



quality control requirements for repair systems

TECHNICAL REPORT



TR 5.1

REPAIR MATERIALS

quality control requirements for repair systems

TECHNICAL REPORT

TR 5.1

REPAIR MATERIALS

Author:

Rita Moura

Author:

Rita Moura

Design manager of rehabilitation, Teixeira Duarte

Reviewer:

Afonso Póvoa

Senior civil engineer, EP

NOTE:

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

PREFACE

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

This report contains an example of the testing program for quality control of repair material to comply with EN 1504, established by a contractor.

WG A5 – Quality control requirements for repair systems		
WG Leader: Sylvie Yotte Bordeaux University , FR		
Partners active members		
Country	Institution	Members
Portugal	<i>Teixeira Duarte</i>	Rita Moura
France	<i>University of Bordeaux</i>	Sylvie Yotte

DURATINET project approved by the Atlantic Area Programme and co-financed by ERDF

CONTRACT N°: 2008-1/049

PROJECT TITLE: Durable Transport Infrastructure in the Atlantic Area Network

ACRONYM: DURATINET

LEADER: Manuela Salta

Laboratório Nacional de Engenharia Civil (LNEC)

Materials Department

Portugal

CONTENTS

1	Common prescriptions to all the materials.....	1
2	Water	2
3	Aggregates	3
3.1	Sand for concrete	3
3.2	Sand for cleaning purposes, applied through jet.....	5
3.3	Gravel	5
4	Cement based materials	9
4.1	Hydraulic binder	9
4.2	Repairing mortar	10
4.3	Sealing mortar.....	11
4.4	Cement related protection for the reinforcement.....	11
5	Adjuvants and additions.....	13
5.1	Adjuvants	13
5.2	Additions	14
5.2.1	Pozzolans for concrete	14
5.2.2	Fly ash	14
5.2.3	Granular slag	14
5.2.4	Limestone filler.....	14
5.2.5	Silica fume	14
5.2.6	Corrosion inhibitor to be mixed	15
5.2.7	Migratory corrosion inhibitor.....	15
6	Metallic materials	17
6.1	Steel for reinforcement.....	17
6.2	Stainless steel	17
6.3	Steel plates and profiles.....	18
6.3.1	Rolled steel	18
6.3.2	Stainless steel plates	18
7	Electrochemical systems	19
7.1	Cathodic protection systems	19
7.1.1	Anodes.....	19
7.1.2	Reference electrodes.....	19
7.1.3	Junction boxes.....	19
7.1.4	Transformer/rectifier	19
7.1.5	Electric cables.....	19

7.1.6 Cables between anode connections and power cable.....	20
7.1.7 Cables between anode the junction box and T/R	20
7.2 Galvanic anodes	20
8. Painting and coating	21
8.1 Outdoor concrete surfaces	21
8.2 Surfaces in splash zone	24
8.3 Film forming products for the curing	25
8.4 Painting of metals elements	26
9. Specific materials for underwater repair	27
9.1 Protective lining of frequently submerged surfaces.....	27
9.2 Fiber reinforced polymer (FRP) liner	27
9.3 Epoxy grout.....	29
9.4 Adhesive marine epoxy paste	30
9.5 Marine epoxy paste.....	31
10 Traditional Formwork	32
11 Spacers.....	33

1 Common prescriptions to all the materials

All the materials to be applied in the works should comply with:

- a) If national, with the National Standards, official laboratories homologation documents, regulations in affect and specifications from these Technical Conditions;
- b) If manufactured abroad, with the Standards and regulations in affect in the Country of origin, if there are no National Standards applicable to them and with the specifications from these Technical Conditions;
- c) With European Standards, especially the EN 13670:2009 which is considered a mandatory reference document as well as any alterations that may have been introduced in the meantime.

Within the scope established, the materials to be used in the structure rehabilitation works should comply with the prescribed in EN 1504-9:2008 (Products and systems for concrete structures protection and repair – Definitions, requirements, quality control and conformity evaluation – Part 9 – General principles for the use of products and systems) especially in relation to the established in point 7.

The properties specifically required for a certain product application stage should mandatorily be kept preserved during the whole storage period that precedes its application.

All the remaining properties of a certain product (material) should remain unchanged during the structure useful life in order to assure the implementation of the rehabilitation principles defined in point 6 of EN 1504-9:2008.

Before, during and after the works execution and whenever it deems convenient, it could be taken complementary control tests to check if materials characteristics and its application comply with the established in the Project, as well as collect new samples and order analysis, tests and proof-tests in duly certified laboratory for this specific purpose. For this purpose, samples should always be collected in triplicate and be adequately identified.

Materials that get decayed due to weather conditions shall be mandatorily deposited in warehouses that offer safety and protection against soil dampness, against the environment at the site and against all sorts of weather conditions.

During the storage and deposit, there should be assured the safeguard and preservation of the materials.

All materials that decayed shall be rejected. The deposit of materials or equipment in the site yard should not be done if:

- a) They are different from the approved ones;
- b) They were not applied in accordance with the Technical Specifications of this Tender or, if they do not exist, with the Standards or processes to be complied with and which cannot be re-used.

2 Water

The water to be used in the works, both in the manufacture and in the curing of mortar and concrete to be applied, and also in the cleaning and preparation of the surfaces to be repaired, must rigorously comply with the established in this Project and with the prescribed in the standards and regulations, specially EN 206-1:2000 (Concrete - Part 1: Specification, performance, production and conformity), and should not, in any circumstance, contain any harmful constituents in such quantity that it might affect the different types of mortar and of concrete setting and durability or cause the reinforcements corrosion.

The water should be, in general, fresh, clean, and colourless or slightly yellowish, without any oil or fat in film or emulsion, should not contain any detergents, sugar, acids and deliquescent salts, organic substances or any other alien matters in solution or suspension that may harm the adherence among the several elements.

The water to be used in the mortar and concrete cure should not have high concentration of salts, in order to prevent any negative action, in terms of durability, on the concrete, after having evaporated.

In any case, the water should be previously analysed, in order to assure its adequateness to be used. Thus, water parameters to be used should comply with the limits indicated. The national standards (LNEC E 372:1993 Specification) refer to Chart 1(Portuguese case).

It is expressly forbidden the use of non-tested, brackish water or water from wells, the sea or any other source, either in kneading, curing, cleaning or surface preparation.

3 Aggregates

3.1 Sand for concrete

The sand to be used at the site, in the manufacture of concrete, should rigorously comply with the established in the Project and with the prescribed in the regulations in affect, especially EN 206-1:2000 (Concrete - Part 1: Specification, performance, production and conformity) or national standards, in the case of Portugal, LNEC E 373:1993 Specification (Aggregates and mortars and concrete – Characteristics and conformity checking), and should not, by any chance, contain harmful constituents in such quantity that might affect the different types of concrete, either conventional or projected, or to cause the reinforcements corrosion.

An eventual plan for the obtainment of sand, cleaning, source, transportation and storage, as well as its aggregate grading, in order to check the production, supply and maintenance assurance of its characteristics, in the required quantities and dimensions, should be previously submitted for approval.

The sand should display mechanical resilience, adequate shape and chemistry for the aimed utilisation.

The sand should be natural, hard, clean, washed and screened, if the inspections deems necessary, free of dirt, organic substances, clay or any other coating that isolates it from the binder, soft, brittle or too fine particles, organic matter and any other impurities.

The substances considered to be harmful are:

- a) Elements with dimensions smaller than 75 µm (very fine particles and soluble matter), such as silt, etc. If these elements are:
 - enveloping the sand, then they should be very well washed;
 - loose, only if its percentage does not exceed the limit of 3 % of the sand quantity it is not necessary to wash;
 - The determination of the contents in very fine particles and matter should be done (Portuguese case) in accordance with NP 86:1972 (Aggregates for mortars and concretes – Determination of the contents in very fine particles and soluble matters);
- b) Brittle particles, liable to be reduced to dust during the kneading, such as shells, bits of agglomerated clay, etc., should not exceed the limit of 1 % of the quantity of sand;

The determination of the brittle particles contents (Portuguese case) should be done in accordance with NP 1380: 1976 (Aggregates for mortars and concretes. Determination of brittle particles contents);

- c) Organic matter. The sand should not contain organic matter in such quantity that when subject to test to ascertain it does not produce a colour darker than the standard colour, in accordance with NP 85:1964 (Sand for mortar and concrete. Research of organic matter through the tannic acid) (Portuguese case);
- d) Clay particles should not exceed the limit of 2 % of the quantity of sand.

The determination of the clay particles contents should be done (Portuguese case) in accordance with LNEC E 196:1967 (Soils. Aggregate grading analysis).

- e) Light particles, such as coal, lignite, wooden bits, etc. should not exceed the limit of 0.5 % of the quantity of sand.

The determination of the light particles contents should be done (Portuguese case) in accordance with NP 953:1973 (Aggregates for mortars and concretes. Determination of light particles contents);

- f) Sulphates, sulphide, chlorides and alkalis. It is advisable to do the regular control of sulphates, sulphides, chlorides and alkalis contents in the sand. For that purpose, one should observe the frequency and the systematic established in the pertinent documents, listed below:
- The determination of the sulphates contents should be done (Portuguese case) in accordance with NP 2106:1984 (Aggregates for mortars and concrete. Determination of sulphates contents).
 - The determination of sulphides contents should be done (Portuguese case) in accordance with NP 2107:1984 (Aggregates for mortars and concrete. Determination of sulphides contents).
 - The determination of chlorides contents should be done (Portuguese case) in accordance with LNEC E 253:1971 (Aggregates for mortars and concrete. Determination of soluble halides contents).
 - The determination of alkalis contents should be done (Portuguese case) in accordance with NP 1382:1976 (Aggregates for mortars and concrete. Determination of soluble alkalis contents. Flame spectro-photometry process).
 - The determination of the reactivity with sulphates should be done (Portuguese case) in accordance with LNEC E 251:1985 (Aggregates for mortars and concrete. Reactivity test with sulphates in the presence of calcium hydroxide).

The physical characteristics of the sand, such as the specific weight, water absorption, bulk density, percentage of voids and humidity should be determined in accordance with the applicable standards, when Inspection seems fit. The aggregate grading of the sand for concrete should be such that its Abrahms fineness module does not vary more than 20 % in relation to the sand fineness of the standard sample. Whenever there is a higher alteration than the referred maximum limit, should be readjusted the aggregate grading trend in relation to the reference trend.

Especially for the projected concrete, the sand should have a spherical shaped grain, rough to the touch, and preferably siliceous. A particle has a spherical shape if its shape coefficient is unitary.

The relative humidity of the sand to be used should be maintained as most uniform as possible and should not exceed the limit of 4 %.

The storage in the site yard should consider the following requirements:

- a) the types of sand should be on top of drained light concrete in order to render uniform and therefore to maintain its surface humidity status, avoiding its variance and the consequent need of correcting the quantity of kneading water to be used in the concrete composition or deposited in silos, laid on rock filling that assures the efficient draining and flowing of the water (of the rain and sand wetting) fallen with gravity.
- b) The sand should be sheltered and put in order according to cross-sections that comply with the different sources and aggregate grading, if applicable.
- c) Each cross-section should be well identified, with its clear designation, in order not to get mixed with other substances or with other kinds of aggregates.

- d) All the sand portions that were washed can only be used for its specific purpose twenty four hours after having been washed. This operation should be done in a place sufficiently far away from the storage place.

3.2. Sand for cleaning purposes, applied through jet

In general, the sand to be used should not, in any circumstance, contain harmful constituents in such quantity that may affect the performance of the surfaces cleaning process or to cause the reinforcements corrosion.

The sand to be used in the cleaning, applied in humid jets under controlled pressure, should be dry, a property that shall always require an accurate control, as the use of damp sand shall cause the formation of clumps that will clog the jet machines hoses, preventing the good continuity of the service.

The sand to clean surfaces that were the object of in-depth concrete removal should comply with the following requirements, so that the mechanical performance of the process (to give much roughness to the surface) is assured:

- a) Maximum diameter of the particles should correspond to the opening of sieve n.º 8 (2.38 mm) – (ASTM C 33 – 03: Standard Specification for Concrete Aggregates, item 6);
- b) The sand can be of quartz or silica, always not very soft so that the surface becomes sufficiently rough and not just polished;
- c) The sand should preferably have angular particles, which are the ones showing less original wear (adequate to be worn off with its own use).

The sand to clean surfaces that have been the object of surface concrete removal should comply with the following requirements so that the mechanical performance of the process (to give much roughness to the surface) is assured:

- a) Maximum diameter of the particles should correspond to the opening of sieve n.º 20 (850 m) – (ASTM C 33 – 03: Standard Specification for Concrete Aggregates, item 6);
- b) The sand can be of quartz or silica, always not very soft so that the surface becomes sufficiently rough and not just polished;
- c) The sand should preferably have rounded particles, which are the ones displaying few angles.

3.3. Gravel

Gravel to be used in the manufacture of concrete should strictly comply with the established in the Project and with the prescribed in the regulations in affect, especially EN 206-1:2000 (Concrete - Part 1: Specification, performance, production and conformity) and national standards, in the case of Portugal LNEC E 373:1993 Specification (Aggregates for mortars and concrete. Characteristics and conformity checking), and should not in any circumstance contain harmful constituents in such quantity that may affect the durability of the concrete or cause the reinforcements corrosion.

Should be submitted for previous approval the gravel obtainment, washing, source, transportation and storage, as well as its aggregate grading, in order to check the production, supply and maintenance assurance of its characteristics, in the required quantities and dimensions.

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

The stone should be cleaned and washed, free of dirt, organic substances, clay film or any other coating that isolates it from the binder, soft, brittle or too fine particles, organic matters and any other impurities, complying with the following conditions:

- a) Be preferably of rolled material with spherical shape or gravelled material with cubic shape, that is, with shape coefficient 1 or 0.37, respectively, value that cannot in any circumstance, be lesser than 0.25;
- b) Should not contain elongated or flat elements that exceed 20% of the total quantity. One particle is considered to be flat whenever the d/b is less than 0.5 and elongated when l/b is higher than 1.5, being b the width, l the length and d the particle thickness;
- c) Be hard, not marl nor frost-susceptible and well washed;
- d) To display mechanical resilience and the adequate chemical composition;
- e) Have a fineness module that is not more than 20 %, removed from the gravel fineness module that has been adopted as standard sample.

The stone should have variable dimensions so that, together with the sand, a greater concrete compactness is obtained, being these dimensions in such a way that allow the easy penetration of the stones among the reinforcement rods; therefore, they should be compatible with the mixing and launching equipment.

In particular for the use of projected concrete, the maximum dimension of the aggregate should be 10 mm.

The different types of gravel should constitute well selected lots, among well determined gauges. The gravelling processes and selection used by the Supplier should assure the grain size of the different types of gravel and the aggregate grading to be used should be previously submitted to the Inspection approval.

The substances considered to be harmful are:

- a) Elements with smaller size than 75 μm (very fine particles and soluble matter), such as silt, etc. If these elements are enveloping the stones, then the latter should be very well washed; If they are loose, it is not necessary to wash it, only if its percentage does not exceed the limit of 3 % of the gravel quantity; The determination of very fine particles and soluble matter contents should be done (Portuguese case) in accordance with NP 86:1972 (Aggregates for mortars and concrete. Determination of very fine particles and soluble matter contents).
- b) Brittle particles, liable to be reduced to dust during kneading, such as mica, bits of clay, etc. should not exceed the limit of 0.25 % of the quantity of fine gravel;
 - The determination of the brittle particles contents should be done (Portuguese case) in accordance with NP 1380:1976 (Aggregates for mortars and concrete. Determination of brittle particles contents).
- c) Organic matter. Gravel should not contain organic matter in such a quantity (Portuguese case) that whenever subjected to tests for its determination, according to NP 85:1964 (Sand for mortars and concrete. Research of organic matter through the tannic acid process), it produces a darker colour than the standard colour.
- d) Clay particles should not exceed the limit of 2 % of the quantity of gravel
 - The determination of the clay particles contents should be done (Portuguese case) in accordance with LNEC E 196-1967 (Soils. Grain sizing analysis).
- e) Light particles, such as coal, lignite, wooden bits, etc, should not exceed the limit of 1 % of the quantity of gravel;

The determination of the light particles contents should be done (Portuguese case) in accordance with NP 953:1973 (Aggregates for mortars and concrete. Determination of the light particles contents).

- f) Sulphates, sulphide, chlorides and alkalis. It should be done a regular control of sulphates, sulphides, chlorides and alkalis contents in the gravel; for that purpose, one should observe the frequency and the systematic established in the pertinent documents listed below:
 - The determination of the sulphates contents should be done (Portuguese case) in accordance with NP 2106:1984 (Aggregates for mortars and concrete. Determination of sulphates contents).
 - The determination of sulphides contents should be done (Portuguese case) in accordance with NP 2107:1984 (Aggregates for mortars and concrete. Determination of sulphides contents).
 - The determination of chlorides contents should be done (Portuguese case) in accordance with LNEC E 253:1971 (Aggregates for mortars and concrete. Determination of soluble halides contents).
 - The determination of alkalis contents should be done (Portuguese case) in accordance with NP 1382:1976 (Aggregates for mortars and concrete. Determination of soluble alkalis contents. Flame spectrophotometry process).
 - The determination of the reactivity with sulphates should be done (Portuguese case) in accordance with LNEC E 251:1985 (Aggregates for mortars and concrete. Reactivity test with sulphates in the presence of calcium hydroxide).

Gravel should have enough mechanical resilience to assure the characteristics defined for concrete. In any case, the rock rupture stress that constitutes it should never be lesser than 50 MPa. Its determination should be done (Portuguese case) in accordance with NP 1040 (Natural stones. Determination of rupture tension by compression of the rock).

The storage at the site yard should consider the following requirements:

- a) Gravel should be on top of drained light concrete in order to render uniform and therefore to maintain its surface humidity status, avoiding its variance and the consequent need of correcting the quantity of kneading water to be used in the concrete composition, or deposited in silos, laid on rock filling that assures the efficient draining and flowing off through gravity of rain water and the gravel wetting.
- b) The gravel should be sheltered and put in order according to cross-sections that comply with the different sources and aggregate gradings, if applicable.
- c) Each cross-section should be well identified, with its clear designation and indication of the size, in order not to get mixed with other substances or with other kind of aggregates that shall harm the manufacture of concrete.
- d) In the storage and transportation operations the segregation of materials should be prevented. The gravel unloading and transportation processes to the concrete mixer inlet should be in such a way as to avoid any alterations to its grain size characteristics.
- e) All the gravel portions that were washed can only be used to manufacture concrete, twenty four hours after the washing. This operation should be carried out in a place removed from the storage place.

3.4 Rock filling

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

Rock filling to be used in coating the landfill under the works shall be comprised by gravelled aggregates, should be exempt of fines (fine aggregates), unchangeable and with identical granulometry (aggregate grading) to the already existing one.

Quality control tests shall be run on the proposed material. These tests shall include the determination of the porosity, tension failure due to simple compression, wear and tear and expansion.

The admissible limits are as follows:

- Porosity < 5 %
- Expansion < 2×10^{-4}
- Compression strength > 80 MPa
- Wear and tear < 35 %

4 Cement based materials

4.1 Hydraulic binder

Binders to be used in the manufacture of structural mortars and concrete should be of a hydraulic nature, should comply with the provisions contained in the Project and in the applicable regulations, particularly in the EN 206-1:2000 (Concrete - Part 1: Specification, performance, production and conformity), EN 196-7:2007 (Methods of testing cement - Part 7: Methods of taking and preparing samples of cement), EN 197-1:2011 (Cement - Part 1: Composition, specifications and conformity criteria for common cements) and EN 197-2:2000 (Cement - Part 2: Conformity evaluation) and, in the case of Portugal, specification LNEC E378:1996 (Concrete. Guidelines for the use of hydraulic binders).

In general, the hydraulic binder component of mortars and concrete to be manufactured should be Portland cement EN 197-1:2011, Type CEM I of class 42.5 R, and (Portuguese case) should mandatorily contain the NP mark of conformity with the regulation in affect.

For aggressive environmental conditions, a pozzolanic cement EN 197-1:2011, type CEM IV of class 42,5R should be used, and (Portuguese case) should mandatorily contain the NP mark of conformity with the cement standards.

The cement should be recently manufactured, and must be very well packed, in order to be protected against humidity, impurities and bad weather.

Bulk supplied cement:

- a) Should be stored in humidity proof silos and adequately equipped with thermometers;
- b) All cement which has hardened, with granules, badly packed or stored should be rejected.

When supplied in bags:

- c) It should be made of waterproof paper, with the brand of the Supplier and the quality mark perfectly stamped, allowing the easy inspection and differentiation of each stored allotment, to exclude any possibility of error;
- d) After reception on site, cement bags cannot be stored outdoors, but in a place protected against humidity and impurities, dry, with adequate ventilation, taking all the due steps indicated in Article 9.6.2.1. of EN 206-1:2000;
- e) Each cement bag should contain the net weight of 50 kg, with a tolerance of 2 %;
- f) All cement that is contained in open bags or with signs of having been violated shall be rejected. Rejected cement should be identified and immediately removed from the site yard.

The cement should be stored in such a way as to be possible to be used according to its delivery order.

All the cement, when being applied, should be dry, without any signs of humidity and free of granules and impurities.

The cement to be used in the concrete stipulated for a certain work element should, whenever possible, be of the same source, proved by certificates of origin. Otherwise, it should give be given evidence, through tests, of the equivalence of physical, chemical and mechanical properties of the cements used and paying special attention to its alkalinity.

The cement to be used for a certain concrete composition must not have quality characteristics quite inferior to those of the allotment that was the basis for the establishment

of the concrete composition. If no other rule is agreed upon, the result of the mechanical strength to compression tests at 28 days should not be inferior in 5 MPa to the average of the values allocated to the above referred allotment.

The tests to determine the resistance to compression at 28 days should be done in accordance with the established in NP EN 196-1:2006 (Cement test methods. Determination of the mechanical strength).

The cement samples collected at the site storing place should comply with the established in NP EN 196-7:2008.

The mixture of additions to cements on site shall only be allowed in exceptional, duly justified cases, only when its consequence shall be the improvement of the concrete and mortars durability and only if the Cement Industry does not produce, in a current manner, certified cements with equivalent characteristics.

The mixture of additions to the cements should (Portuguese case) be subordinated to the established in Specification LNEC E 378:1996, or any other national standard, and comply with the established in the regulation in affect (Portuguese Standard or other national standard) applicable to each addition.

In case of use of white cements, the established in NP 4326:1996 (White cements. Composition, types, characteristics and conformity checking) (Portuguese case) should be complied with.

4.2 Repairing mortar

The repairing mortar should be supplied already pre-mixed, in closed packages, in a powder composition based on cement, sand, additives and adjuvants. To prepare it on site it will only be required the addition of water, in accordance with the Supplier's specifications.

In any case the repairing mortar should be thixotropic, free of chlorides and of aluminium powder.

The powder mixed with water shall form a viscous-plastic mass, shrinkage free, with good initial and final mechanical strength, with high adherence to steel and to concrete, waterproofing and durability.

The mortar should have the following characteristics:

- a) Water/cement relation inferior to 0.35;
- b) Adherence by direct traction higher than 2.0 MPa (EN 1542:1999 - Products and systems for the protection and repair of concrete structures. Test methods. Measurement of bond strength by pull-off);
- c) Compression strength obtained in 4 cm edge cubes, superior to 45 MPa at 28 days (EN 12190:1998 - Products and systems for the protection and repair of concrete structures. Test methods. Determination of compressive strength of repair mortar);
- d) Shrinkage inferior to 0.09 % (900×10^{-6} m/m) – (EN 12617-4:2002 - Products and systems for the protection and repair of concrete structures. Test methods. Part 4: Determination of shrinkage and expansion));
- e) Capillary absorption inferior to $0.5 \text{ kg} \cdot \text{m}^{-2} \cdot \text{hour}^{-0.5}$ (EN 13057:2002 - Products and systems for the protection and repair of concrete structures. Test methods. Determination of resistance of capillary absorption);

- f) CO₂ Penetration strength (carbonation) inferior to 1 mm (EN 13295:2004 - Products and systems for the protection and repair of concrete structures. Test methods. Determination of resistance to carbonation);
- g) Setting time superior to 20 minutes (EN 13294:2002 - Products and systems for the protection and repair of concrete structures. Test methods. Determination of stiffening time);
- h) Diffusion to chloride ion inferior to 0.05 % (EN 1015-17:2000 - Methods of test for masonry mortar. Part 17: Determination of water-soluble chloride contents of fresh mortars);

Adequate workability for the different situations foreseen in the Contract Job.

The product proposed to be use should have the quality certificates with indication of the limit date for its use, at least 60 days beforehand in relation to the first application foreseen to take place.

4.3 Sealing mortar

The sealing mortar should be supplied in bags, pre-dosed and together with the quality certificate. Its preparation should follow the Supplier's indication.

The mortar should be thixotropic, free of chlorides and aluminium powder, with low shrinkage rate, quick setting and high adherence to concrete.

Essentially and where applicable, the main characteristics of this product, duly indicated by the Supplier, should be checked in accordance with the same above established systems for repairing mortars.

It should be guaranteed by the Supplier that the sealing mortar does not crack or get unstuck from the cracks' edges when subject to pressures resulting from the injection process.

The mortar should be prepared at the moment that it is going to be used and in proportion to its consumption, rejecting all that start to stiffen or set when being kneaded or that have been re-wetted.

The product to be used should be proposed, together with the quality certificates proposal with indication of the limit dates for their use.

4.4 Cement related protection for the reinforcement

The reinforcements exposed by the concrete removal works should be protected against corrosion through the application of a protecting cement mixture. For this function, it shall not be accepted the use of products which are not based on cement.

Product to be applied must have been formulated in order to assure the protection of the steel bars of the reinforcement, forming an effective barrier against the entrance of corrosive substances such as chlorides, carbon or sulphur dioxide, water and salts dissolved in water, with excellent adherence to the base and maximum durability.

The constitution of the product should contain inhibitors that not only protect the steel bars of the reinforcement against corrosion, but also the adjacent steel surfaces which are not directly treated.

Product to be used must be alkaline, not toxic, free of calcium nitrite, phosphates and solvents, not flammable and safe to use, without affecting the concrete physical properties (air introduction, setting time, strength or lowering).

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

The conditions and the maximum time of the protector storage in the site yard, as well as its transportation, should comply with the conditions stipulated by the Supplier so that its quality is not affected.

The product intended to use should be submitted, for approval, together with all the indications about the technical characteristics, as well as about the application mode and the product limitations, which should be supplied together with the certificate of origin, manufacture specification, composition, certificate of warranty and storing conditions.

5 Adjuvants and additions

5.1 Adjuvants

The adjuvants to be incorporated in the concrete and mortars should strictly comply with the established in the Project and in the regulations in effect, especially EN 206-1:2000 (Concrete - Part 1: Specification, performance, production and conformity) and, in the Portuguese case, the Specifications LNEC E 374:1993 (Adjuvants for mortars and concrete. Characteristics and conformity checking) and LNEC E 378:1996 (Concrete. Guideline for the use of hydraulic binders), and others that might be applicable.

It shall not be permitted, under any circumstance, the incorporation of adjuvants in supplied already pre-dosed mortars.

Adjuvants to incorporate in concrete and mortars should not contain harmful constituents in such quantities that may affect the concrete durability or cause the reinforcements corrosion.

It should be submitted for approval, the use of the adjuvants and the percentages it intends to adopt in the formulation of the different kinds of concrete, as well all the indications and clarifications about the tests ran to determine the identification characteristics (homogeneity, colour, effective component, volume mass, conventional solids content and pH value), of compatibility (setting time) and behaviour (chlorides contents, alkalis contents, air contents in fresh concrete, compression strength and warranty of not favouring corrosion in the reinforcements), as well as about the product's application mode, which should be supplied together with certificate of origin, manufacture specification, composition, warranty certificate, storing conditions and sensibility of the concrete to the adjuvant's dosage.

The use of a specific adjuvant should comply, besides the previously referred elements, the required tests run to check the characteristics of the adjuvants used, its compatibility with any other concrete components or if the adjuvants used produce the desired effect on the concrete.

The conditions and the maximum storage time of the adjuvants at the site yard, as well as its transportation should comply with the conditions stipulated by the Supplier, so that its quality is not affected by physical or chemical actions. If absent, tests giving evidence of the maintenance of the specified and proven characteristics for the adjuvants should be made. They should be clearly identified and stored in order to exclude any possibility of error.

At the time of using the adjuvants, the container should be very well mixed and stirred in order to prevent any deposit of its solid residue. Also, whenever there is more than one type of adjuvant, it should be guaranteed a safety system, so that no changes can happen at the dosing device inlet.

The total quantity of adjuvants in the composition should not exceed 50 g/kg of cement and it is not convenient that is it should be less than 2 g/kg of cement. Only smaller quantities of adjuvants shall be permitted if the latter are spread out in parts of kneading water.

The quantity of liquid adjuvants should be considered in the calculation of the A/C relation whenever it exceeds 3 litres/m³ of concrete.

Under no circumstance the use of adjuvants that contain chlorides and/or aluminium powder shall be admitted.

Adjuvants for the concrete setting acceleration through the increase of temperature should be liquid, added to the kneading water.

Adjuvants in powder for mass waterproofing should be added to dry cement and very well mixed with it before the addition of the aggregates and the water. On the contrary, liquid adjuvants should be added to the kneading water and be very well stirred.

Adjuvants to increase concrete workability should not be of the type that increases the total quantity of air in the masses beyond 1 %.

Setting adjuvants should be object of preliminary experiences that determine, in fact, its real effect in concrete.

5.2 Additions

5.2.1 Pozzolans for concrete

Pozzolans to be used in concrete as an addition should strictly comply with the established in the Project and with the prescribed in the regulations in effect, especially (Portuguese case) the NP 4220 (Pozzolans for Concrete. Definitions, Specifications and Verification of Conformity).

5.2.2 Fly ash

Fly ashes to be used in concrete as an addition should strictly comply with the established in the Project and with the prescribed in the regulations in effect, especially the EN 450:2005 (Fly ash for concrete - Part 1: Definition, specifications and conformity criteria).

5.2.3 Granular slag

Granular slag to be used in concrete as an addition should strictly comply with the established in the Project and with the prescribed in the regulations in effect, especially (Portuguese case) the LNEC E 375:1993 (Ground Granular slag of Blast Furnace for Concretes. Characteristics and Verification of Conformity).

5.2.4 Limestone filler

Limestone filler to be used in concrete as an addition should strictly comply with the established in the Project and with the prescribed in the regulations in effect, especially (Portuguese case) the LNEC E 376:1993 (Limestone Filler for Concretes. Characteristics and Verification of Conformity).

5.2.5 Silica fume

Silica fume to be used in concrete as an addition should strictly comply with the established in the Project and with the prescribed in the regulations in effect, especially (Portuguese case) the LNEC E 377:1993 Specification (Silica fume for concrete. Characteristics and conformity checking).

The silica fume to be incorporated in the composition of the concrete to be used, either conventionally applied or projected, has the purpose of reducing permeability and open porosity of the mass and also to inhibit the penetration and diffusion of chlorides ions.

The product intended to use, as well as the percentages to adopt in the formulation of the different kinds of concrete, as well all the indications and clarifications proposal about the tests ran to determine the physical and chemical characteristics, as well as the product application mode, should be supplied together with the certificate of origin, manufacture specification, composition, warranty certificate, storing conditions and sensibility of the concrete to silica fume dosage.

It may be done tests to check the proposed silica fume characteristics, if it is compatible with the concrete or if it in fact produces the desired effect in the concrete.

The conditions and the maximum storage time of silica fume at the site yard, as well as its transportation should comply with the established by the Supplier, so that its quality is not affected. Silica fume should be clearly identified and stored in order to exclude any possibility of mistake and confusion when it is used.

5.2.6 Corrosion inhibitor to be mixed

Surfaces that have been object of rehabilitation through concrete removal and replacement (or mortars), should be protected also by means of the addition of a migratory corrosion inhibitor, in powder.

This inhibitor, when added to fresh concrete (or mortar) for the replacement that wraps up the reinforcement exposed in the meantime, always in accordance with the Suppliers' indications, should be spread out and form a corrosion inhibiting protection layer on the reinforcement bars surface.

In the cases where the reinforcements are not exposed, but there was only the replacement of the material of the coating layer, the inhibitor should be able to migrate through the existing concrete porosity, assuring an effective protection to the steel bars inserted in it.

The inhibitor should not be toxic, should be free of nitrites, phosphates or solvents, not flammable, safe to use and should penetrate in depth, protecting the anodic and cathodic areas of the steel, always allowing the concrete to "breathe" and not being a barrier to the diffusion of the water steam, nor affecting the setting time of the replacement material strength.

The addition of the inhibitor to the mixture should be carefully carried out taking, in consideration the Supplier's indications.

The conditions and the maximum time of storage of the inhibitor at the site yard, as well as its transportation, should comply with the conditions established by the Supplier so that its quality is not affected by physical or chemical actions.

The use of the inhibitor should be proposed with all the indications about the technical characteristics, as well as about the application mode and the product limitations, which should be supplied accompanied of certificate of origin, manufacture specification, composition, warranty certificate and storing conditions.

5.2.7 Migratory corrosion inhibitor

All exposed surfaces of the works, whether they have been repaired or not, should be protected through the application on the surface of a migratory corrosion inhibitor.

The inhibitor to be applied should have been designed to migrate through the concrete or mortar porosity until it reaches the reinforcement bars, assuring its protection against corrosion.

The inhibitor to be applied should not be toxic, should be free of nitrites, phosphates or solvents, not flammable, safe to use and should penetrate in depth, protecting the anodic and cathodic areas of the steel, always allowing the concrete to "breathe" and not being a barrier to the diffusion of the water steam, and being effective even in environments already contaminated by chlorides.

The conditions and the maximum time of storage of the inhibitor at the site yard, as well as its transportation should comply with the conditions established by the Supplier so that its quality is not affected.

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

The use of the inhibitor should be proposed with all the indications about the technical characteristics, as well as about the application mode and the product limitations, which should be supplied accompanied of certificate of origin, manufacture specification, composition, warranty certificate and storing conditions.

6 Metallic materials

6.1 Steel for reinforcement

The reinforcements shall consist of the sections specified in the Project and must comply with the (EN 1992-1-1:2004 Design of concrete structures. General rules and rules for buildings). The steel to be used for both reinforcements and frames to be added, by overlapping splice, to the rods already present in the reinforced concrete elements to repair, should be (Portuguese case) A500 NR, in round and ribbed rod, classified according to EN 10020:2000 (Definition and classification of grades of steel).

The frames must have markings to allow their easy identification on site. Specifically, and in the Portuguese case, for the A500 NR steel rods, their characteristics and markings must meet the requirements of LNEC Specification E 450:1998 (NR A500 steel rods for reinforced concrete frames. Characteristics, Tests and Markings).

The steel must be a standard type, fine-grained, not brittle and have a homogeneous texture, while the rods must be free of corrosion pits, zinc coating, painting, asphalt, lamination scales, clay, oil, grease, soil, loose rust and any other material that may damage it.

Tensile and bending strength tests shall be conducted on long proportional samples, in accordance with standards, including EN 10002-5:1992 (Metal materials. Tensile test. Part 5: High-temperature testing method) and (Portuguese case) NP 173:1996 (Metal materials. Bending test).

The steel should have a good bending strength, i.e. the samples must not show any cracks after the bending tests carried out according to NP Standard 173 (Portuguese case), with at least 95 % probability.

Except in exceptional cases, duly justified or in the cases shown on the project drawings, welding repairs shall not be permitted.

The rods should be transported and stored made in such a way to avoid, between their receipt and placement on site, dents or nicks, section losses due to corrosion, deposition on the surface of substances that may chemically damage the steel or concrete, or negatively affect adhesion and the possibility of identification.

For storage, the rods must be properly stacked on supports and off the ground, in order to prevent their initial deformation.

6.2 Stainless steel

It is recommended that the choice of stainless steel reinforcements should be as follows.

Environment Class	Aggressiveness	Recommended Reinforcing Steel
Passive		High yield reinforcement steel
Moderate		High yield reinforcement steel / 1.4301
Aggressive	- Low - Medium - High	1.4301 1.4401 1.4460 (Duplex)
Extra aggressive		Super austenitic Super duplex

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

The definition of an aggressive environment is:

Environment	Example	Effect
Low	Inland - industrial area	Carbonation
Medium	Marine and coastal areas (road salt)	Chloride penetration
High	Extreme temperature differences. Extreme chloride concentrations. Extreme environment conditions.	Carbonation, Chloride penetration, other.

6.3 Steel plates and profiles

6.3.1 Rolled steel

The rolled steel to be used in the various metal parts of the site, unless otherwise explicitly specified, shall be of the S235 JR type, complying with all specifications and requirements set out in Eurocode 3 - Design of Steel Structures, and EN 10025 A1 and its amendment A1 of 1993, and the tests to be carried out must be those stated in that document.

6.3.2 Stainless steel plates

The stainless steel plates that may eventually be required shall have a breaking strength of at least 588 N/ mm², must comply with A.S.T.M. Standard 276 in everything that applies to them, and their surface in contact with the parts they will have to slide along shall receive the Class C treatment under that Standard. Their supply shall be accompanied by certificates stating that their quality complies with the provisions of these Technical Conditions.

7 Electrochemical systems

7.1 Cathodic protection systems

7.1.1 Anodes

Two types of anodes shall be used:

- Internal anode of activated mixed metal oxide coated Titanium - beams, struts and piers.
- Lida®Ribbon Type I, or equivalent, anode strips - deck slab, boarding front and stairs.

The anodes must have a useful life of at least 40 years.

7.1.2 Reference electrodes

Silver/Silver Chloride (Ag/AgCl) or Manganese/Manganese Dioxide (Mn/MnO₂) electrodes must be used.

7.1.3 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.

7.1.4 Transformer/rectifier

The function of this unit is to provide low intensity direct current from alternating current, and enable measuring the potential at each monitoring point.

The unit must be powered by single-phase 230 V - 50 Hz and composed of at least:

- Main switch;
- Voltmeter with high impedance $\geq 10 \text{ M}\Omega$ to measure the monitoring points, selectable using a selector and with a switch;
- Individual switch for each output, to measure the Instantaneous Off potential;
- On indicator;
- Residual ripple outputs of up to 100 mV RMS; continuously variable output voltage up to the maximum voltage; continuously adjustable current limit, up to the rated current;
- Number of outputs equal to the number of areas;
- Voltmeter and ammeter to measure the voltage and current of each output.

The unit must be manufactured in accordance with Item 6.9 of Standard EN 12696:2000.

The cabinet must be suitable for outdoor installation and have a degree of protection of at least IP 65. The material must be suitable for marine environments, preferably AISI 316 stainless steel with anticorrosion paint, polycarbonate (PC) or fibre-reinforced polyester.

7.1.5 Electric cables

The sizing and specification of the cables shall be the responsibility of the supplier of the PC system. The cables must be:

- Multi-strand (at least 7 wires) copper conductors;
- Must be marked with specific identifiers.

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

Only couplings in cables shall be permitted, after the coupling method has been approved.

7.1.6 Cables between anode connections and power cable

Direct current cables:

- Anode connection cable - at least 4 mm² XLPE/PVC or equivalent;
- Cathode connection cable - at least 4 mm² XLPE/PVC or equivalent;
- Power cables - at least 16 mm² XLPE/PVC or PVC/PVC, if in conduit.

Monitoring cables:

- Frame connection cable – at least 4 mm² XLPE/PVC or equivalent.

7.1.7 Cables between anode the junction box and T/R

These must be PVC/PVC multi-core cables.

7.2 Galvanic anodes

The galvanic anodes used may be of zinc or magnesium. The most commonly used are the magnesium anodes.

8. Painting and coating

8.1 Outdoor concrete surfaces

It is recommended that the protection coating for outdoor concrete surfaces (outdoor surfaces) that are not in contact with water (even in the form of spray), should be composed by an acrylic paint. Paint to be applied should have good air drying characteristics and exceptional adherence to the substrate.

The protecting coating to be applied shall have the purpose of granting high protection to the elements of reinforced concrete, namely against carbonation, water and chlorides penetration. Thus, it should form a waterproof film and have low resistance to the diffusion of water steam, high resistance to the diffusion of CO₂ and very low coefficient of chlorides ions diffusion.

The painting should have the following physical characteristics:

a) Colour

The final colour and respective colour shade shall be chosen among several samples submitted previously.

b) Volume mass

The volume mass should comply with the tolerance of $\pm 3 \%$ in relation to the value specified by the Supplier. The determination of the volume mass should be done in accordance with standard EN ISO 2811-2:2001 (Paints and varnishes. Determination of density. Part 2: Immersed body (plummet) method.

c) Viscosity

Viscosity should comply with the tolerance of $\pm 5\%$ in relation to the value specified by the Supplier.

d) Dry film aspect

The paint should give origin to a continuous dry film without pores, uniform and matt, without any shade irregularity in the colour, totally covering the support, allowing a good plugging of the concrete superficial porosity, with a smooth finishing and the colour and shine wanted.

e) Drying time

Drying times between coats should comply with the technical data sheet indications for the product.

The paint should also have the following properties:

- a) Repel dirt;
- b) Free of organic solvents;
- c) Good impregnation capacity;
- d) Resistant to UV rays;
- e) Resistant to acids and bases;
- f) Non-pollutant, odourless and non toxic;
- g) Assure the concrete protection against erosion and degradation;

- h) High adherence in relation to the base, requiring a minimum tension of 1.5 MPa in the dry film adherence.

The paint behaviour and durability characteristics should be determined in several types of test specimens in accordance with the specified in these Technical Conditions and in EN 1504-2 (Products and systems for the protection and repair of concrete structures – Definitions, requirements, quality control and conformity assessment. Part 2: Surface protection systems).

Aspects to comply with, in that sense, are:

- a) Dry thickness

It is recommended that the dry thickness of the paint should be, at least, 200 μm , a tolerance of -5% to +25% being admitted in relation to the rated thickness value adopted for the works. Value adopted, which may vary with the type of selected product, should never be inferior to the one indicated in these Technical Conditions.

The measurement of the dry film thickness should be done in accordance with standard EN ISO 2808-2000 (Paints and varnishes. Determination of the film thickness) – Method 3B or 5B (Benchmarking method or microscopic method after the wedge cut of the film).

- b) Adherence by grid

Painting scheme should show good adherence to the application base and in between coats. The adherence should be the one required by classes 0 to 1, in accordance with standard EN ISO 2409-1995 (Paints and varnishes. Adherence by grid method), using a cutting plunger with 3 mm spaced blades.

- c) Resistance of alkalis of hydraulic binders

The coating with paint should show good resistance of the alkalis of the hydraulic binder, without showing significant alterations in the film after 48 hours immersion, when tested in accordance (Portuguese case) with Specification LNEC E 319:1978 (Paints and varnishes. Alkalis resistance to hydraulic binders).

- d) Resistance to abrasion by falling sand

The coating with paint with the recommended thickness of 200 μm should not allow the appearance of the application base after the fall of 50 litres of sand, when tested in accordance with standard ASTM D 968-93-2001 (Standard test methods for abrasion resistance of organic coatings by falling abrasive).

- e) Permeability to water steam

The permeability to water steam is defined in accordance with the equivalent permeation air layer thickness (s_{D,H_2O}). Thus, $s_{D,H_2O} \leq 5 \text{ m}$ is required for the established dry thickness ($\geq 200 \mu\text{m}$). This characteristic control shall be done in accordance with standard EN ISO 7783-1:2001 (Paints and varnishes. Determination of the water steam transmission speed. Part 1: Capsule method for free films).

- f) Permeability to water

The permeability (w) to the painting water should be inferior to 0,1 $\text{kg}/(\text{m}^2 \times \text{hour}^{0.5})$, in accordance with standard EN 1062-3:2001 (Paints and varnishes. Painting products and painting schemes to apply in external masonry and

concrete. Part 3: Determination and classification of liquid water transmission speed (permeability) and EN 1504-2.

g) Permeability to CO₂

Permeability to CO₂ is defined according to the equivalent permeation air layer thickness (s_{D,CO_2}). Thus, $s_{D,CO_2} > 50$ m is required for the established dry thickness (≤ 200 μ m) and respective control should be done in accordance to standard EN 1062-6:2002 (Paints and varnishes. Coating materials and coating systems for exterior masonry and concrete. Part 6: Determination of carbon dioxide permeability).

h) Permeability to chloride ions

According to the established by EN 1504-2, in coatings which water permeability coefficient (w) is inferior to 0.1 kg/ (m² × hour^{0.5}) it is not foreseen that the diffusion of chloride ions might occur; therefore, the control of this property shall be done by the assurance of the compliance with the established in paragraph q) above.

i) Resiliency (Capacity to accommodate cracks of the substrate)

The paint should be exceptionally resilient in order to follow in an adequate way the supporting movements and act as protecting bridge for the cracks that might exist, even when they are opening.

For that purpose, the resiliency of the paint should consider the established requirements for the following classes:

Static testing A5 (10 °C)

Dynamic test B4.2 (10 °C)

Tests to give evidence of resiliency should comply with the established in standard EN 1062-7:2002 (Paints and varnishes. Coating materials and coating systems for exterior masonry and concrete. Part 7: Determination of crack bridging).

j) Resistance to ageing

The coating with paint should show an excellent resistance to ageing, so that its characteristics are kept in a minimum period of 10 years.

Evidence shall be given of resistance to aging by test results after 2000 hours of artificial accelerated aging (xenon) in accordance with standard EN ISO 11341:2000 (Paints and varnishes. Accelerated aging and exposure to artificial radiation. Exposure to filtered xenon arch radiation) or other equivalent standard, complemented with the information about the works where it was applied. It is desired that the following conditions should take place:

- Aspect alterations: without tendency to turn to powder and admitting a slight colour alteration;
- Permeability to CO₂ and to chloride ions: There should not be any reduction to the equivalent penetration air layer thickness, or to the chlorides migration coefficient, in relation to the values determined with the non-aged coating.
- Colour. The measurement of colour differences to determine the ΔE should be done in accordance with ISO 7724-3:1984 (Paints and varnishes. Colorimetry. Part 3: Calculation of colour differences).

The paint performance should also be directly checked after its application on the concrete for the quantitative evaluation of its effect concrete resistance to carbonation, Coefficient K that relates the carbonation depth (x) in mm with time (t) in years ($x=Kt^{1/2}$), should be inferior to $K \leq 2,7 \text{ mm/year}^{1/2}$, for the concrete with the specified painting. To assess this performance, K value measured in the accelerated carbonation test in chamber with 5 % of CO_2 in test specimens lined with paint should be inferior to $K' \leq 20 \text{ mm/year}^{1/2}$, that is, at the end of 1 month the carbonation depth, in that test, should not exceed 5.7 mm.

Paint containers should be stored in dry, cool and ventilated places in order to be adequately protected against negative temperatures and against the aggression of heat sources and ignition.

Should be proposed the coating intended to use, accompanying not only with the certificate of origin, composition, storage conditions, warranty certificate and consider all characteristics required in this chapter, but also of the paint schemes that the Supplier advises.

Complementary tests could be carried out to verify the characteristics of the paint.

8.2 Surfaces in splash zone

It is recommended that the surfaces in the concrete splash zones should be protected with an epoxy coating, compatible with the application in humid base. The coating should be an epoxy base paste, without dribbling, enabling the application in vertical surfaces, under the water level (flotation) and in the presence of the waves action.

The protecting coating to be applied should grant high protection to the reinforced concrete elements, namely against concentrated alkalis, non oxidant acids, grease and oils, and resist to the waves action during and after its curing process.

The coating should have the following characteristics:

- Be free of solvents;
- Thick consistency and quick curing;
- Resistant to UV rays;
- Resistant to acids and bases;
- Non-polluting, odourless and non toxic;
- Assure the concrete protection against erosion and degradation;
- Highly effective, especially in humid surfaces;
- High resistance to traction.

It is also recommended to guarantee the following technical characteristics:

- a) Density $\approx 1,8 \text{ g/cm}^3$
- b) Pot-life (20°C) ≈ 45 minutes
- c) Tests to flexion $> 40 \text{ MPa}$
- d) Tests to compression $> 80 \text{ MPa}$
- e) Adherence (concrete rupture) $> 2.5 \text{ MPa}$

All the above referred characteristics should be checked in accordance with the same above established systems for acrylic base coatings.

Should be proposed the coating intended to use, accompanying not only with the certificate of origin, composition, storage conditions, warranty certificate and consider all characteristics required in this chapter, but also of the paint schemes that the Supplier advises.

The product should be supplied in closed packages, which should be stored, grouped and very well identified, in a protected, aerated place with room temperature between 15 °C and 30 °C and far from smoke or fire emitting systems.

Handling of products should only be done by specialized personnel. The information and recommendations given by the Supplier for its handling should be complied with.

The packages should only be opened at the time of the product application and should only be prepared the quantity that one is able to place during the workability time of the specified product.

The product to be used should be properly labelled in accordance with the legislation in affect and should be accompanied of the technical data sheet, in which the handling and application conditions should be highlighted the particular precautions to be taken during its storage, preparation and application should be indicated.

All products contained in open packages or with signs of having been violated should be rejected. The rejected products should be identified and removed from the site yard.

The Supplier should submit documentation giving evidence of the product characteristics and the quality certificate, the Inspection having the right to request the realization of tests, in Laboratory, as the required condition for the products acceptance.

If should seem convenient, complementary tests could be carried out, to give evidence of the coating's characteristics.

8.3 Film forming products for the curing

Concrete and mortars curing can be done by means of the application of film forming products which main property is to delay the loss of water during the setting and stiffening of the concrete, reducing, at the same time, the temperature increase due to the exposure to sunlight, by forming a film.

Film forming (filmogenic) products for the concrete and mortars curing are composed by an aqueous emulsion of resin or paraffin that break when in contact with an alkaline means and by a finely divided pigment, normally clear (in order to absorb not solar radiation), already mixed, for immediate application without alteration.

Film forming products for the curing should have such consistency as to be easily applied through spraying or roll in a uniform layer, at a temperature higher than 4 °C.

The film forming product should be resistant to wear and tear and have special durability, adhesion and quick setting characteristics, in such a way as it should not be removable by the action of water and it should be able to maintain its curing capacities when subject to aggressive environmental conditions, what is natural in the splash areas.

The pigmented film forming product should not, in any circumstance, react with the concrete, especially with water and calcium ions.

Film forming products for the curing should take in consideration the following conditions:

- a) The application rate of the product should be from 0.1 to 0.2 kg/m²;
- b) The volatile fraction of the product must be non-toxic and not easily flammable;

- c) When tested according to standard ASTM E 1347-03 (Standard test method for colour and colour-difference by tristimulus (Filter) colourimetry) they should have a minimum reflecting power of 60 % of the natural light, in relation to magnesium dioxide

The curing product should adhere to fresh concrete in such a way as not to deteriorate during its application; it should form a continuous film when applied in the specified dosage. Once dry, the formed film should be flexible, without visible ruptures or cracks and should remain intact at least seven days after its application, and then after three or four weeks it should be easily disintegrated due to the manual brushing, so that it does not create any difficulties to the adherence of future coating to the cured concrete or mortars.

The control to be exercised over film forming products for the curing should fall on its effectiveness checking, which is usually done through the measurement of the loss of weight of witness specimens, to which the product is applied in all faces, comparing to the loss of witness specimens without any protection. This test, carried out according to ASTM C 156-03 (Standard test method for water retention by concrete curing materials) should indicate a water loss inferior to 0.055 g/cm^2 , at 72 hours. It could be done, if it deems convenient, comparative tests of rupture tension related to flexion and compression of protected and non-protected specimens.

Film forming products for the curing are usually supplied in its liquid form, in cans or metal containers and should be stored in cool and dry places, sheltered from humidity and extremely cold temperatures, in its original package, closed and not deteriorated, for periods not exceeding those specified by the Supplier.

8.4 Painting of metals elements

It is recommended that the paints for metal elements should be based on polyurethane resins of two components for the finishing work, with high chemical and mechanical resistance.

The device, the primer, the finishing paint, diluents and complementary products, all from the same origin, should form an adequate set, in accordance with the compatibility specifications of respective manufacturer.

The brand of paints intended to use should be presented with, not only, the quality and the tests certificates, but also the adequate painting schemes that the manufacturer advises.

The colour of the paints shall be chosen based on samples of the previously indicated colours, for ulterior choice, samples that should be composed by painting in metal plate and with at least, $0.30 \times 0.20 \text{ m}$.

Complementary tests could be carried out to give evidence of the paint qualities, especially regarding aging.

9. Specific materials for underwater repair

9.1 Protective lining of frequently submerged surfaces

The protective lining for frequently submerged surfaces must consist of an encapsulation system. The materials constituting this system are:

- a) Fibre-reinforced polymer (FRP) liner;
- b) Epoxy grout;
- c) Marine epoxy paste;
- d) Adhesive marine epoxy paste.

The handling and storage of the encapsulation materials must comply fully with the Supplier's recommendations.

The liners must be transported in closed containers or covered with canvas to prevent contamination by dust or asphalt particles. They must be stored on site in order to minimize distortion and prevent contamination by traffic and airborne material. If on-site storage exceeds 30 days, a shady place must be provided to store the liners.

The silicon dioxide powder, a component of the epoxy grout, must be duly packaged and labelled, stating the origin and batch number of the Supplier. Storage must ensure that the powder remains dry until it is used.

All the liquid epoxy components on site must be kept in closed and hermetically sealed containers, stating:

- a) Name of the Supplier;
- b) Name of the product and list of components;
- c) Batch number of the Supplier and expiry date;
- d) ANSI (American National Standards Institute) classification for hazardous materials and handling precautions.

The liquid epoxy components must be stored in shady and well-ventilated areas. Once received on site, the storage temperature for the liquid components must never exceed 49 °C, nor be less than 4 °C.

The containers holding the liquid epoxy components must be closed and hermetically sealed from the time of their receipt on site until they are used in the batching and mixing process. If the containers are opened for sampling or any other purpose and they remain partially full, they must be tightly closed to prevent contamination by moisture or other airborne substances. Once the seal on the containers is broken, their content should be used within 7 days, otherwise it must be rejected and removed from the site yard.

The products must be handled only by properly qualified personnel, complying with the Supplier's instructions and recommendations.

9.2 Fiber reinforced polymer (FRP) liner

The fibre-reinforced polymer liners must be a marine laminate, made of glass mesh and fabric impregnated with a transparent polyester resin, stable to ultraviolet radiation.

The liners must be translucent to allow observing and monitoring the progress of grout injection from the outside.

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

The use of liners made by simultaneous spraying is not permitted.

The amount of glass should be sufficient to meet the strength requirements specified in these Technical Conditions and must not be less than 30 % of the strength of the laminate.

The polyester resin matrix must contain a fully bonded ingredient that makes the laminate stable to ultraviolet radiation.

The strength and thickness of the liner must be sufficient to provide adequate strength and rigidity to withstand the forces and strains to which the liner may be subjected during the handling, installation and injection of the epoxy grout. However, the liner must not have a thickness of less than 3 mm.

The liner must be equipped with 2.5 cm diameter injection holes, spaced at intervals not exceeding 1.5 metres along its entire length. The injection holes must be placed alternately on the opposite sides of the liner to allow a better distribution of the epoxy grout. The injection holes must also be polymers and fixed to the wall of the liner before installing it, except in special situations previously approved, when the addition of the hole is required to deal with the occurrence of an unforeseen situation on site.

The liner must have a sufficient number of polymer separators fixed to the inner surface to keep a minimum space of 9.5 mm between the concrete surface and the liner.

The material of the liner, with the exception of the precast polymer separators and injection holes, must have at least the following physical properties, unless otherwise specified:

- a) Maximum tensile strength, ASTM D 638 (Standard test method for tensile properties of plastics) - 103.5 MPa
- b) Impact resistance, ASTM D 256-04 (Standard test methods for determining the izod pendulum impact resistance of plastics) - 1066 J/m
- c) Hardness, ASTM D 2583-95 (Standard test method for indentation hardness of rigid plastics by means of a barcol impressor) - 35
- d) Water absorption, ASTM D 570-98 (Standard test method for water absorption of plastics) - 1 % (maximum)
- e) Stability to ultraviolet radiation. Determination of stability to ultraviolet radiation through accelerated weathering tests. The liner samples subjected to 500 hours of exposure in a weathering meter with a dual carbon electrode (ASTM G 23 Method (Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials), Type D), at an operating temperature of 63 °C, do not show any delamination or detachment. These tests shall be conducted in 20-minute cycles, with 17 minutes of exposure to arc light and 3 minutes to water dew throughout the whole 500 hour period of the test.

The liner must have been made in sections. Each section shall contain no more than two longitudinal joints. The liner sections must be placed on top of each other, connected by transverse joints. All the joints of the liner must meet the following minimum requirements:

- a) All joints must have sufficient strength to prevent their opening or detachment when subjected to installation strains, sea forces and epoxy grout injection pressures;
- b) The detail of the longitudinal joint must have an overlapping structure and allow for small on-site adjustments to the concrete surface. The design of all joints must ensure that an 8 mm ring is kept between the liner and the concrete surface.
- c) The transverse joints (if any) must have an overlapping structure.

- d) The lower end of each liner must have a moulded cavity to receive and adequately contain the seal of the next liner.

The liners must be provided with the following accessories:

- a) Cast polymer injection accessories;
- b) Stainless steel tips to ensure sealing of the liners;
- c) Precast polymer separators to keep the minimum thickness;
- d) Adjustable polymer separators for special applications;
- e) Compressible seals for the bottom of the liners.

All materials must be kept closed in their original containers. Appropriate safety equipment must be used to handle the liners and products, including gloves, goggles and face mask. When handling the liners, special care must be taken with protruding wires, which can cause skin damage.

All the materials intended to use should be presented with the certificates of origin, compositions, storage conditions, certificates of guarantee and of compliance with all the characteristics required in this chapter.

9.3 Epoxy grout

The epoxy grout must be a solvent-free, marine adhesive product, consisting of three components: an epoxy resin (component A - liquid), a hardener (component B - liquid) and a material with silicon dioxide powder (component C).

The components of the grout must be properly mixed, proportionally with the content of the containers and in accordance with the Supplier's instructions.

The mixed epoxy grout shall have the following properties in the plastic state:

- a) The viscosity of the resin and adhesive agent should be such that they can be pumped without segregation, and also injected into the space between the liner and the concrete surface. The viscosity should be such that the mixed grout completely fills the space between the liner and the concrete surface, without leaving any gaps, and that it self-levels reasonably well when placed inside the liner;
- b) The pot life of the mixed grout must be adequate for it to be properly placed without leaving any gaps and provide enough time for a reasonable self-levelling inside the liner. However, it must never exceed 65 minutes after mixing at a controlled temperature of 25 °C;
- c) After the epoxy grout has been cured under water or not, it must have at least the following properties in the hardened state, unless otherwise specified:
 - Compressive strength at 7 days: 48 MPa (ASTM C 579 - Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes)
 - Tensile strength at 7 days: 7MPa (ASTM C 307 (Standard Test Method for Tensile Strength of Chemical-Resistant Mortar, Grouts, and Monolithic Surfacing))
 - Bond/shear strength at 7 days: 1MPa (ASTM C 882 (Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear))
 - Linear shrinkage at 7 days: 0.07 % (maximum) (ASTM C 531 (Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes))

QUALITY CONTROL REQUIREMENTS FOR REPAIR SYSTEMS

- Water absorption at 7 days: 0.45 % (maximum) (ASTM C 413 (Standard Test Method for Absorption of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes))

The grout components must be supplied in their original, unbroken containers, bearing the printed name and address of the Supplier, the product's brand name, reference to its composition and purpose of use.

The grout containers must be stored, grouped according to their identification, in a well-ventilated, cool and dry place, protected from dampness and extreme cold, in their original closed and undamaged containers, at a temperature between 4 °C to 32 °C, for periods never exceeding those specified by the Supplier.

The containers can only be opened when the grout is to be applied.

The products must be handled in compliance with the instructions stated in their datasheets.

All the products supplied in open or tampered containers must be rejected. Rejected products must be identified and removed from the site yard.

All the materials intended to use should be presented with the certificates of origin, compositions, storage conditions, certificates of guarantee and of compliance with all the characteristics required in this chapter.

9.4 Adhesive marine epoxy paste

The adhesive must be a bi-component epoxy composite (resin and hardener), to be applied to surfaces above and below the water level.

The paste, to be used as an adhesive in the joints between liners, must ensure consistent and uniform adhesion.

After the adhesive epoxy paste has been cured under water or not, it must have at least the following properties in the hardened state, unless otherwise specified:

- Compressive strength at 7 days: 62 MPa (ASTM C 579 - Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes)
- Tensile strength at 7 days: 15.5 MPa (ASTM D 638 (Standard Test Method for Tensile Properties of Plastics))
- Bond/shear strength at 7 days: 20.5 MPa (ASTM C 882 (Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear))

The components of the paste must be properly mixed, proportionally with the content of the containers and in accordance with the Supplier's instructions.

The components of the paste must be supplied in their original, unbroken containers, bearing the printed name and address of the Supplier, the product's brand name, reference to its composition and purpose of use.

The containers of the paste must be stored, grouped according to their identification, in a well-ventilated, cool and dry place, protected from dampness and extreme cold, in their original closed and undamaged containers, at a temperature between 4 °C to 32 °C, for periods never exceeding those specified by the Supplier.

The containers can only be opened when the resins are to be applied.

The products and equipment must be handled only by properly qualified personnel. Contact of the product with skin should be avoided and the handling information and recommendations given by the Supplier observed.

All the products supplied in open or tampered containers must be rejected. Rejected products must be identified and removed from the site yard.

It should be provided documentary evidence of the product's properties and quality assurance certificate, and it could be requested the performance of laboratory tests as a necessary condition for the acceptance of the products.

9.5 Marine epoxy paste

The epoxy paste must be a non-dripping, bi-component composite (resin and hardener), to be applied to surfaces above and below the water level and subjected to wave action.

The marine epoxy paste, to be used to finish off the upper portions of the encapsulations and seal the sample collection areas, must ensure good adhesion to the concrete.

After the epoxy paste has been cured under water or not, it must have at least the following properties in the hardened state, unless otherwise specified:

- Compressive strength at 7 days: 55 MPa (ASTM C 579 - Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes)
- Tensile strength at 7 days: 25 MPa (ASTM D 638 - Standard Test Method for Tensile Properties of Plastics)
- Bond/shear strength at 7 days: 1MPa (ASTM C 882 - Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear)
- Bond/tensile strength at 7 days: 1MPa (ASTM D 4541 - Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers)
- Water absorption at 7 days: 0.5 % (maximum) (ASTM C 413 -Standard Test Method for Absorption of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes)

The components of the paste must be properly mixed, proportionally with the content of the containers and in accordance with the Supplier's instructions.

The components of the paste must be supplied in their original, unbroken containers, bearing the printed name and address of the Supplier, the product's brand name, reference to its composition and purpose of use.

The containers of the paste must be stored, grouped according to their identification, in a well ventilated, cool and dry place, protected from dampness and extreme cold, in their original closed and undamaged containers, at a temperature between 4 °C to 32 °C, for periods never exceeding those specified by the Supplier.

The containers can only be opened when the resins are to be applied.

The products and equipment must be handled only by properly qualified personnel. Contact of the product with skin should be avoided and the handling information and recommendations given by the Supplier observed.

All the products supplied in open or tampered containers must be rejected. Rejected products must be identified and removed from the site yard.

It should be provided documentary evidence of the product's properties and quality assurance certificate, and it could be requested the performance of laboratory tests as a necessary condition for the acceptance of the products.

10 Traditional Formwork

Woods to be used should be of the woody core of the trees, duly dry, not burned, without vicious knots, free of woodworms, cracks or flaws that might compromise their durability, resistance and the final aspect of the concrete pieces.

The woods should be first choice that is, selected so that even small defects (knots, cracks, etc.) do not occur often or assume large proportions, or come to appear in areas of the pieces that might bear significant stresses.

The woods should be of live gum kino and quite straightened, with straight and united fibres.

The boards to be used for the concrete pieces forms should be thicker than 2.5 cm, planed, lined with halving joints.

The wedges to be applied should be made of hard wood.

The wood to be used in formwork should be highly resilient and reasonably resistant, enabling good performance as to workability, bearing in mind the sawing and nail penetration and extraction. For that purpose, it should be light or moderately heavy, with apparent specific mass between 0.45 kN/m^3 and 0.70 kN/m^3 .

If wooden horses are used, the use of excessively low weight pieces should not be allowed and in no case the number of wooden growth rings may be less than three, being desirable that this number is equal or close to six.

11 Spacers

The spacers should have sufficient strength to resist to the predicted loads, before and during concreting, without deformations that compromise the cover specified for the reinforcements.

The spacers should preferably be of cement mortar and it may be used plastic spacers on structures subject to environmental exposure classes X0, XC1 and XC2.

The mortar used should generally be made of cement CEM I and CEMII/A, have a minimum compressive strength of 50 MPa, when constructed, maintained and tested according to EN 196-1:2006 or, in alternative, determined according to the methodologies in NP EN 12390-2:2003 and NP EN 12390-3:2003.

If for reasons of durability another type of cement is used in the structure, or concrete of strength classes above C40/50, the mortar must be made of this cement and, after 28 days, at least match the strength of concrete provided to apply.

The molds used should lead to the attainment of rough surfaces in the spacers, to improve the adhesion to concrete and hinder the entry of aggressive agents.

The spacers may have many geometric shapes.

The spacers must have the appropriate size to support the anticipated loads and meet the covers rating of 20 to 65 mm.

The spacers attached by a wire must be at least 20 mm in the direction of the supported reinforcement and 3/4 of the cover towards the perpendicular direction.

The plastic spacers on the market must indicate the cover intended to provide.

DURATINET PARTNERS

PORTUGAL

Laboratório Nacional de Engenharia Civil, I.P. (LNEC)
Estradas de Portugal, SA (EP)
REFER, E.P.
TEIXEIRA DUARTE – Engenharia e Construções, S.A.
Administração do Porto de Lisboa (APL)
Fundo para o Desenvolvimento das Ciências da
Construção (FUNDcic)

FRANCE

Institut français des sciences et technologies des
transports, de l'aménagement et des réseaux
(IFSTTAR)
Université de Bordeaux
Université de Nantes
Université de La Rochelle
Conseil General de la Charente-Maritime (CG-17)

IRELAND

Dublin University- Trinity College (TCD)
National Roads Authority (NRA)

SPAIN

Universidade de Vigo (UV)
Porto de Vigo
Xunta da Galiza

UNITED KINGDOM

Queen's University Belfast (QUB)

