curing is prevention against premature drying, particularly due to solar radiation and wind.

The protection prevents:

a) Fines from being dragged due to rain or running water;

b) Quick cooling during the first days after placement;

c) Large differences in internal temperatures;

d) Low temperatures;

e) Vibration and impact that can rupture the concrete and interfere with its adhesion to the reinforcements.

Curing and protection should begin as soon as possible after the concrete and mortar works end, so that during hardening the concrete and mortar are protected against losses of water by evaporation, extreme temperatures, damages due to internal and/or external restrictions, and deformations caused by the heat developed inside the mass.

The curing method defined in these Technical Conditions uses filmogenic products to cure concrete and mortar.

Curing duration shall depend on the necessary time to obtain a certain impermeability of the superficial area of the concrete and mortar.

In general, curing should take place during the minimum period indicated in table F1 of Annexe F of EN 13670:2009, given the following factors:

a) Weather conditions during curing;

b) Concrete/mortars temperature during the curing;

c) Concrete/mortars composition.

When the concrete and mortar are exposed to severe weather conditions (spatter areas), the curing times indicated above shall be clearly increased.

Should a careful assessment of the abovementioned factors not be carried out, a minimum curing period of 12 days, or until the average desired strength is obtained, should be adopted.

The curing of the concrete should guarantee control of the temperature of the concrete and mortar to the following levels:

a) The maximum temperature of concrete/mortar during hardening should not surpass 70 ºC.

b) The maximum relative temperature between the existing and the new concrete/mortar should not surpass 12 ºC.

The product should be applied with a roller or low-temperature spraying equipment in accordance with the Supplier’s instructions.

The product should be applied in a continuous layer, in two coats and in crossed directions, overlapping the layers, avoiding interruptions in application.

Before being applied, the product should be very well mixed.

The product to be used should be duly labelled in accordance with the legislation in affect and should include its technical data sheet.

The necessary safety measures should be taken into account in order to obtain the expected finishing, namely to protect personnel and equipment, as well as storage and preparation, following the Supplier’s instructions.

3 Repair and reinforcement of reinforced concrete elements

3.1 Cleaning of the surfaces with water-jets

All exposed surfaces should be previously cleaned with water jets applied under controlled pressure in order to remove foreign substances, such as oils, paint, dust, soot, superficial laitance of the cement and similar products, as well as poor or disaggregated material, until the surface is clean and uniform.

This work is meant to facilitate identifying and marking anomalous areas in need of rehabilitation.

The equipment used is, in general, a water-jet coupled with a compressor, rubber hose and spray nozzle.

The jet should be applied in circular movements with the hose, under pressure, in the compressor, at around 8 bar. For a more efficient cleaning, the water jet should make an angle between 30 º to 60 º with the surface. On vertical surfaces, cleaning should begin from the bottom up.

The water for the jets should be clean, free from impurities, oil or grease in film or emulsion, and should not contain detergents, acids, organic substances or any other foreign substances in solution or suspension that may hinder the proper running of the equipment or physically or chemically affect the various concrete elements.

In any case, it is crucial to confirm that the compressor does not pass any oil to the line, so the equipment maintenance systems should be very rigorous.

3.2 Marking the areas to be repaired

The areas to be repaired should be marked considering the degree of anomaly of the surfaces, with three methodologies standing out:

a) Areas previously defined in the Project Design;

b) Visible anomalies;

c) Non-visible anomalies;

The markings' spray color shall be different, depending on the type of methodology.

3.2.1 Previously defined areas in the project design

The areas previously defined in the Project Design correspond to 1st degree main repair interventions, which require the removal of large extensions of concrete, already perfectly defined in the drawings, both in extension, and in depth. The contour of these areas should be marked with a lively coloured spray, whenever possible, resorting to a gauge.

In any case, these areas should always have a regular geometry, in composed rectangle sections.

3.2.2 Anomalies

The areas with visible anomalies correspond to 2nd degree main repair interventions, requiring the removal of limited extensions of concrete. The contour of these areas should be marked with a lively coloured spray.

The areas at issue present obviously delaminated and/or cracked areas and possibly even exposed reinforcements. However, since these anomalies extend beyond what is visible, the

true dimension of these areas shall be determined after exploratory demolition with a manual hammer.

One must keep in mind that, in any case, these areas should always have a regular geometry, in composed rectangle sections.

3.2.3 Non-visible anomalies

Besides the areas defined above, which can be identified by simple observation, the rehabilitation methodology defined in the Project Design establishes, as a measure to reduce the risk of corrosion, that all the areas with an overlapping thickness below 20 mm be subject to a 15 mm thick replacement of concrete by new concrete (or mortar) more capable of preventing the penetration of aggressive agents (carbonation and chlorides).

Searching for these flawed areas requires using the following method:

- Identification of the reinforcements' mesh, with a metal detector (pachometer). This type of equipment uses electromagnetic waves to detect the position of the reinforcements. The model should be constituted by a receptor unit equipped with a small monitor and a sensor to allow visualizing the reinforcement's location;
- The reinforcement's mesh should then be marked using a ruler and crayon or a ruling pen;
- Once the reinforcement's mesh is outlined, the points to be inspected are marked on that mesh, configuring a quincunx with a rhythm equal to double the spacing of the reinforcements in each direction;
- At these points, the thickness of the reinforcements' overlapping is measured using a pachometer.

Besides searching for points with deficient overlap thicknesses, it is also important to search for potential or actual corrosion that has not yet appeared through superficial eclosions. This search should be carried out using sclerometric methods on the same points defined above to measure the overlap thickness.

Sclerometric methods are simple tests that supply vital information regarding the homogeneity of the used reinforced concrete. The equipment determines the concrete's superficial hardness, measuring the residual energy of an impact on the concrete surface. The top of the compression shaft is placed perpendicularly to the surface to be tested, pushing the body of the sclerometer against it, continuously, until the hammer releases itself and an impact is heard. It then measures the hammer's rebound value.

As a result, the following should be interpreted:

a) A dry sound and average rebound value are good indicators;

b) A hollow sound and below half the average rebound value are indicators of:

- Voids within the concrete
- Corrosion of the reinforcements.

It should be kept in mind that these areas should always have a regular geometry, in composed rectangle sections. The marked areas should be inspected by Supervision prior to continuing the works.

3.3 In depth concrete removal

The removal of the degraded concrete should necessarily take into account, the following requirements:

- The concrete removal process may not affect the construction's structural integrity. Therefore, whenever necessary, it will be required resorting to shoring;
- The extension and depth of the concrete to be removed should always be the minimums necessary to guarantee the optimal performance of the repair system, taking into account:
- The nature of the contamination and its concentration, particularly around the reinforcement bars, before and after the repair process;
- The corrosion level of the reinforcements;
- The need to clean the reinforcement bars;
- The thickness of the carbonated concrete;
- The profiles of chloride concentration, in depth;
- The porosity and permeability of the layer covering the reinforcements;
- The distance of the reinforcement bars to the surface;
- The necessary thickness to guarantee the adequate compactness to the replacement material;
- The need to guarantee adhesion of the replacement material to the substratum.

The concrete surfaces with exposed reinforcements should be prepared using light demolishing hammers, pneumatic or electric, or hidro-demolition, in order to remove the concrete from behind the reinforcements' bars and obtain a roughness that, not being excessive, increases the contact surface and improves the adhesion of the material to the existing base.

The hammers should weigh, at most, around 6 kg, in order to enable their use in works to be executed over the operator's head and be easy to handle, making it possible to remove the concrete even in places with great reinforcement density. The pivots should be sharp, with an exposed length of more than 10 cm.

The concrete should be removed throughout the contour of the repair up to a depth beyond the reinforcement bars that shall not be below 20 mm and in no case whatsoever below the maximum diameter of the aggregates composing the replacement material.

If during the concrete removal process microcracks emerge in the concrete, this cracked layer should be removed, by pricking this surface. To better identify the cracks, water or air-jets at a controlled pressure should be applied on the surface in question to clean off dust, followed by steeping. After drying, the surface should be thoroughly observed, in order to detect water retention that normally occurs throughout the cracks and, once again, remove the cracked layer. Should these cracks occur around a reinforcement bar, its entire perimeter should be unobstructed.

When removing the concrete, it should be ensured that the angle between the remaining surface and the original one is closer to 90 º, thus avoiding applying "zero thickness" of replacement material, which could lead to deficient adhesion and future delamination.

3.4 Correction of the borders of the areas subjected to concrete removal

The concrete removal works should be complemented by cutting, using angle grinders with a crescent-shaped abrasive, delimiting the contour of the repair areas.

The edges of the repair areas should be cut at a minimum depth of 5 mm, so that the angle between the remaining surface and the original one is 90 º, with a ± 5 º error tolerance.

The use of abrasive cutoff wheels should not, in any circumstance whatsoever, mutilate the reinforcement bars of the reinforced concrete parts.

The contours of the faces of the cut should not be cracked or torn, so that the replacement material does not form scales that dry too fast and loosen quickly.

3.5 Cleaning of the surfaces with water and sand jets

All surfaces that have been object of superficial or deep concrete removal works should be cleaned using pressure-controlled wet sand jets, in order to remove dust and debris. All loose material, or material that does not adhere well, should also be removed.

In general, the equipment used is a sand and water jet coupled with a compressor, rubber hose and spray nozzle. Particularly in the case of cleaning for preparation of frequently immersed surfaces, special equipment should be used.

The sand to be used must be clean, of appropriate grading for the hose diameter, be washed, perfectly dry and free from organic substances. The sand should not be reused.

The jet is applied in circles, under pressure, in the compressor, at around 8 bar, to remove all dirt, concrete and reinforcement bar corrosion residues and also to confer the appropriate roughness to the substratum, acceptable when in the average distance between the points of greatest and least protrusion is 2 to 3 mm.

Cleaning of the reinforcement bars should guarantee the removal, throughout the entire exposed surface, of all the corrosion products that are loose, besides oil, grease, paint, etc. The operator should take advantage of the system's own rebound for a more efficient cleaning, particularly behind the reinforcement bars, on their hidden side.

The sand jets may also serve to help remove the microcracked concrete layers during the removal process, in which case a slightly higher pressure should be used in the compressor.

The sand jet used for cleaning the surfaces should always be followed by a low-pressure compressed air and cold water jet for the final washing of the surface. This is carried out using directed fine nozzle hoses to guarantee cleaning in the areas that are of more difficult access.

In any case, it is crucial to assure that the compressor does not pass any oil to the line, so the equipment maintenance systems should be very rigorous.

3.6 Treatment and replacement of the reinforcements

The reinforcements shall be treated by cleaning the surface of the bars through an abrasive method (dry sand jet, moist sand jet, high pressure water jet or wire brush) or through a chemical method, in order to guarantee that the steel is descaled and completely free from signs of corrosion.

3.7 Steeping of the surfaces prior to applying the replacement material

Since the product used in the repair has a cement base, the surface of the substratum should be previously moistened to prevent that, particularly during hot and dry weather; the repair material loses water, hindering the cement hydration process.

The saturation time depends on the quality of the concrete. However, it should be at least 4 to 5 hours.

It should be preferentially applied through continuous wetting. We suggest using a hose.

When the replacement material is applied, the surface should be moist, without forming any sumps. Excess water (visible water) should be removed using compressed air or a sponge.

The water to be used for steeping should follow what is set forth in these Technical Conditions.

3.8 Injection of cement grout to fill voids

The mix should be studied taking into account local and actual injection conditions in order to obtain good workability, which should always be tested with a Marsh cone. The flow time through the lower tube should be less than twenty-five seconds until at least thirty minutes have passed since the grout manufacturing or until the end of the injection period.

3 hours after mixing the water/cement, the cement grout shall not present more than 0.5 % bleeding per volume, nor 1 % as an absolute maximum, when measured at 20ºC, in a grout thickness of around 100 mm placed in an air-tight glass or metal cylinder, with an internal diameter of 100 mm. The laitance should absorb all water penetration within the following 24 hours.

In preparing the mix, the dosage of solids should be ascertained by weighing. The amount of water should be measured through a duly calibrated counter or a measuring container.

The procedure to obtain the mix to produce the grout should be: first, pour around 2/3 of the cement in the water; second, place the adjuvant, if there is any; and finally, pour the remaining third of the cement. The grout should be mixed in a high speed mixer, working at, at least, 1000 r.p.m., during enough time to obtain a grout that has a uniform consistence, but never for a period of more than 15 minutes.

After mixing, the grout should be continuously shaken. The cement grout should be passed through a sieve with a mesh opening of 1.2 mm prior to injection. It should be injected as soon as possible after mixing and within a limit of 30 minutes, except when using delaying agents.

The cement grout injections mentioned in these Technical Conditions, to fill the voids, should be carried out using an appropriate injector, coupled with the grout producing equipment.

The injection pressure to be applied should not cause any damage.

Prior to injection, a sample of the grout shall be collected, from which 100 mm grout cubes shall be prepared. These cubes should be cured and tested according to EN 12390 and the LNEC E 226:968 specification (Concrete. Compression test) (Portuguese case)

9 cubes should be prepared for each injection operation to determine compression strength.

Systematic strength tests should be carried out at 3, 7, and 28 days to guarantee the strength required and adjust the composition of the grout. Each of these tests should be carried out, for each kneader-mixer on at leastone three test piece sample. Supervision shall be responsible for increasing the number of samples per kneader-mixer. Its compression strength at 28 days shall not be less than 25 MPa.

3.9 Spacers placement

The fixation of the spacers in the reinforcement can be performed through wires previously embedded or passed through holes or gutters.

In the case of plastic spacers, may be attached through systems of self-fixation.

The spacers should be placed to ensure that the concrete cover specified in the project is satisfied.

Their arrangement depends on the type of structural element, the diameter of the steel rods and the geometry of the cross section, in accordance with the Standards in affect, and must always be placed at a distance of about 5 mm from the folding area of the rod supporting them.

3.10 Application of the repair mortar

The task of replacing the material in the regions in which contamination of the concrete has already reached the reinforcements, but which are small, and in the regions in which the reinforcements have not yet been affected, shall be carried out with the material mentioned in these Technical Conditions.

The manufacturing of the mortars should be carried out, in principle, through mechanical means, although it is possible that they be manufactured manually in iron plate pallets. However, first, the Supplier's instructions should be followed.

To make it, only original, sealed packages may be used, being open immediately prior to being placed in the mixer drum, and using as much as possible the entire contents of the bag.

For preparation on site, it is enough to add the corrosion inhibitor to the dry mix. When the mortar is applied, the water should be in enough quantity to enable hydrating the mix, always in accordance with Supplier instructions. No admixtures should be added on site.

Mortars should be manufactured when they are to be used and in the proportion of their consumption.

All mortar that begins to set while in the mixer should be rejected.

The mortar components should be stored in a dry and fresh location. These components may only be used up to the use limit date indicated by the product's Supplier.

The mortar should always be manually applied, molding a ball with one's hand for immediate application, in very thin layers of around 10 to 20 mm. The pressure of the hand against the substratum will enable developing the desired adhesion and manual spreading, behind the bars, shall ensure total filling of the spaces.

In no case whatsoever, is the use of a trowel or spatula allowed, since it would lead to a loss in sensitivity, not guaranteeing the necessary homogeneity during application, even if the tightness of the material was appropriate or the involvement around the bars was complete.

As soon as the application of the mortar ends, the works should be inspected to search for deficient areas. Should flaws be found, they should be immediately repaired, prior to the mortar beginning to set. The flawed material should be removed and new mortar applied.

After finishing applying the mortar, the surface should carefully be smoothened, using a moist sponge, always in short rotating movements.

After manually applying and finishing the surface, when the material begins to set, it should immediately be protected through a continuous curing system using filmogenics products, as specified in these Technical Conditions.

3.11 Sealing and injection of cracks with epoxy resin

Cracks whose openings are less than 0.3 mm should be only subject to superficial sealing in accordance with these Technical Conditions, except, naturally, the references to setting the injection pipes. The product for this sealing should be in compliance with what is specified in these Technical Conditions. Prior to applying the sealant, the surface along the crack should be cleaned in accordance with what is set forth in these Technical Conditions.

Cracks whose opening is greater than 0.3 mm and 15 mm deep should be injected. These cracks should be subject to superficial sealing, in accordance with these Technical Conditions, prior to injecting. The work involves the following:

- Opening holes;
- Cleaning the cracks;
- Placing injection and purge pipes;
- Superficial sealing of the crack;
- Injection;
- Finishings.

3.11.1 Opening holes

Throughout the extension of the crack, 10 f mm or f 12 mm, 3 cm deep holes should be opened, with the help of a drill.

The hole openings shall be carefully spaced in order to guarantee that the space to be injected is totally filled when the resin appears in the next opening. In accordance with the crack geometry and extension, the location of the injection and purge pipes, that should be 10 cm to 30 cm away from each other shall be studied and shall not exceed the thickness of the injected element.

3.11.2 Cleaning the cracks

The concrete surface throughout the extension of the crack, in a 5cm width towards each side, should be clean of any and all impurities, removing the disaggregated and delaminated material, cement laitance, plaster, dirt and dust that may hinder penetration and adhesion of the resin.

Cracks should be cleaned by superficial brushing or pricking of the sealing area, followed by cleaning with a compressed air-jet.

The crack and the structure should be dry, so this work should be carried out during a dry period.

Placement of injection and purge pipes;

The injection and purge pipes are generally constituted by transparent plastic pipes and shall be introduced in the previously made holes.

3.11.3 Superficial sealing of the crack

The contour of the crack, object of cleaning mentioned in these Technical Conditions should be sealed with mortar on all sides. This product should strictly comply with what is set forth in these Technical Conditions. Sealing should guarantee that the injected resin, while liquid, does not drip out and should firmly set the injection and purge pipes. The sealing mortar should be resistant, in order to support the injection pressure to be applied by a spatula. The injection and purge pipes should be checked using compressed air, to ensure that they communicate between each other and that sealing was effective.

3.11.4 Injection

The mixing of the two components of epoxy resin should be a continuous process and not be prepared in individual batches. The mix shall be injected after checking the hardness of the sealant. The resin should be injected through the consecutive openings mentioned above. During the injection operation, the pressure should always be constant and strictly controlled,

and should not exceed the admissible value which the superficial sealing can support, nor reach values that may deform or damage the parts to be injected. The injection should, whenever possible, be carried out from the bottom up or from side to side, through consecutive injection openings, taking the necessary precautions not to form air bubbles. The personnel in charge of the injection operations should ensure that the joints are totally filled. The injection should, thus, extend at each opening until the resin appears in the next opening. The first opening should then be sealed and the injection restarted in the next opening. The two components of the resin to be injected should be stored in reservoirs connected to the equipment and should enable an easy control of the injected amounts. The injection equipment to be used should include dosing pumps that enable guaranteeing the correct ratio of the two components of epoxy resin, and mixing devices that assure uniformity of the mix prior to injection. The equipment should include manometers that enable controlling the pressure directly at the injection head. It should be maintained clean the mixing and injection equipment , keeping in mind the need to avoid hardening of the epoxy compound inside the mixing and injection system. For this purpose, the appropriate thinners recommended by the epoxy resin Supplier should be used.

3.11.5 Finishing

After concluding the injection and quality control of the works, sealing materials, pipes and any excess, injection material should be removed so as not to hinder the works' aesthetic appearance. Next, the concrete surface should be corrected with an abrasive disk to improve the final appearance of the concrete surface.

Sealing and injection of cracks can only be carried out by specialized personnel, with the appropriate equipment and technology, based on qualification certificates

3.12 Reinforcement through gluing of CFRP laminates and sheets

3.12.1 Preparation of the surfaces

The performance of the reinforcement systems through gluing of CFRP laminates and sheets depends directly on the preparation of the receiving surfaces.

The receiving surfaces should be free from cement laitance, loose or non-cohesive particles, oil and grease, dirt, organic and vegetal substances, etc. For this purpose, they should be cleaned with pressure-controlled sand jets, as indicated in these Technical Conditions.

For the laminates, the superficial non-adhering layer of the concrete should not be exaggerated, in order to limit the thickness of the adhesive to 2 mm, since a greater amount of adhesive resin, given its great deformation capacity, will delay the laminate's loading, compromising the system's performance.

The receiving surface should be regular, so that the laminate and sheets are not submitted to the action of deviating forces. For the laminates, the regularity of the surface should be controlled through a 2 m long gauge. For each measurement, overpasses of more than 3 mm are not allowed.

The application of the reinforcements shall not be allowed on structures that present degraded, delaminated or cracked concrete surfaces, with exposed and corroded reinforcements. The prior repair of those surfaces is always required, using the methods specified in these Technical Conditions that are most appropriate for each specific case.

In the cases in which there is overlapping between laminates layed-out in two directions, the one that is in the lower position should be applied over a groove, with strictly enough width and depth. These grooves should follow what has been defined for the removal works and cleaning of the surfaces. The agreement between the embedded laminated points and the

surface should be carried out so as to respect the limits established above for prevention of deviating forces.

In the cases in which there is overlapping between laminates layed out in two directions, what is set forth in these Technical Conditions should be observed.

For the sheets, edges should be rounded so that they present a minimum radius of around 25 mm, thus avoiding a greater influence of the deviation forces.

When applying the laminates and sheets, the substratum should never be more than 4% moist, controlled through appropriate equipment. If it is not possible to limit moisture to the previously indicated level, special resins should be used, with a composition that guarantees maintaining its characteristics even when applied over a moist base.

It is recommended at least one pull-off test should be carried out for each 200 linear meters of reinforcement.

3.12.2 Application of the laminates and sheets

The elements to be strengthened should have a minimum temperature of 5 ºC. It should be confirmed that, when applied, the temperature is 3 ºC above the dew point.

Once the surface is prepared and clean, when specified by the supplier, an epoxy resin primary should be applied to improve the superficial mechanical characteristics and enable a good adhesion of the resin to glue the laminates.

The primary should be applied in one coat, without being diluted, uniformly over the entire surface, with the aid of a brush or roller, guaranteeing the complete impregnation of the porosity and hollows of the elements to be strengthened.

The epoxy adhesive should be applied on the surface to be strengthened and over the laminate or steeping the sheet. The adhesive resin should be applied 90 minutes, and before 48 hours have elapsed after the application of the primary.

A 1 mm thick layer should be applied over the surface to be repaired, covering the small blisters or irregularities, using a spatula or trowel.

When there is no protection film, the laminates should be clean with the appropriate solvent, particularly on the face that will be in contact with the adhesive. A 2 mm or 3 mm adhesive resin layer should be applied, in the clean surface of the laminate, with its thickness being controlled using a ruler. The laminate and the sheet should be manually applied, by pressing against the surface of the substratum with a semi-rigid roller/ until the entire excess adhesive is expelled.

When there is a need for bending, CFRP sheets should be added to strengthen the transversal stress or to improve the laminate’s mooring conditions.

The laminates and sheets should be protected by a complementary layer of plaster or appropriate mortar and later painted with acrylic paint.

The materials should be applied by specialized personnel, based on qualification certificates, and respecting the information and recommendations provided by the Supplier as to its handling.

3.12.3 Control of the CFRP laminate’s and sheet´s mechanical characteristics

During the strengthening, sacrifice samples should be taken in areas adjacent to the applied reinforcement, in order to carry out tests that represent the pull-out adherence, without damaging the applied strengthening.

Samples should be 20 cm laminate or sheet straps installed under an adjacent support area, with the same characteristics and treatment, using portions of the resin mixture prepared for the installation of the reinforcement.

Adhesion tests should be carried out over the samples of sacrifice at the ratio of at least:

- One measurement for each 100 meters of installed laminate or sheet;
- No less than one measurement per works.
- The following results should be obtained:
- Rupture values of at least 1.5 MPa;
- The rupture points should be homogeneous;
- At least 90% of the rupture points should be cohesive concrete ruptures (rupture in the base concrete).

After concluding the reinforcement, the presence of hollow areas (tap-test) should be confirmed, by continuous tapping with a metal hammer.

The hollow areas are identified by the deaf sound to impact, and should be marked.

Should areas with a lack of adhesion be detected in laminates and sheets, they should be repaired by injection or, if necessary, by repeating the application process.

4 Painting and coating

4.1 Overhead concrete surfaces

It is recommended at the end of the works, the structure's overhead surface should be painted with acrylic paint, as specified in these Technical Conditions.

So that the protection coat is efficient it is essential that the surfaces to be coated are free from wire, nails, wood chips, styrofoam, material that is degraded, loose, or with little adhesion capacity constituting a base free of pores and irregularities, with a roughness that potentiates a new adhesion of the paint.

The surfaces that are not subject to local repair, prior to applying the superficial protection, should be prepared in accordance with the following specifications:

a) Cleaning of the surface by pickling with a water jet with abrasive (silicon sands) in order to eliminate all harmful substances, such as: disintegrating particles, rust points, dust, cement laitance, paint, grease, etc., until the surface is clean and homogenous;

b) After this cleaning, the concrete surface should be inspected in order to check if it is necessary or not to reinforce the cleaning, namely to eliminate pores, blisters and other irregularities. Pores with diameters of more than 1 cm should be individually covered and the areas with many pores (more than 5 pores with 1 mm in a 10 cm × 10 cm area) should be covered with a cement-base coat (pre-dosed mortar).The cracks should be previously treated in accordance with what is specified in these Technical Conditions;

c) The cleaning works should be developed by sections so that the time between them and the painting is no more than two weeks old in order to prevent, during this period, harmful accumulation of dust and other harmful substances to a good connection to the concrete;

d) Prior to applying the painting scheme, the surfaces should be clean and dry.

e) The pickling and cleaning system should not enable contamination of the surrounding area with the products removed from the surface.

f) The final appearance of the concrete surface prepared to receive the painting scheme should be previously approved. For this approval, a surface designated as the "reference surface" should be created on the structure, where the water jet and the abrasive jet with different intensities shall be applied, resulting from a progressive increase in pressure, until the intended preparation is obtained.

In general, preparation of the surfaces that are object of local repair shall only include cleaning with a water jet to eliminate existing dust, cement laitance or grease and reduce pores, blisters and other irregularities according to the abovementioned.

After the surface is duly prepared, a painting scheme should be applied, made up by:

a) A first diluted coat that should guarantee an efficient penetration in the small pores, their sealing and, at the same time, constitute a compatible base with subsequent finishing coats. This coat should be applied with a brush in order to guarantee an efficient colmatage of the pores.

b) A second coat, without dilution.

c) A final coat.

For a good behaviour and an efficient action of the paint coating, the care taken during its application is very important, as are the weather conditions at the time it is applied, taking into account:

a) Preparatory care

All the products should possess technical data sheets and shall follow all the recommendations indicated. Painting should not be applied on repaired areas that are less than 15 days old. It should be ensured that the concrete surface, after being repaired and prepared, does not possess more than 5 % (m/m) moisture prior to painting. Excepted are the cases in which the technical data sheet of the product expressly indicates that it is applied to surfaces with greater moisture. The superficial moisture should be measured with an electrical or dielectrical type device (resistivimeters).

b) Checking weather conditions

Painting can only be authorized when the air temperature is between 5 ºC to 35 ºC (neither cold, nor intense sun) and 3 ºC above the dew point temperature, relative moisture does not exceed 80 % without strong winds that lead to quick drying of the film or if it is recommended by the supplier. Due care should also be taken regarding the possibility of condensation of the water steam at the surface since it could lead to the formation of an invisible moist film that may hinder the adhesion of the coat.

The hygrometric and temperature conditions indicated in the product' technical data sheet should also be taken into account, if more limiting than those prescribed in these Specifications, and should be recorded, during the execution of the works, the weather conditions under which they were applied.

c) Application process

Products should be applied with a roller, brush or gun. The first coat should be applied with a brush or equivalent.

Prior to or during the execution of the works, it should be performed the necessary analysis or tests to demonstrate the products' characteristics prior to and after being applied, complying with those established in these Technical Conditions and in the documents provided by the Supplier, namely technical data sheets, testing bulletins, and certificates issued by renowned entities.

The acceptance of the painting system depends on the approval of a technical file on which the proposal based on the results of the requirements and tests specified in these Technical Conditions is grounded.

4.1.1 Product acceptance

4.1.1.1 Product identification

The products to be used during the execution of the works should be duly labelled in accordance with the legislation in affect and should include the respective technical data sheet, prepared according to NP 3284-2011 (paints and varnishes) (Portuguese case) and contents of the product's technical data sheet, where handling and application conditions should be highlighted and indicating the particular precautions to be followed during its application and storage.

4.1.2 Collection of samples on-site

Throughout the execution of the works and for each batch of paint received, should be collected, in a five litre sample representative of each product used. The sample should be stored in litre cans, sealed and duly labelled with the product's name and collection date.

Three of the cans should be sent to the testing Laboratory to control the reception of the products. The remaining two cans should be preserved.

4.1.2.1 Tests on the product samples

The tests to receive the products on-site, meant to evaluate the constancy of the batches supplied, are the following:

- Identification of the binder type (resin);
- Determination of the relative density;
- Determination of viscosity.

4.1.3 Applicators

The applicators should be qualified personnel and should have previous experience in painting works on concrete structures.

4.1.4 Quality control of the surface preparation and application of the paint coat.

Control of the painting application and of the surface the preparation should be carried out based on the creation of a reference surface. It should serve as a standard during control of the different operations to be carried out. This reference surface includes an area in which the degree intended for the preparation of the concrete surface is observed, in accordance with that established in the relevant section and other area in which the final appearance of the paint could be analysed. This analysis shall have as base the following parameters:

- Degree of preparation of the concrete surface;
- Setting time;
- Final appearance of the paint (color and texture);
- Thickness;
- Adhesion.

In this same area, samples should be taken for lab tests to confirm the dry thickness and the characteristics defined in these Technical Conditions.

It is recommended that this reference surface should be constituted by a 4 m long, 1.5 m high concrete wall, executed near the margins. This wall shall be covered, with the repair materials to be used in the works, in order to confirm the appropriateness of the paint and the application method.

4.1.4.1 Acceptance of the painted works

The acceptance of the works shall be based on the assessment of the appearance of the painting and on adhesion and average coat thickness results. The measuring sites and their regularity should be previously defined, given the volume of the works and access conditions.

4.1.4.2 Assessment of appearance

The colour and the texture should be in accordance with the reference surface.

4.1.4.3 Assessment of adhesion

To assess adhesion, random adhesion tests should be carried out in accordance with EN ISO 2409:2007 (Paints and varnishes. Adhesion through the cross-cut test method). Since this is a destructive method, the affected area should be repainted.

4.1.4.4 Checking average thickness

To check the average thickness of the coating, measurements shall be randomly carried out in accordance with standard EN ISO 2808-2007 (Paints and varnishes. Determination of the film thickness). Since this is a destructive method, the affected area should be repainted.

4.1.4.5 Performance of the painting system applied over the concrete

The reception of the works depends on confirming that the painting system with the proposed thickness reaches the requirements set forth in these Technical Conditions, for which the necessary tests should be carried out, even after acceptance of the system proposed for painting the works.

It should be presented, for approval, the methods and processes that it proposes, to establish an appropriate protection of the surrounding area and, if there are any, of roads, railroads and navigation paths, including the methods to be implemented.

Collection in the pickling areas should comply with class 11, as published in Guide 61 of the SSPC (Steel Strucrure Painting Council - Guide for Containing Debris Generated During Paint Removal Operations). The Contractor's proposal should include the description of the methods and drawings for implementation and fulfillment of the following requirements:

a) Supply of coverings, suspension or temporary structures capable of holding all the debris from the cleaning and painting operations. These supplies should comprise means that include all the lower protection of the structure. These methods and means should be sufficiently wide and long to enable protecting the areas where works are underway (in progress).

b) All the debris resulting from preparing the surface should be recovered and conveniently removed and deposited.

c) During the pickling operations by abrasion, the material used in the collection should be airtight and capable of resisting the direct incidence of the abrasive jet.

d) A collection system made up by rigid panels may be used.

The collection means can be fixed to the structure so that they do not impose excessive load to the actual structure.

These means must be structurally safe and should allow space for access to the work in all the structure areas to be repainted.

It may be used a mobile platform system supported on the structure.

In order to assure a minimum escaping of dust and debris during the pickling operations, the collection system should possess sealed joints and a closing system, designed in such a way that it prevents possible collapses of the system and/or debris leaking.

For sealing and setting of the system, magnetic bars or other provenly efficient systems may be used.

During surface preparation operations a negative pressure should be internally maintained on the surface.

The negative pressure maintained inside the system could be checked at any point through the concave appearance of the canvases, when used, or in case of a rigid system, through manometers.

The negative pressure should be kept through a recyclable dedusting system wich should be subject to control.

The dust removers should be defined in accordance with Guide 6 published by the SSPC.

a) It should be indicated the capacity of its dust remover, in m3 per minute and supply the drawings with the calculations for the proposed collection system.

b) During the pickling operations by abrasive jet or high pressure washing, it may be used curtains or canvases designed to collect abrasives and loose paint during preparation of the surface. These curtains or canvases should be designed and manufactured so as to enable retaining abrasives and filtering water, except in the below-mentioned areas.

c) In the sections under which there are infrastructures, such as houses, streets, railroads, parking, etc., water is not allowed to fall, even if filtered. It should be considered the use of collection systems that hold the used water and channel it to areas that protect the existing infrastructures from any damages.

d) The chosen method should guarantee that no accident or damage of any nature takes place.

e) All the debris that remains in the collection system must be removed, at least daily. No debris should remain on the structure's deck or on the pavements.

f) All the debris should be removed from the yard area and be deposited in accordance with the applicable local standards.

g) The emission of visible dust and debris resulting from the preparation of the surface and painting of the structure should be monitored. Should these emissions occur, the work should be suspended until correction measures are taken to prevent future emissions.

4.1.4.6 Generic dispositions

a) Equipment - It should be available all essential machines, utensils and tools for total execution of the contractual works.

b) Protection and Safety Measures - It should be removed all the residues resulting from pickling, will be elaborated and established essential safety and protection measures.

4.2 Surfaces in spatter areas

At the end of the works, the surfaces in the structure's spatter areas should be coated with a protective paste, as specified in these Technical Conditions. It must be ensured that the used product possesses a technical data sheet and that the recommendations indicated for the product are followed, namely regarding application temperature.

Preparation on-site should comply with the Supplier's specifications.

Prior to applying the paste, the surface should be cleaned, removing loose sand, dust, grease, oil, cement laitance, existing coatings or marine organisms, through water-jet with abrasive, on the surfaces that were not subject to repair, and by water jet on the surfaces that were subject to repair.

The coat should be applied with a trowel, after preparing the surfaces and always taking into account the Supplier's instructions. Special care should be taken to ensure there are no air bubbles between the paste and the surface.

After finishing applying the paste, the surface should be leveled, carefully using a trowel.

It should be observed the necessary safety measures for this work in accordance with the Supplier's instructions, namely, regarding the protection of personnel, storage, and preparation.

5 Underwater repairs

5.1 Encapsulating and epoxy grout injection

5.1.1 Application of the protective lining of frequently submerged surfaces

The frequently submerged surfaces of the bridge shall be lined with an advanced encapsulation system, as specified in these Technical Conditions.

All the products used in the encapsulation system must be accompanied by their datasheets and that the recommendations given on them are observed.

It should be submitted, for approval, the types of equipment it intends to use in the batching, preparation and pumping of the epoxy grout, together with the relevant specifications, manuals and other descriptive documentation.

The works should be preceded by a workplan presentation that shall include (without being necessarily limited to) the following:

a) Ensuring access to the level of the position of each liner;

b) Details and location of the longitudinal and transverse joints of the liners, including a description of the method(s) used for sealing the joints;

c) Details of the fixed and/or adjustable precast polymer separators to control the thickness of the grout and its location in the liner;

d) Detail of the bottom seal of the liner;

e) Location and details of the temporary anchor and support of the liner required during the placement and curing of the epoxy grout;

f) Details of the injection holes and other points on the liner to ease the placing of the epoxy grout;

g) Details of the installation sequence for placing the epoxy grout in the space between the liner and the concrete surface;

h) Detail of the final coat of epoxy grout on the upper part of the encapsulation;

i) Details of the permanent closure of all the injection holes and the location of the samples used in tests to be conducted on the liner after having completed the placement of the epoxy grout.

The application of the protective lining of permanently submerged surfaces, consisting of an encapsulation system, must be performed according to the following procedure:

a) Cleaning the surface;

b) Repairing the surface;

c) Placing the fibre-reinforced polymer liner;

d) Preparing the epoxy grout;

e) Injecting the epoxy grout;

f) Finishing off and inspecting the encapsulation.

5.1.2 Cleaning the surface

Prior to encapsulation, all permanently submerged concrete surfaces must be thoroughly cleaned, removing marine organisms, grease, oil, mud, oxides, loose concrete,

microorganisms and other hazardous materials that may impair the proper adhesion between the epoxy grout and the concrete surface. It is advisable that the concrete surface be cleaned by sandblasting, in the case of submerged surfaces, or by divers using powerful abrasive rotary equipment, or also to ensure the effectiveness of the process, resorting to jetting with “bazooka” type equipment, which will require highly skilled personnel.

It should be proposed, for approval, the cleaning method to be used on permanently submerged surfaces.

The cleaning of the concrete surface must ensure, on a final surface along the entire area to be encapsulated, a bonding strength between the grout and the concrete surface above the minimum specified in these Technical Conditions.

In environments where there is active growth of marine organisms, it may be necessary to clean the concrete surface in two phases. The first phase will consist of the removal of marine organisms, grease, oil, oxides, loose concrete, etc… to be carried out within a period not exceeding 7 days before encapsulation. The second phase shall be a final surface preparation phase, removing any remaining deteriorated substances, including microorganisms, which must be carried out within not more than 48 hours before placing the epoxy grout in the liner.

5.1.3 Placing the fibre-reinforced polymer liners

Only the use of liners with preinstalled injection holes shall be permitted.

The whole inner surface of the liner should be slightly trimmed to remove any residual adhesive.

All threaded nuts of the fixed or adjustable precast polymer separators must be fixed to the liner, in accordance with the previously approved installation plans. The maximum spacing between the fixed separators must be 45.5 cm longitudinally and 30.5 cm transversely.

The liner should be placed around the pier in such a way as not to damage the separators and prevent the occurrence of movements that may affect the adhesive in the joint during its curing process.

Both longitudinal and transverse joints, if any, must be sealed using a marine epoxy adhesive paste, as specified in these Technical Conditions, and with 4 mm-diameter stainless steel tips to ensure sealing of the liners. The spacing between the individual tips should not exceed 13 mm.

The liner must be supported by a temporary clamp or other means to ensure the positioning of the liner during the placement of the epoxy grout and the curing period, and also to ensure a space of at least 8 mm between the liner and the concrete surface during the whole encapsulation process.

A packing must be installed at the bottom of the liner to prevent the grout from trickling out from underneath during the injection process. This packing must be placed inside the moulded cavity at the bottom of the liner, fixed with marine epoxy paste.

The material used in the packing of the bottom seal must remain inside the moulded cavity and under no circumstances should it spread upward.

5.1.4 Preparing the epoxy grout

The batching and mixing of the epoxy grout must be performed with equipment specifically designed for this purpose and in a suitable working area, and will also be balanced according to the length of the injection hose.

The proportion between the silicon dioxide powder and liquid components must be carried out strictly in accordance with the Supplier's recommendations, especially with regard to temperature control.

If the water and/or air temperature is expected to fall below 21 °C, the grout and liquid components supplied for that day must be preheated above 27 ºC, but never exceeding 49 °C, before they are placed in the mixing equipment. Under no circumstances should an open flame be used in direct contact with the equipment or epoxy components.

5.1.5 Injecting the epoxy grout

Before beginning the injection process, at least 4.5 litres of lubricant must be placed in each hole.

The lubricant must be an epoxy thinner, compatible with the chemical properties of the epoxy grout used.

This lubricant must be pumped through the whole equipment in order to cover all the wet surfaces of the holes, pump(s) and hose(s). Once the lubricant level has reached the bottom of the holes, epoxy grout injection must commence immediately. The lubricant that did not come into contact with the epoxy grout can be reused.

The epoxy grout must be pumped through the hoses to the injection holes on the liner, using the multi-component method in accordance with these Technical Conditions.

Grout injection must commence at the lower injection holes. As the grout flows from the next upper injection hole, and once the space between the liner and the concrete surface is filled, the lower hole must be closed and the next hole immediately above injected. This process must be carried out from hole to hole, until the grout reaches the top of the liner. The lower hole, already injected, must be closed with 2.5 cm-diameter PVC or polypropylene plugs.

The injection process must be continuous, except for brief interruptions while moving the nozzle from one hole to another. The speed of the injection process must be controlled to prevent the entry of water or air in the cavity that is being filled with the epoxy grout.

The maximum allowable number of gaps in the epoxy grout inside the liners must not exceed 9 cm^2 for every 900 cm^2 of the encapsulation area. Any gap greater than 2.5 cm in diameter must be repaired.

5.1.6 Finishing off and inspecting the encapsulation

Once the grout injection and curing process has finished, all the temporary supports of the liner must be removed.

If the sample results from the bond strength test, reveals a bonding strength below the specified by the Supplier of the materials or in these Technical Conditions, the encapsulation in question must be placed in a "retained condition" for further inspection and final decision. Should any portion of the liner or epoxy grout "shift" from the concrete surface during sample removal, the affected area must be repaired using the method outlined in the installation plans previously approved.

The epoxy grout protruding from the top of each encapsulation must be finished off with marine epoxy paste, as specified in these Technical Conditions.

5.1.7 Equipment

The epoxy grout to be injected into the liners must be handled using the multi-component method, where reactive epoxy components are kept separate during batching, premixing and pumping, to later mix themselves in the final flow of the hoses, just before entering the liner.

Manual or electrical mixing of the components in their original containers or any other type of can or drum is not permitted.

If the water and/or air temperature is expected to fall below 21 °C, a hot water source must be provided, such as a water heater. The heated water shall go towards the water liners surrounding the injection hose(s). This equipment must be capable of sending a sufficient amount of heated water to maintain the proper viscosity of the grout during its application.

6 Electrochemical systems

6.1 Cathodic protection systems

6.1.1 Tests

Before installing the Cathodic Protection System, the following trials and tests shall be conducted:

a) Visual inspection and delamination test of the whole area to be cathodically protected;

b) Ascertainment of the electrical continuity of the reinforcements. It is necessary to ascertain the electrical continuity of the frames of each element and between consecutive elements;

c) If there are discontinuous rods in a given element, where cathodic protection is applied, continuity must be ensured through welding to another continuous rod;

d) There must be electrical continuity between consecutive elements, so that there is electrical continuity between all the elements constituting an area.

During the installation of the Cathodic Protection System, the following trials and tests shall be conducted:

a) Calibration of the reference electrodes, before and after their installation;

b) Ascertainment of the operability of all equipment;

c) Ascertainment of the absence of short circuit between the anode and frames throughout the system's installation process;

d) Ascertainment of interference in all the metal elements embedded in the concrete, such as pipe supports, etc.; if there is interference, these elements must be connected to the frames.

6.1.2 Internal anodes - beams, piers and struts

The anodes must be installed in accordance with the Supplier's instructions.

The internal anodes must be installed in holes with a diameter 10 mm wider than the width or diameter of the anode. The holes shall be detected using a frame detector. If a frame is accidentally found during the drilling process, the hole must be interrupted and repaired. Another hole must be made up to 50 mm from the position specified in the project.

To place the Titanium bar/wire of the current distributor, a suitably sized groove shall be made by cutting the surface of the concrete, between the anode holes.

The anode filling material must be a cement-based concrete repair mortar or equivalent.

All anodes must be tested for possible cases of short circuits between the anode and frames.

If any anode is short-circuited with the frame or has very low resistance, it must be abandoned and a new anode installed nearby.

Internal anodes must be of activated mixed metal oxide (MMO) coated Titanium and installed in holes made in the element to be protected and encapsulated by a cement-based concrete repair mortar or equivalent.

The anodes must be interconnected by a Titanium wire or strip.

The current capacity of the anodes should be 220mA/m^2 and 2.2 mA by 100 mm long.

6.1.3 Anode mesh strips – deck slab (lower side), stairs and boarding front

The anode to be used must be Lida® Ribbon Type I or equivalent, which consists of mixed metal oxide coated activated Titanium mesh strips.

The strip shall be 23 mm wide and 0.88 mm thick, or equivalent, with a current capacity of 110mA/m^2 and a linear capacity of 5.3 mA. These must be connected to a 15 mm-wide and 1 mm-thick Ti strip (current distributor).The anode strips must be installed with a spacing equal to or lower than that specified on the drawings.The anode strips should be connected to the anode current distributor through spot welding.The method used for the installation of the strips will depend on the degree of concrete deterioration.

In areas where it is not necessary to remove deteriorated concrete, the strips can be installed in grooves made in the surface.

In areas that have significant deterioration, and where it is necessary to remove the coating layer, the strips must be placed on the repair mortar and coated with a final 20-25 mm-thick layer of shotcrete, for small areas, or between two layers of shotcrete, for large areas to be repaired.

6.1.3.1 Installation in grooves

If the thickness of the coating is uniform and generally greater than 50 mm, the strips can be installed in 6 mm-wide by 35 mm-deep grooves.

After completion of the grooves, these must be filled with a filling material prior to the insertion of the strip.

In areas where the thickness of the coating layer is less than 50 mm, the strips must be installed in grooves approximately 23 mm wide, depending on the width of the strip, and 25 mm deep.

6.1.3.2 Installation between shotcrete layers

In areas where the concrete is very deteriorated and requires the removal of the coating layer, it will be necessary to manually apply repair mortar, in small areas, or a shotcrete layer of approximately 25 mm, in large areas to be repaired.

One day after shotcreting, the strips must be fixed to the new concrete layer by plastic fasteners.

After having connected the strips to the current distributor, a second shotcrete layer of 20-25 mm must be placed to cover the strips.

6.1.4 Reference electrodes

Silver/Silver Chloride (Ag/AgCl) or Manganese/Manganese Dioxide (Mn/MnO2) electrodes must be used. At least two electrodes must be installed in each area. Each electrode must be provided with its connection to the frames (monitoring). The electrodes must be provided with an XLPE/PVC cable of at least 2.5 mm^2 and of sufficient length to reach the junction box, without couplings.

The electrodes must be suitable to be installed in concrete and have a useful life of at least 30 years.

6.1.5 Connections

6.1.5.1 Connections to the Frames

The amount and location of connections to the frames shall depend on the degree of electrical continuity between each element and the various elements of the structure.

At least two connections must be made per area, if there is electrical continuity between the various elements of the area. These connections shall be made by welding between a metal electrode, which is attached to an electric cable, and a rod of the structure. These must be made at the top of the tidal section, if electrical continuity is confirmed between the frames of the foundation and those of the crossbeam.

6.1.5.2 Anode Connections

Connections shall be made by spot welding between the connection electrode, attached to the electric cable, and one end of the current distributor's strip. There must be at least two connections per area or sub-area.

6.1.5.3 Anode Connections – Anodic power cable

These connections must be made with proper terminals and encapsulated in appropriate connection kits. The encapsulation material must be 3-M Scotchcast® resin type or equivalent.

6.1.6 Junction boxes

The junction boxes to be used must be suitable for outdoor installation, made of PVC, polycarbonate or GRP, and have a degree of protection of at least IP 66, in accordance with Standard EN 60529. The cables must enter through appropriate glands and in such a way as to keep the same IP 66 degree of protection. If junction boxes are used for DC cable couplings in classified areas, they must be suitable for the classified environment and provided with a certificate that guarantees their classification.

6.1.7 Start-up and commissioning of the system

The supplier shall be responsible for the start-up and commissioning of the system, in order to prove that it is operating according to pre-set criteria. Commissioning must be carried out in accordance with Item 8 of Standard EN 12696:2000.

The start-up of the system must be carried out immediately after completing the installation of all the components and no later than three months after installation.

A System Start-up and Commissioning report must be submitted within three months after the full commissioning of the system.

6.1.8 Galvanic anodes

The galvanic anodes, zinc or magnesium, are typically installed in fill material ("backfill") to reduce the resistivity of the surrounding environment, prevent the passivation of the anode and encourage a uniform anodic consumption, optimizing the performance of the anode.

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