BRITISH STANDARD

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1504-10:2003
Incorporating
Corrigendum No. 1

Products and systems for the protection and repair of concrete structures — Definitions — Requirements — Quality control and evaluation of conformity —

Part 10: Site application of products and systems and quality control of the works

The European Standard EN 1504-10:2003 has the status of a British Standard

ICS 01.040.91; 91.080.40

BSI
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National foreword

This British Standard is the official English language version of EN 1504-10:2003, including Corrigendum October 2005.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags [AC] ⟨AC⟩. Tags indicating changes to CEN text carry the number of the CEN corrigendum. For example, text altered by June 2006 corrigendum is indicated by [AC1] ⟨AC1⟩.

The UK participation in its preparation was entrusted by Technical Committee B/517, Concrete, to Subcommittee B/517/8, Protection and repair of concrete structures, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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Products and systems for the protection and repair of concrete structures - Definitions - Requirements - Quality control and evaluation of conformity - Part 10: Site application of products and systems and quality control of the works

Produits et systèmes pour la protection et la réparation de structures en béton - Définitions, prescriptions, maîtrise de la qualité et évaluation de la conformité - Partie 10: Application sur site des produits et systèmes et contrôle de la qualité des travaux

Produkte und Systeme für den Schutz und die Instandsetzung von Betontragwerken - Definitionen, Anforderungen, Qualitätsüberwachung und Beurteilung der Konformität - Teil 10: Anwendung von Produkten und Systemen auf der Baustelle, Qualitätsüberwachung der Ausführung

This European Standard was approved by CEN on 28 February 2003.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This document (EN 1504-10:2003) has been prepared by Technical Committee CEN/TC 104 "Concrete and related products", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

This document is part of the series of European standards EN 1504 "Products and systems for the protection and repair of concrete structures". The other parts of the standard are given in clause 2 – Normative references.

This European Standard shall be given the status of National Standard, either by the publication of an identical text or by endorsement.

This European standard specifies requirements for the execution of protection and repair of concrete structures.

It has been prepared by CEN/TC 104, Subcommittee 8 "Products and systems for the protection and repair of concrete structures", the secretariat of which is held by AFNOR.

Annex A is informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This standard is part of the EN 1504 series of European standards which define and specify products and systems for the protection and repair of concrete structures. This Standard defines and specifies site application of these products and systems and quality control of the works.

The execution of this work is an important and integral part of the complex process of protection and repair, and this Standard specifies how it shall be carried out. The Specifications in this Standard are part of the definition of the intended use for the relevant products and systems. The execution shall be in accordance with this series of standards, ENV 13670-1, EN 1990, ENV 1992-2-4, EN 206-1 and any other relevant EN and European Technical Approval.

The specification for products and systems for protection and repair of concrete structures are given in Parts 2 - 7 of this standard. They can only be satisfied if the rules given in part 9 of this standard and this part of the standard are followed.

This standard contains an Annex A which provides guidance and background information to the normative text. The contents of the Annex A are numbered in the same way as the normative text to facilitate reference, but prefixed with "A".

1 Scope

This part of EN 1504 gives requirements for substrate condition before and during application including structural stability, storage, the preparation and application of products and systems for the protection and repair of concrete structures including quality control, maintenance, health and safety, and the environment.

2 Normative references

This part of this European standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 206-1, *Concrete – Part 1: Specification, performance, production and conformity.*

EN 1008, *Mixing water for concrete – Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.*

EN 1504-1, *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 1: Definitions.*

prEN 1504-2:2000-03, *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 2: Surface protection systems.*

prEN 1504-3:2001-03, *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 3: Structural and non structural repair.*

prEN 1504-4:2000-04, *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 4: Structural bonding.*

prEN 1504-5:2002-01, *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 5: Concrete injection.*

prEN 1504-6:2001-12, *Products and systems for the protection and repair of concrete structures - Part 6: Grouting to anchor reinforcement or to fill external voids.*

prEN 1504-7[1)] , *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control, evaluation of conformity - Part 7: Reinforcement corrosion prevention.*

prEN 1504-8:2000-10, *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 8: Quality control and evaluation of conformity.*

ENV 1504-9, *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.*

EN 1542, *Products and systems for the protection and repair of concrete structures - Test methods - Measurement of bond strength by pull-off.*

EN 1766, *Products and Systems for the protection and repair of concrete structures – Test methods - Reference concretes for testing.*

prEN 1881:2003-06, *Products and systems for the protection and repair of concrete structures - Test methods - Pull-out test of rebar from concrete.*

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1) currently under preparation

EN 1990:2002, *Eurocode - Basis of structural design.*

[AC1] ENV 1992-2: 1996, *Eurocode 2: Design of concrete structures – Part 2: Concrete bridges.* [AC1]

ENV 1992-3:1998, *Eurocode 2: Design of concrete structures – Part 3: Concrete foundations.*

ENV 1992-4:2000, *Eurocode 2: Design of concrete structures – Part 4: Liquid retaining and containment structures.*

prEN 10080–1:1999-07, *Steel for reinforcement of concrete - Weldable reinforcing steel - Part 1: General requirements.*

EN 12190, *Products and systems for the protection and repair of concrete structures – Test Methods - Determination of compressive strength of repair mortar.*

EN 12350-1, *Testing fresh concrete - Part 1: Sampling.*

EN 12350-2, *Testing fresh concrete - Part 2: Slump test.*

EN 12350-3, *Testing fresh concrete - Part 3: Vebe test.*

EN 12350-4, *Testing fresh concrete - Part 4: Degree of compactability.*

EN 12350-5, *Testing fresh concrete - Part 5: Flow Table test.*

EN 12350-6, *Testing fresh concrete - Part 6: Density.*

EN 12350-7, *Testing fresh concrete - Part 7: Air Content - Pressure methods.*

EN 12390-1, *Testing hardened concrete - Part 1: Shape, dimension and other requirements for specimens and moulds.*

EN 12390-2, *Testing hardened concrete – Part 2: Making and curing specimens for strength tests.*

EN 12390-3, *Testing hardened concrete - Part 3: Compressive strength of test specimens.*

EN 12390-7, *Testing hardened concrete - Part 7: Density of hardened concrete.*

EN 12390-8, *Testing hardened concrete - Part 8: Depth of penetration of water under pressure.*

EN 12504-1, *Testing concrete in structures – Part 1: Cored specimens - Taking, examining and testing in compression.*

EN 12504-2, *Testing concrete in structures – Part 2: Non destructive testing - determination of rebound number.*

prEN 12504-4:1998-07, *Testing concrete in structures – Part 4: Determination of ultrasonic pulse velocity.*

EN 12696, *Cathodic protection of steel in concrete.*

EN 13395-1, *Products and systems for the protection and repair of concrete structures - Test methods - Determination of workability - Part 1: Test for flow thixotropic mortars.*

EN 13395-2, *Products and systems for the protection and repair of concrete structures - Test methods - Determination of workability - Part 2: Test for flow of grout or mortar.*

EN 13395-3, *Products and systems for the protection and repair of concrete structures - Test methods - Determination of workability - Part 3: Test for flow of repair concrete.*

EN 13395-4, *Products and systems for the protection and repair of concrete structures - Test methods - Determination of workability - Part 4: Application of repair mortar overhead.*

ENV 13670-1, *Execution of concrete structures - Part 1: Common.*

PrCEN/TS 14038-1:2000-09, *Electrochemical re-alkalisation of re-inforced concrete – Part 1: Re-alkalisation.*

prEN 14038-2[1)], *Electrochemical re-alkalisation and chloride extraction treatments for reinforced concrete – Part 2: Chloride extraction.*

prEN 14487-1:2002-06, *Sprayed concrete – Part 1: Definitions, specifications and conformity.*

prEN 14487-2:2003, *Sprayed concrete – Part 2: Execution of structures.*

prEN 14629:2003-03, *Products and systems for the protection and repair of concrete structures – Test methods - Determination of chloride content in hardened concrete.*

prEN 14630:2003-03, *Products and systems for the protection and repair of concrete structures – Test methods - Determination of carbonation depth in hardened concrete by the phenolphthalein method.*

EN 24624, *Paint and varnishes – Pull-off test (ISO 6424:1978).*

EN ISO 2409-6, *Method for tests for paints - Part 6: Cross Cut Test.*

EN ISO 2808, *Paint and varnishes – Determination of film thickness (ISO 2808:1997).*

EN ISO 3274, *Geometrical Product Specifications (GPS) - Surface texture: Profile method - Nominal characteristics of contact (stylus) instruments (ISO 3274:1996).*

EN ISO 4288:1997, *Geometrical Product Specifications (GPS) – Surface texture: Profile Method – Rules and procedures of the assessment of surface texture (ISO 4288:1996).*

EN ISO 4628-1:2003, *Paints and varnishes - Evaluation of degradation of coatings - Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 1: General introduction and designation system (ISO 4628-1:2003)*

EN ISO 4628-2:2003, *Paints and varnishes - Evaluation of degradation of coatings - Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 2: Assessment of degree of blistering (ISO 4628-2:2003).*

EN ISO 4628-3:2003, *Paints and varnishes - Evaluation of degradation of coatings - Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 3: Assessment of degree of rusting (ISO 4628-3:2003).*

EN ISO 4628-4:2003, *Paints and varnishes - Evaluation of degradation of coatings - Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 4: Assessment of degree of cracking (ISO 4628-4:2003).*

prEN ISO 4628-5:2003-04, *Paints and varnishes – methods of tests for paints, designation of intensity, quantity and size of common types of defects – Part 5: Designation of degree of flaking.*

EN ISO 4628-6, *Paints and varnishes - Evaluation of degradation of paint coatings - Designation of intensity, quantity and size of common types of defect - Part 6: Rating of degree of chalking by tape method (ISO 4628-6:1990).*

EN ISO 8501–1, *Preparation of steel substrates before application of paints or related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrate and of steel substrate after overall removal of previous coatings (ISO 8501-1:1988).*

EN ISO 8501-1, *Supplement to Part I, Preparation of steel substrates before application of paints or related products - Visual assessment of surface cleanliness – Informative Supplement to Part 1: Representative photographic examples of the change of appearance imparted to steel when blast-cleaned with different abrasives (ISO 8501-1:1988/Suppl:1994).*

ENV ISO 8502-1, *Preparation of steel substrates before application of paints or related products – Tests for the assessment of surface cleanliness – Part 1: Field test for soluble iron corrosion products (ISO/TR 8502-1:1991).*

EN ISO 8502-2, *Preparation of steel substrates before application of paints or related products – Tests for the assessment of surface cleanliness – Part 2: Laboratory determination of chloride on cleaned surfaces (ISO 8502-2:1992).*

EN ISO 8502-3, *Preparation of steel substrates before application of paints or related products – Tests for the assessment of surface cleanliness – Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method) (ISO 8502-3:1992).*

EN ISO 8502-4, *Preparation of steel substrates before application of paints or related products - Tests for the assessment of surface cleanliness – Part 4: Guidance on the estimation of the probability of condensation prior to paint application (ISO 8502-4:1993).*

ISO 4677-1, *Atmospheres for conditioning and testing - Determination of relative humidity - Part 1: Aspirated psychrometer method.*

ISO 4677-2, *Atmospheres for conditioning and testing - Determination of relative humidity - Part 2: Whirled psychrometer method.*

ISO 7031, *Concrete hardened - Determination of permeability.*

ISO 8047, *Concrete hardened - Determination of ultrasonic pulse velocity testing.*

3 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply in addition to those given in parts 1 and 9 of this standard some of which are included to assist users of this standard.

3.1
appropriate person
the freeholder and if different the person in legal occupation

3.2
bond
the adhesion of the applied product or system to the substrate

3.3
cement grout
mixture of cement, water and in some cases admixtures

3.4
cementitious repair products and systems
hydraulic or polymer hydraulic mortars, concretes and grouts

3.5
coating
treatment to produce a continuous layer on the surface of concrete. The thickness is typically 0.1 mm to 5.0 mm. Particular applications may require a thickness greater than 5.0 mm

3.6
dew point
temperature at which water vapour condenses

3.7
hydrophobic impregnation
treatment of concrete to produce a water repellent surface. The pores and capillaries are not filled, but only lined. The visual appearance remains nearly unaffected

3.8
hydraulic mortars and hydraulic concrete (CC)
mortars or concrete based on a hydraulic binder which is blended together with graded aggregates and may include admixtures and additions which, when mixed with mortar, set by hydrated reaction

3.9
impregnation
the treatment of concrete to reduce surface porosity and to strengthen the surface. The pores and capillaries are partly or totally filled. Usually the treatment results in a discontinuous thin film of 10 µm to 100 µm thickness on the concrete surface

3.10
mortars or concrete
hydraulic, polymer hydraulic and polymer mortar and concrete

3.11
polymer hydraulic cement mortars and concrete (PCC)
hydraulic mortars or concrete modified by the addition of a polymer

3.12
polymer mortars and polymer concretes (PC)
blended mixture of polymer binder and graded aggregate which set by polymerisation reaction

3.13
preformed hole
hole or slot formed or cut in concrete into which reinforcement or other fixing is to be anchored

3.14
quality plan
a programme to ensure that the activities of a process are undertaken to the intended design

3.15
removal
removing of contaminated, damaged and or sound parts of the substrate

3.16
roughness
the degree of irregularity of a surface

3.17
roughening
removal of the substrate by removing matter of the substrate to a maximum of 15 mm

3.18
smoothing coat
a coating applied to a surface to fill voids, cracks, and cavities or to level an uneven surface. The purpose is to prepare the surface for the application of protection systems

3.19
spray fog
air born debris resulting from the application of sprayed concrete or mortar which may form an unwanted coat on the substrate

3.20
sprayed mortar or concrete
mortar or concrete applied under pressure through a nozzle delivered through pipes

3.21
substrate
the surface on which a protection or repair material is to be applied

3.22
wet on wet
application of a cementitious mortar or concrete onto the surface of a similar material which has set but not hardened

4 Structural stability during preparation, protection and repair

Safety and stability before, during and after repair shall be maintained in accordance with Part 9 of this Standard.

Any period required for gain of strength of the repair products and systems shall be a part of the duration of the repair.

5 General requirements

Consideration shall be given to the chemical, electrochemical and physical condition of the substrate and any contaminants, the ability of the structure to accept loading, movement and vibration during protection and repair, ambient conditions, and the characteristics of the materials contained in the structure and those of the protection and repair products and systems.

The following requirements shall be met:

— The achievement of the required condition of the substrate regarding cleanliness, roughness, cracking, tensile and compressive strength, chloride or other contaminant and their penetration, depth of carbonation, moisture content, temperature and degree of corrosion of reinforcement.

— The achievement of the compatibility of the original concrete and reinforcement with the protection or repair products and systems and compatibility between any different products and systems, including avoiding the risk of creating conditions which may cause corrosion.

— The achievement of the specified properties of products and systems when applied and in their hardened condition regarding the fulfilment of their purpose for protection and repair of the structure.

— The achievement of the required storage and application conditions regarding ambient temperature, humidity and dew point, wind force and precipitation and any temporary protection which is needed.

6 Methods of protection and repair

The principles and methods of protection and repair given in ENV 1504-9 are described below excluding those methods specified in another EN or European Technical Approval.

The excluded methods are given below. Information on methods 1.4, 1.6 and 11.3 is given in informative Annex A, on 7.3 and 7.5 in a standard in preparation and on 10.1 in the EN 12696.

The information on methods 1.4, 1.6 and 11.3 is for information only and is not to be regarded as part of this standard.

Methods excluded :

Method 1.4	Locally bandaged cracks	(See informative Annex A)
Method 1.6	Transferring cracks into joints	(See informative Annex A)
Method 1.7	Erecting external panels	
Method 1.8	Applying membranes	
Method 2.3	Sheltering or overcladding	
Method 2.4	Electrochemical treatment	
Method 3.4	Replacing elements	

Method 4.7	Prestressing (post tensioning)	
Method 7.3	Electrochemical re-alkalisation of carbonated concrete (See prEN 14038-1:2000-09)	
Method 7.5	Electrochemical chloride extraction	(See EN 14038-2[11])
Method 10.1	Applying electrical potential	(See EN 12696)
Method 11.3	Applying inhibitors in or to the concrete	(See informative Annex A)

[AC1] The preparation, application, quality control and maintenance for each method shall comply with Clauses 7,8,9 and 10 of this part of EN 1504. [AC1]

The relevant sub-clauses are given below in Table 1 for each method together with any deviations, additions, necessary precautions and limitations.

Table 1 — Table for each method together with any deviations, additions, necessary precautions and limitations

Principles and methods		Preparation See clauses	Application See clauses	Quality control See clauses
Method	**Methods to satisfy principle 1 – Protection against ingress** The following methods satisfy the principle of reducing or preventing the ingress of adverse agents e.g. water, other liquids, vapour gas such as carbon dioxide, chemicals such as chlorides and biological agents.			
1.1	**Hydrophobic impregnation** This method is to apply a product to prevent or reduce the passage of water by lining the surface pores with material with hydrophobic properties.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
1.2	**Impregnation** This method is to apply liquid products which penetrate the concrete and block the pore system.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
1.3	**Surface coating with and without crack bridging ability** This method is to apply a product to the surface of the concrete to prevent the passage of agents.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
1.4	**Locally bandaged cracks** See clause A.6 informative Annex A.	7.1, 7.2.1, 7.2.2	[1] 8.1, 8.2.1, 8.2.2, 8.2.5, 8.2.6	
1.5	**Filling cracks** This method is to fill crack to protect against ingress.	7.1, 7.2.1, 7.2.2	[1] 8.1, 8.2.1, 8.2.2, 8.2.5, 8.2.6	9.1, 9.2
[1] concrete at the edges of cracks shall be prepared and repaired in accordance with clauses 7 and 8. Clauses 8.2.2 and 8.2.5 apply only to cementious grouts.				

to be continued

Table 1 - (*continued*)

Principles and methods		Preparation See clauses	Application See clauses	Quality control See clauses
	Methods to satisfy principle 2 – Moisture control The following methods satisfy the principle of adjusting and maintaining the moisture content in the concrete between a specified range of values.			
2.1	**Hydrophobic impregnation** This method is to apply a product to reduce the penetration of water and other agents into the treated concrete by lining the surface pores with materials with hydrophobic properties.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
2.2	**Surface coating** This method is to apply a product to the surface of the concrete to prevent the passage of water or water vapour.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
	Methods to satisfy principle 3 – Concrete restoration The following methods satisfy the principle of restoring the original concrete of an element of the structure to the originally specified shape and function. Restoring the concrete structure by replacing part of it.			
3.1	**Applying mortar by hand**	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.5	9.1, 9.2
3.2	**Recasting with concrete**	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4 and ENV 13670-1	8.1, 8.2.1, 8.2.4, 8.2.5 and EN 206 and ENV 13670-1	9.1, 9.2
3.3	**Spraying concrete or mortar**	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4 and ENV 13670-1 and prEN 14487-1: 2002-06 & prEN 14487-2:2003	8.1, 8.2.1, 8.2.3, 8.2.5 and ENV 13670-1 and prEN 14487-1: 2002-06 & prEN 14487-2:2003	9.1, 9.2

to be continued

Table 1 - (*continued*)

	Principles and methods	Preparation See clauses	Application See clauses	Quality control See clauses
	Methods to satisfy principle 4 – Structural strengthening The following methods satisfy the principle of increasing or restoring the structural load bearing capacity of an element of the concrete structure.			
4.1	**Adding or replacing embedded or external reinforcing steel bars**	7.1, 7.3.1, 7.3.2, 8.2.1, 8.3.2	8.1, 8.2.8, 8.3.1, 8.3.3 and ENV 13670-1 and prEN 10080-1:1999-07	9.1, 9.2
4.2	**Installing bonded rebars in preformed or drilled holes in the concrete**	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.8, 8.3.1, 8.3.3	9.1, 9.2
4.3	**Plate bonding** This method is to bond the strengthening plates externally to an element of the concrete structure.	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.6, 8.2.9	9.1, 9.2
4.4	**Adding mortar or concrete** This method is to bond additional mortar or concrete to the concrete structure.	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5	9.1, 9.2
4.5	**Injecting cracks, voids or interstices** This method is to inject the concrete with appropriate fluid.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.2, 8.2.5, 8.2.6	9.1, 9.2
4.6	**Filling voids, cracks or interstices**	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.2, 8.2.5, 8.2.6 [2]	9.1, 9.2
[2] Clauses 8.2.1 and 8.2.5 apply only to cementitious grouts.				

to be continued

Table 1 - (*continued*)

	Principles and methods	Preparation See clauses	Application See clauses	Quality control See clauses
	Methods to satisfy principle 5 – Physical resistance The following methods satisfy the principle of increasing resistance to physical or mechanical attack.			
5.1	**Overlays or surface coatings** These methods are to increase the physical resistance with:			
	— Concrete or mortar overlays	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5	9.1, 9.2
	— Surface Coatings	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
5.2	**Impregnation**	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
	Methods to satisfy principle 6 – Resistance to chemicals The following methods satisfy the principle of increasing resistance of the concrete surface to deterioration by chemical attack. Reducing the penetration of chemical agents into treated concrete to prevent or reduce deterioration due to chemical attack.			
6.1	**Overlays or surface coatings** These methods are to reduce penetration of chemical agents into treated concrete to prevent or reduce deterioration:			
	— Concrete or mortar overlays	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5	9.1, 9.2
	— Surface coatings	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2

to be continued

Table 1 - (*continued*)

	Principles and methods	Preparation See clauses	Application See clauses	Quality control See clauses
	Methods to satisfy principle 7 – Preserving or restoring passivity The following methods satisfy the principle of creating chemical conditions in which the surface of the reinforcement is maintained at or is returned to a passive condition.			
7.1	**Increasing cover to reinforcement with additional cementious mortar or concrete or surface coating** These methods are to increase cover or to provide surface coating to prevent penetration of the de-passivating agents:			
	— Concrete or mortar overlays	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5	9.1, 9.2
	— Surface coatings	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
7.2	**Replacing contaminated or carbonated concrete** This method is to replace carbonate concrete with uncontaminated mortar or concrete.	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.5	9.1, 9.2
7.3	**Electrochemical re-alkalisation of carbonated concrete**	See prEN 14038-1:2000-09	See prEN 14038-1:2000-09	See prEN 14038-1: 2000-09 and 9.1, 9.2
7.4	**Re-alkalisation of carbonated concrete by diffusion**	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4 [3] [4]	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5 [5]	9.1, 9.2

[3] Coating to concrete which prevents repassivation shall be removed and the concrete shall be cleaned, roughened and removed where necessary.

[4] Concrete needs to be removed only to the depth to which it has been cracked or loosened. Embedded reinforcement shall be cleaned in accordance to 7.3.1 and 7.3.2.

[5] Hydraulic mortar or concrete shall be used.

to be continued

Table 1 (*continued*)

Principles and methods		Preparation See clauses	Application See clauses	Quality control See clauses
	Methods to satisfy principle 8 – Increasing resistivity The following method satisfies the principle of increasing the electrical resistivity of the concrete by limiting moisture content.			
8.1	**Hydrophobic impregnation** This is a method to reduce water content and as a result increase the electrical resistance of concrete.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
8.2	**Limiting moisture content by surface coatings or sheltering** This is a method to reduce water content and as a result increase electrical resistance of concrete. Surface coatings.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
	Methods to satisfy principle 9 – Cathodic control The following methods satisfy the principle of creating conditions in which potentially cathodic areas of reinforcement are unable to drive an anodic reaction.			
9.1	**Limiting oxygen content (at the cathode) by saturation or surface coating** Saturation. Surface coating.	7.1, 7.2.1, 7.2.2 7.1, 7.2.1, 7.2.2	**The concrete shall be continuously saturated with water** 8.1, 8.2.1, 8.2.7	9.1, 9.2 9.1, 9.2
	Method to satisfy principle 10 – Cathodic protection			
10.1	**Applying electrical potential**	See EN 12696	See EN 12696	See EN 12696 and 9.1, 9.2

to be continued

Table 1 (*end*)

Principles and methods		Preparation See clauses	Application See clauses	Quality control See clauses
	Methods to satisfy principle 11 – Control of anodic and cathodic areas The following methods satisfy the principle of creating conditions in which potentially anodic and cathodic areas of reinforcement are unable to take part in the corrosion reaction.			
11.1	**Painting reinforcement with coatings containing active pigments** This is a method which provides either: 1. Coatings to provide an alkaline environment. 2. Coatings which function as inhibitors of electrochemical action. 3. Coatings provide sacrificial galvanic reaction.	7.1, 7.3.1, 7.3.2	8.1, 8.3.1	9.1, 9.2
11.2	**Painting reinforcement with barrier coatings** This is a method to provide a barrier to prevent pore water containing chlorides or other contaminants from reaching the reinforcement.	7.1, 7.3.1, 7.3.2	8.1, 8.3.1	9.1, 9.2
11.3	**Applying inhibitors to or in concrete** See clause A.6 informative Annex A.			

7 Preparation of substrate

7.1 General

The preparation of the substrate of concrete and reinforcement shall be suitable for the required condition of the substrate and the structural status of the structure, so that the products and systems can be properly applied, and shall be carried out in such a way as to produce protection or repair which is in accordance with this and other parts of this standard. The requirements for preparation are given in the following sub-clauses and are related to the methods of repair and protection in Table 2.

Table 2 - Preparation of substrate

Preparation process	Sub-clause numbers (background information in Annex A)	References	Method numbers							
			Methods involving hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving Filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in pre-formed holes	Method for plate bonding	Methods involving coating reinforcement
			1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
General	7.1		X	X	X	X	X	X	X	X
Preparation of concrete substrate										
General	7.2.1	ENV 1504-9	X	X	X	X		X	X	
Cleaning	7.2.2		X	X	X	X		X	X	
Roughening	7.2.3					X			X	
Concrete removal	7.2.4	ENV 1504-9				X			X	
Preparation of reinforcement										
General	7.3.1	ENV 1504-9					X	X		X
Cleaning	7.3.2	ISO 8501-1					X	X		X

7.2 Preparation of concrete

7.2.1 General

Weak, damaged and deteriorated concrete and where necessary sound concrete shall be removed in accordance with the principle and method chosen from ENV 1504-9.

If necessary cleaning shall be carried out after roughening or concrete removal to comply with 7.2.2 unless water based methods are used which may make this unnecessary.

Micro cracked or delaminated concrete including that caused by the techniques of cleaning, roughening or removal which reduces bond or structural integrity, shall be subsequently removed or remedied. The finished surface shall be visually inspected and tested by tapping with a hammer to detect loose concrete.

7.2.2 Cleaning

For those methods which require cleaning the following requirements shall be met:

a) The substrate shall be free from dust, loose material, surface contamination and materials which reduce bond or prevent suction or wetting by repair materials;

b) unless cleaning is carried out immediately before application of protection and repair materials the cleaned substrate shall be protected from further contamination.

7.2.3 Roughening

For those methods which require roughening the following requirement shall be met.

The texture of the roughened surface shall be appropriate for the products and systems to be applied and shall be specified.

7.2.4 Concrete removal

For those methods which require the removal of concrete, the following requirements shall be met:

a) the extent of the removal shall be appropriate to the Principle and Method chosen from those given in ENV 1504-9;

b) removal shall be kept to a minimum;

c) removal shall not reduce structural integrity beyond the structure's ability to perform its function. Temporary support may be necessary;

d) the depth of carbonation and the concentration profiles of chloride or other contamination in the concrete shall be established and taken into account;

e) the extent of the removal of the concrete shall be in accordance with the method chosen and shall be specified. It shall take into account the following:

   1) the penetration resistance of the concrete against gases and fluids;

   2) the nature and concentration of the contamination before and after the repair;

   3) the depth of the contamination;

   4) the depth of the carbonation;

   5) the corrosion activity of the reinforcement;

6) cover to reinforcement;

7) the need for compaction of the repair material;

8) the need for bond to the substrate;

9) the need for treatment of reinforcement.

7.3 Preparation of reinforcement

7.3.1 General

Before protection and repair systems are applied, the required condition of the existing and any new reinforcement shall be prepared in accordance with the specification and the principle and method chosen from ENV 1504-9 and the required structural performance. The extent of any cleaning, coating, removal or replacement shall be specified taking into account the possible need for corrosion prevention and the need to provide the specified bond between the repair products and systems and the reinforcement.

7.3.2 Cleaning

For those methods which require cleaning the following requirements shall be met:

a) rust, scale, mortar, concrete, dust and other loose and deleterious material which reduce bond or contribute to corrosion shall be removed;

b) the whole circumference of the exposed reinforcement shall be uniformly cleaned, except where structural considerations prevent it;

c) unless the cleaning is carried out immediately before application of protection products and systems the cleaned substrates shall be protected against further contamination;

d) reinforcement shall be cleaned without causing damage to it or damage to or contamination of the adjacent concrete or environment;

e) where exposed reinforcement is contaminated with chloride or other material which may cause corrosion, the whole of the circumference of the contaminated reinforcement shall be cleaned by water jets not exceeding a pressure of 18 MPa to remove the chlorides and other contaminants unless electrochemical methods of protection and repair are to be used (see A.7.3.2);

f) for Method 11.2 the standard of cleaning shall be to Sa2½. For method 11.1 and other methods except method 11.2 where reinforcement is to be coated the standard of cleaning shall be specified and shall be suitable for the coating to be applied. The specification, method and choice of cleaning shall take into account bar congestion, contact between bars, proximity to concrete substrate and other factors which prevent access for cleaning (see A.7.3.2).

8 Application of products and systems

8.1 General

The application of the products and systems shall be suitable for the substrate and structure to which it is applied and to produce protection and repair which is in accordance with other parts of this standard and EN 206-1 and ENV 13670-1.

Products shall be stored before use so that their properties shall not be impaired.

Access for the work shall be adequate so that products and systems can be prepared and applied in accordance with this standard.

Protection shall be provided so that preparation, application and subsequent curing shall be carried out in accordance with this standard.

Before and during application of the products and systems the substrate temperature and moisture content, and the characteristics of the environment for example temperature, relative humidity, dew point, rate of change of moisture content as influenced by precipitation and wind shall be considered.

Mixing of products and systems shall be in accordance with EN 206-1 and ENV 13670-1 or shall be specified.

The thickness of layers of products and systems shall comply with this Standard or be specified.

The bond of the repair material with the substrate and between layers of repair material, shall be not less than the bond strength specified.

The requirements for application are given in the following sub-clauses and are related to the methods of repair and protection in Table 3.

Table 3 - Application of products and systems

Application process	Sub-clause numbers (background information in Annex A)	References	Method numbers							
			Methods involving hydrophobic impregnation and impregnation	Methods involving surface coatings	Methods involving Filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in pre-formed holes	Method for plate bonding	Methods involving coating reinforcement
			1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
	8.1		X	X	X		X	X	X	X
Defects in concrete and structural strengthening										
Bonding	8.2.1	EN 206-1		X	X	X		X	X	
Hand applied mortar and concrete	8.2.2	ENV 13670-1			X*	X*				
Sprayed mortar or concrete	8.2.3	prEN 14487-1 : 2002-06 & prEN 14487-2 :2003				X*				
Cast mortar or concrete	8.2.4	ENV 13670-1				X*				
Curing	8.2.5	ENV 13670-1			X*	X				
Cracks and joints	8.2.6	ENV 1504-9			X				X*	
Surface coatings and hydraulic impregnation and impregnation	8.2.7		X	X		X*				

* Where relevant.

to be continued

Table 3 - Application of products and systems (continued)

Application process	Sub-clauses (background information in Annex A)	References	Method numbers							
			Methods involving hydrophobic impregnation and impregnation	Methods involving surface coatings	Methods involving Filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in pre-formed holes	Method for plate bonding	Methods involving coating reinforcement
Anchoring	8.2.8	EN 1504-6 :2001-12 ENV 13670-1 ENV 1992 2-4					X	X		
Plate bonding	8.2.9	EN 1504-4 :2000-04 ENV 1992 2-4 ISO 8501-1							X	
Defects caused by reinforcement corrosion										
Coating reinforcement	8.3.1						X			X
Removal	8.3.2						X			
Replacement	8.3.3	ENV 13670-1 prEN 10080-1: 1999-07					X			

8.2 Defects in concrete and structural strengthening

8.2.1 Bonding

Bonding requirements shall be specified and for applied mortar and concrete shall comply with prEN 1504-4:2000-04.

The water for wetting the substrate shall comply with the purity requirements for mixing water of EN 206-1 and EN 1008.

8.2.2 Hand applied mortar and concrete

Where cementitious products or systems are used without a bonding primer the concrete substrate shall be well pre-wetted but free from water on the surface at the time of the application. The condition of the substrate shall be specified where a bonding primer is used.

Repair mortar shall be worked into the prepared substrate and shall be compacted without inclusion of entrapped air pockets and in such a way that the required strength is achieved and the reinforcement is protected against corrosion.

It shall be decided whether the repair mortar or concrete is to be built up in layers to prevent sagging or slumping. The layer thickness, time between application of layers and other requirements shall be specified. Where the application of layers is interrupted and layers cannot be applied wet on wet, surface treatment for bonding to the previous layer shall be in accordance with 7.2.2, 7.2.3 and 8.2.1.

8.2.3 Sprayed mortar or concrete

Sprayed concrete and sprayed mortar used as repair material shall comply with the standard for sprayed concrete (see prEN 14487-1: 2002-06 &prEN 14487-2:2003).

The need for pre-wetting of the substrate shall be considered. It depends upon its condition and the composition of the products and systems used.

Sprayed concrete and mortar shall be placed without the formation of voids and loose rebound material and in such a way that the required strength is achieved and the reinforcement is protected against corrosion.

Spray fog deposits or overspray and loose rebound material shall be removed from surrounding areas and from the substrate before sprayed concrete or mortar is applied.

Where sprayed concrete or mortar is to be applied in more than one layer and, where the work is not applied wet on wet, intermediate surfaces shall comply with 7.2.2 and 8.2.1.

No treatment shall be allowed to the surface of sprayed mortar or concrete unless the sprayed mortar or concrete is non-structural to avoid the possibility of reducing bond. If treatment is required to structural sprayed concrete or mortar it shall be applied to the final layer which has not been applied wet-on-wet to the structural material.

8.2.4 Cast mortar or concrete

Where cementitious products or systems are used without a bonding primer, the concrete substrate shall be well pre-wetted but free from water on the surface at the time of application. The condition of the substrate shall be specified where a bonding primer is used.

Concrete shall be replaced in accordance with ENV 13670-1 and shall be specified to avoid segregation bleeding and loss of cement paste.

Formwork shall comply with ENV 13670-1.

Formwork shall be fixed in place as soon as possible after the substrate has been prepared as specified in clause 7 of this standard. Openings in the formwork shall be protected to prevent entry of debris or contaminants.

Concrete intended for compaction by vibration shall be compacted around the reinforcement and elsewhere without inclusion of entrapped air pockets and in such a way that the required strength is achieved and the reinforcement is protected against corrosion.

Where casting is to be with flowing concrete intended to be compacted by gravity, the following shall also apply:

a) the substrate shall comply with clause 7;

b) formwork shall be watertight to the existing concrete and shall be free from obstructions to the free flow of concrete. It shall be designed to allow air and bleed water to escape;

c) the concrete shall be introduced into the formwork in such a way that the air and water can escape. It shall not be vibrated.

8.2.5 Curing

Where cementitious repair products and systems are used curing is necessary and shall comply with ENV 13670-1 and shall be specified.

The method and period of any wet curing shall be specified taking into account the nature of the products and systems, the thickness of the repair and environmental conditions.

Curing compounds shall not be used where they adversely affect subsequently applied products and systems.

8.2.6 Cracks and joints

Account shall be taken of the position and size of cracks and joints, any movement in the substrate and of the effect on the stability, durability and function of the structure and the risk of creating new cracks as a result of any treatment.

The treatment of cracks shall be in accordance with the Principle and method chosen from ENV 1504-9 and the following :

a) cracks shall be cleaned in accordance with clause 7.2.2;

b) cracks to be treated to restore structural integrity shall be filled with a bonding product or system;

c) cracks to be treated to prevent the passage of agents shall be covered or filled;

d) cracks to be treated to accommodate movement shall be repaired so that a joint is formed to extend through the full depth of any repair material and positioned to accommodate that movement. Cracks shall be filled or covered with a flexible material for that purpose.

The treatment of joints shall ensure that the joint extends through any repair material so that the joint performance is maintained.

8.2.7 Surface coatings and other treatments

Smoothing coatings shall be applied and cured where necessary before surface coatings are applied to fill uneven surfaces and surface pores.

Coatings shall be applied within the specified maximum and minimum thickness.

The maximum and minimum temperature and moisture content of the substrate and the ambient temperature and humidity shall be specified and shall be appropriate to the surface coating hydrophobic impregnation or impregnation material.

8.2.8 Anchoring

Anchoring reinforcement independently of the existing reinforcement to bond it to the substrate concrete shall be in accordance with EN 1504-6:2001-12, ENV 13670-1, ENV 1992-2-4 and any other relevant EN or European Technical Approval.

Anchors shall not be installed in cracked concrete or reduce the structural or electrochemical performance of other reinforcement.

The texture and cleanliness of the surface of anchor holes and grooves shall be in accordance with Clauses 7.2.2 and 7.2.3 and shall be appropriate to the anchoring material.

8.2.9 Plate bonding

Plate bonding shall be carried out in accordance with EN 1504-4:2000-04, ENV 1992-2-4 and any other relevant EN or European Technical Approval.

The exposed surfaces of concrete to receive externally bonded reinforcement shall be cleaned and roughened and voids treated to comply with clauses 7.2.2 and 7.2.3 of this Standard. Weak, damaged or deteriorated concrete shall be removed to comply with Clause 7.2.4 prior to the application of bonded external reinforcement.

The conditions of the surface at the time of application of the bonding agent shall comply with clause 7.1, 7.2.1 and 7.2.2 of this standard.

Replacement of removed concrete and the filling of voids and the treatment of cracks shall be in accordance with Clause 8 of this Standard.

The surface of the steel plates to be bonded shall be free of any contaminants and shall be cleaned to Sa2½ (see ISO 8501-1).

The surface of fibre reinforced or other plates to be bonded shall be prepared in accordance with the specification.

Adhesives shall be applied to comply with the specified ambient conditions.

The exposed surface of plates shall be protected as specified.

8.3 Defects caused by reinforcement corrosion

8.3.1 Coating reinforcement

Bonding requirements shall be specified and shall comply with EN 1504-6:2001-12. The whole exposed circumference of the exposed reinforcement surface shall be uniformly coated.

Coating shall not be allowed to contaminate existing concrete if it is detrimental to the bond between the existing concrete and the repair products and systems.

The treatment of reinforcement to prevent corrosion shall comply with EN 1504-7[1)].

8.3.2 Removal

If reinforcement is removed the following requirements shall be met:

a) the concrete substrate shall not be damaged (see A.8.3.2);

b) remaining reinforcement shall not be damaged.

8.3.3 Replacement

Added or replaced embedded reinforcement shall comply with Clause 8.2.8 of this Standard, ENV 13670-1, EN 10080-1:1999-07 or other relevant EN or European Technical Approval.

To avoid the risk of creating conditions which may cause corrosion, reinforcement shall not make electrochemical contact with a dissimilar metal.

Where electrochemical methods of protection and repair are to be applied, added reinforcement shall be in sufficient electrical contact with existing reinforcement to comply with the Principle and method chosen.

9 Quality control

9.1 General

The execution of the work shall be carried out in accordance with a quality plan prepared for the project.

[AC1] Products and systems for the execution of work shall satisfy the quality control requirements in prEN 1504 parts 2 to 8. 〈AC1〉

The storage conditions and periods for use of products and systems shall comply with clause 5 of this standard and the specification.

9.2 Quality control tests and observations

The properties of the substrate, acceptance for suitability of products and systems, the conditions for their application and final properties of the hardened products and systems shall be subject to quality control which shall be undertaken using tests and observations given in Table 4.

References for test methods are given for tests in EN and ISO Standards and where no standard exists reference is made to tests and observations in informative Annex A which refer where relevant to National Standards. National Standards may be specified where no European Standard exists.

Tests given in National Standards are informative.

Maximum and minimum parameters and frequency of observation or testing shall be in accordance with the project specification. If no frequency is specified those given in the following tables shall apply. If no maximum and minimum parameters are specified guidance is given in informative Annex A (A.9.2).

When excluded methods are used similar requirements for quality control are necessary.

The status of the characteristics to be tested is as follows:

- ■ For all intended uses
- ◆ For certain intended uses where required by the specific or operating conditions
- □ For special applications

Table 4 - Summary of tests and observations for quality control

Test or observation number -See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Methods involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1,8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
Substrate conditions before and/or after preparation													
1	Delamination	Hammer sounding	T		Once before application	■	■		■			■	
2	Cleanliness	Visual wipe test	O T		After preparation and immediately before application	■	■	◆	■		■ 1	■ 3	■
3	Surface Unevenness	Visual	O		Before application		■					■	
4.	Roughness	Visual, sand test or profile meter	O T T	EN 1766 EN ISO 3274 and EN ISO 4288			◆		◆ AC1 *Text deleted* AC1		■ 2	■	

1. Cleanliness of concrete substrate or hole
2. Roughness of concrete substrate or hole
3. Cleanliness of plates and concrete substrate
4. Moisture content of crack and surrounding concrete
5. Water for mixing should be chemically tested if written confirmation of potable water is not available
6. Consistency of grouting cementitious or polymer grout
7. Dry thickness of protective coating on plates

to be continued

Table 4 (*continued*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Methods involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
5	Surface tensile strength of substrate	Pull-off test	T	EN 1542		◆	◆		◆			■	
6	Crack width and depth	Mechanical or electrical gauge, Core and visual or Ultrasonic	O O T	EN 12504-1 prEN 12504-4: 1998-07 and ISO 8047				◆					
7	Crack movement	Mechanical or electrical gauges	O				□	◆	□			◆	
8	Vibration	Accelerometer	O						□			◆	
9	Moisture content of substrate	Visual Site sampling and laboratory analysis, Resistivity test, Relative humidity probes	O T T T		Before and during application	◆	◆	◆ 4			◆	■	

to be continued

Table 4 (*continued*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Method involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
10	Temperature of substrate	Thermometer	O		Throughout application	■	■	◆	■			■	■
11	Carbonation	Phenolphthalein test	T	prEN 14630: 2003-03		◆			□			◆	
12	Chloride Content	Site sampling and chemical analysis	T	prEN 14629: 2003-03		◆			□			◆	
13	Penetration of other contaminants	Site sampling and chemical analysis	T				◆		□				
14	Crack contamination	Core and chemical analysis	T					◆					
15	Electrical resistivity	Wenner test	T						□				
16	Cleanliness of existing reinforcement	Visual	O	ISO 8501-1	Once before application					■			
17	Size of existing reinforcement	Visual	O							■	■		

to be continued

Table 4 (*continued*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Method involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
18	Corrosion of existing reinforcement	Half cell tests or visual	T O							◆	◆	◆	
19	Cleanliness of reinforcing plates	Visual	O	ENV ISO 8502-1, -4	Once before application						■		
36	Compressive strength	Core and crushing test Rebound hammer test	T T	EN12504-1 EN 12504-2					◆			◆	
Acceptance of products and systems													
20	Identity of all applied products	Written certification	O T	EN 1504-8: 2000-10 EN 1008	Before use	■	■	■	■ 5	■	■	■	■
Condition and requirements before and/or during application													
21	Ambient temperature	Thermometer	O		Throughout application	■	■	■	■		■	■	■

to be continued

Table 4 (*continued*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Method involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
22	Ambient humidity	Hygrometer	O	ISO 4677-1 & 2	Throughout application	■	◆	◆			■	■	■
23	Precipitation	Visual	O		Daily	■	■	◆	■	◆	◆	■	◆
24	Wind strength	Anemometer	O		Before use	■	■						
25	Dew Point	Hygrometer and thermometer	O	ISO4677 1-2	Throughout application If product requires it	◆	◆					■	◆
26	Wet thickness of coating	Comb or wheel gauge	T	ISO 2808	After application		◆						
27	Consistency of concrete	Slump test Vebe test Flow table test	T T T	EN 1235-1, -5	Daily or for each batch				■		■ 6		
		Flow trough test	T	EN 13395-3									
	Consistency of mortar and cement grout	Flow trough test Flow table test Overhead test	T T T	EN 13395-1, -2, -4									

to be continued

Table 4 (*continued*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Method involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
28	Air content of fresh concrete	Pressure method	T	EN 12350 -7					◆				
34	Thickness or cover of repair material	Core and visual, Cover meter test	O T	EN 12504-1	Once after repair				■				
36	Compressive strength	Cube and crushing test Rebound hammer test	T T	EN12390-1, -2, -3 and EN 12190 EN 12504- 2	Once after repair				■				
40	Position of reinforcement	Visual or Cover meter	O T		Once before application					■	◆		

to be continued

Table 4 (*continued*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Method involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
Final hardened condition													
1	Delamination	Hammer sounding	T		Once per element type to judge efficiency of repair				■				
15	Electrical resistivity	Wenner Test	T						□				
29	Dry thickness of coating	Wedge cut or quantity measurement	T	ISO 2808	Once to judge the efficiency		■					◆ 7	◆
30	Covering of coating	Visual	O	ISO 4628-1-6: 2003-04	Once to judge the efficiency		■						■
31	Penetration of impregnation	Core and visual. Quantity measurement	O T	EN 12504-1 ISO 2808		◆							
AC1 32	Permeability of coating or repair material or filled cracks to water	Karsten test. Core and penetration test	T T	EN 12390-8 ISO 7031	Once to judge the efficiency	■	◆	◆	◆				

to be continued

Table 4 (*continued*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Method involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
33	Degree of filling of cracks	Core and visual or ultrasonic test	O T	EN 12504-1 prEN 12504-4: 1998-07, ISO 8047				◆					
34	Thickness of cover	Core, visual or covermeter test		EN 12504-1	Once per element type				■				
35	Adhesion of coating, adhesion of repair material	Cross cut test Pull-off test	T T	EN ISO 2409-6 & ISO 4624 EN 1542 (1)	Once for each type of surface or member		■		■				
36	Compressive strength	Core and crushing or Rebound hammer	T T	EN 12504-1 EN 12504-2	Once per element type				■				
37	Density of hardened concrete	Oven dry method	T	EN 12390-7	Once after repair				■				

(1) See Test 35 in Annex A.

to be continued

Table 4 (*continued*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Method involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
38	Shrinkage cracking in repair mortar and concrete	[AC1] Mechanical gauge or visual [AC1]	O		Once to judge the efficiency				■				
39	Presence or voids in and behind hardened repair material	Ultrasonic test or radiography or core and visual	T [AC1] T [AC1] O	EN 12504-4: 1998-07 ISO 804 7 EN 12504-1					◆				
40	Position of reinforcement	Visual Cover meter test	O T							■	■		
41	Bond of reinforcement	Pull out test	T	EN 1881	As required					◆	◆		

to be continued

Table 4 (*end*)

Test or observation number - See Clause A.9.2	Characteristic	Test method or observation (including equipment used where relevant)	Test (T) or Observation (O)	European or ISO Standard reference	Frequency of test or observation	Method numbers							
						Methods involving Hydrophobic impregnation and impregnation	Methods involving surface coating	Methods involving filling cracks, voids or interstices	Methods involving the application of mortar and concrete	Method for adding reinforcing steel bars	Method for installing bonded rebars in preformed holes	Method for plate bonding	Method involving reinforcement coating
						1.1, 1.2, 2.1, 5.2, 8.1	1.3, 2.2, 5.1, 6.1, 7.1, 8.2, 9.1	1.5, 4.5, 4.6	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	4.1	4.2	4.3	11.1, 11.2
42	Presence of voids between bonded plates and substrate	Impact echo test Hammer sounding Ultra sonic test	T T	EN 12504-4: 1998-07 ISO 8047	Once to judge the efficiency							■	
43	Structural performance	Load test	T		As required							◆	
44	Adhesion of crack filling material to substrate	Core and visual Core and compaction test	O T	EN 12504-1				□					
45	Colour and texture of finished surfaces	Visual	O						◆				

10 Maintenance

Details of the method of execution of repair and protection, the results of quality control and other information relevant to future maintenance of the structure shall be recorded and given to the appropriate person.

11 Health, safety and the environment

The execution of the works and the products and systems used shall comply with the requirements of the relevant health and safety, environment protection and fire regulations.

Annex A
(informative)

Foreword

This Annex provides guidance and background information on the Normative text. The contents of this Annex are numbered in the same way as the Normative text to facilitate reference.

A.2 Informative references

The information and references in clause 2 apply to the references given in informative Annex A.

EN 12350-6, *Testing fresh concrete – Part 6: Density.*

ISO 565, *Test sieves metal wire, perforated metal plates, Electro formed sheet.*

Directive 89/106/EEC, *Construction Products Directive.*

Directive 92/57/EEC, *Implementation of minimum safety and health requirements for temporary or mobile construction sites.*

A.3 Definitions

The definitions in clause 3 apply to the annex

A.3.1
blasting
removal of matter from the concrete substrate to a maximum depth of 2 mm

A.3.2
grit blasting
blasting using abrasive as an additive in air

A.3.3
mechanical removal
removal of substrate by percussive or abrasive means

A.3.4
non-selective hydrodemolition
removal of concrete to a selected depth by using high pressure water techniques

A.3.5
selective hydrodemolition
removal of damaged concrete leaving sound concrete of a selected strength using high pressure water techniques

A.3.6
soaking
filling cracks in a horizontal surface by means of gravity using a pond of filling material above the crack

A.3.7
water blasting
blasting using high pressure water with or without abrasives as an additive

A.4 Structural stability during preparation, protection and repair

Deterioration damage and the process of repair can cause reduction in the load bearing capacity of the structure. This should be taken into account in the design of the repair method and subsequent application, any requirement for the permanent or temporary removal of dead and live loads, the provision of temporary or permanent additional support and the design of the order of the repair to accommodate the load.

Although many repairs do not affect structural performance, it should be recognised that successive repairs carried out to the same concrete structure over a period of time can create a danger of progressive weakening caused by repeatedly cutting away structural concrete and replacing it with new material.

The replacement material may not carry its share of the load if it has different properties to those of the materials removed, because of shrinkage or initial thermal contraction, or because of stresses in the structure at the time of the repair.

A.5 General requirements

If vibration (for example due to construction operations or traffic) is expected during the setting of repair concrete or mortar, the selected product or system should be capable of withstanding the vibration without adverse effects or the vibration should be reduced or eliminated by restricting its causes to the necessary extent. See also A.7.2.1 and 8.1.

A.6 Methods of protection and repair

The methods excluded are or will be standardised in other EN or specified in other European Technical Approval. The methods 1.4, 1.6 and 11.3 for which there is no current EN, or approval are described below.

Method 1.4 Locally bandaged cracks

The method is to seal cracks in the concrete to prevent the passage of agents.

Preparation

See clause 7.2.1 and 7.2.2

Application

See clauses 8.1, 8.2.6 and 8.7.6

Free movement shall be maintained. Adhesive shall not be applied to free tape width.

Quality control

See clauses 9.1 and 9.2

If no other information is available pre-tests shall be carried out to determine the adhesion and tightness of bandages against penetrants.

Table A.1 - Quality control method 1.4

The relevant characteristics to be tested are:

Status of test or Observation	Characteristic	Test method or observation (including equipment used where relevant)	Frequency of test or observation	Test Ref. EN or ISO number or Test or observation number in clause A.9
SUBSTRATE CONDITIONS AND/OR AFTER PREPARATION				
■	Cleanliness	Visual	After preparation and immediately before application	2
◆	Surface tensile strength of substrate	Pull-off		5 EN 1542
◆	Vibration	Accelerometer		8
■	Crack width and depth	Mechanical gauge, Core and Visual or Ultrasonic	Once before application	6
■	Crack movement	Strain gauge, crack magnifier or glass plates	Throughout application	7
■	Temperature of substrate	Thermometer	Throughout application	10
■	Moisture content of surrounding concrete	Site sampling and Laboratory test Visual or resistivity test, relative humidity probes	Before and during application	9
ACCEPTANCE				
■	Identity once before use	Written certification	Before application	20
CONDITIONS AND REQUIREMENTS BEFORE AND/OR DURING APPLICATION				
■	Ambient temperature	Thermometer	Throughout application	21
◆	Ambient humidity	Hygrometer	Throughout application	22 ISO 4677 - 1&2
◆	Precipitation	Visual	Daily	23
◆	Dew point	Hygrometer and thermometer	Throughout application if product requires it	25 ISO 4677 1&2
■	Adhesion	Pull-off	On completion	35

Method 1.6 Transferring cracks into joints

This method makes use of existing cracks as an integral part of the structure. The design of the joint and use of materials shall be in accordance with ENV 1992-2-4 or any other relevant EN or European Technical Approval.

Joints shall be formed in accordance with the relevant EN.

Method 4.1 Adding or replacing embedded or external steel

There is a risk of promoting electrochemical action if new reinforcement is added to structures infected with chlorides

Method 7.1 Increasing cover to reinforcement with additional cementitious mortar or concrete or surface coating

The application of surface coatings can assist in the preservation of passivity.

Method 9.1 Limiting oxygen content (at the cathode) by saturation or surface coating

The effectiveness of saturation to prevent oxygen transmission to the reinforcement depends on the impermeability achieved when saturated with water. The effectiveness when surface coatings are used depends upon the characteristics of the surface coating.

Method 11.2 Painting reinforcement with barrier coatings

The effectiveness of the method depends upon the ability of the coating to isolate the reinforcement from the local environment, and so it is important that there are no gaps in the coating.

Method 11.3 Applying inhibitors to the concrete

Inhibitors are applied as a surface treatment or are added to repair products and systems.

Surface Treatment

Inhibitors act as chemical agents which discourage the formation of anodic regions on the reinforcement. Their effectiveness depends on the ability of the product and system to penetrate and affect the surface of the reinforcement.

Application see clauses 7.1, 7.2.1 and 7.2.2.

Preparation

See clauses 8.1 and 8.2.6.

Quality Control

See clauses 9.1 and 9.2.

A.7 Preparation of substrate

A.7.2.1 General

Dust and loose fine material left on the substrate after concrete has been removed may contain enough unhydrated cement to set in the presence of moisture. Although the material is weak, once set it can be very difficult to remove from the rough surface of the prepared substrate and it is important to remove it before setting can occur.

Pull-off tests can only be used to measure the surface tensile strength of the surfaces which are reasonably flat.

The methods of cleaning, roughening and removal include the following

1.	Cleaning	Mechanical, percussion and abrasion Grit and sand blasting Water Blasting with low pressure up to approximately 18 MPa and where low water volumes are necessary up to 60 MPa

2.	Roughening	Mechanical percussion and abrasion Grit and sand blasting Water Blasting with high pressure up to approximately 60 MPa
3.	Removal	Mechanical, percussion Water Blasting with high pressure up to 60 MPa and very high pressure up to 110 MPa

A.7.2.2 Cleaning

The purpose of cleaning is to remove dust, loose material and contaminants so as to improve the bond between the cleaned surface of the substrate and the material being applied. Water blasting, clean compressed air or vacuum cleaning are effective methods.

Where contaminants are on or have penetrated beneath the surface it may be necessary to remove them using methods for example involving the use of solvents or steam cleaning.

Chlorides and other contaminants may be detected by site sampling and chemical analysis reference prEN 14629:2003-03 for chloride content and as in BS 1881 part 124 for other chemical analysis.

Contaminants embedded in the surface may include tie wire, nails and timber.

Cleaning of concrete surfaces without removal of concrete is normally performed with water pressures up to 18 MPa.

Water blasting, using high water pressure techniques, is used for cleaning or superficial removal of concrete to a depth of up to 2 mm. Membranes, asphalt residues, colour markings and laitence are other examples of materials which can be removed.

Cracks and joints can be cleaned with water jetting, flushing with water or compressed air.

When using compressed air care shall be taken that the air is clean and does not contaminate the substrate with oil.

A.7.2.3 Roughening

Roughening is used for removal of concrete up to 15 mm depth and gives a textured surface with good bonding for a new layer of concrete or mortar cast, applied or sprayed onto original concrete.

A.7.2.4 Concrete removal

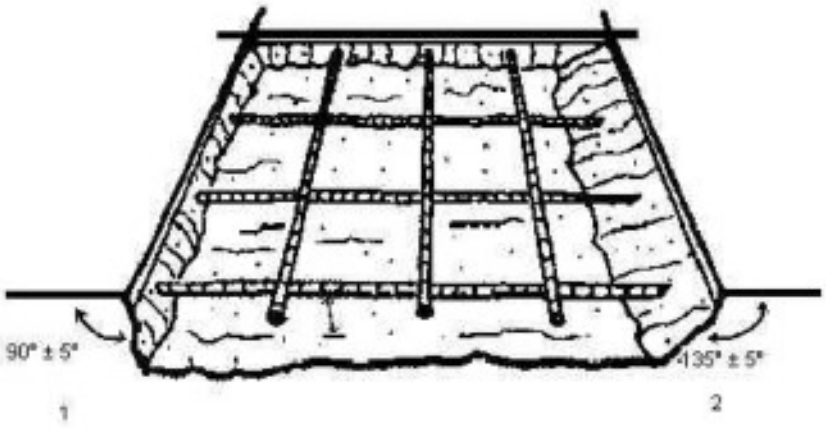
The extent of the removal should take into account the relevant factors and any need to provide uncontaminated cover on all sides of the reinforcement.

Structural considerations may limit the extent of the removal.

Where methods 7.3, 7.5 and 10.1 are to be used, honeycombed or delaminated concrete, surface coatings, and previous repairs with unacceptably high resistivity should be removed. For these methods it is not necessary to remove original sound concrete from around reinforcement.

Tying wire fragments, nails and other metal debris embedded in the concrete should be removed where possible.

The edges where concrete is removed should be cut at a minimum angle of 90° to avoid undercutting and a maximum angle of 135° to reduce the possibility of debonding with the top surface of the adjacent sound concrete and should be roughened sufficiently to provide a mechanical key between the original material and the repair product.



Key

1 Minimum angle

2 Maximum angle

Figure A.1 - Concrete removal

If corrosion is present on the circumference of the reinforcing bar which is exposed after removal of damaged concrete, the depth of removal may need to be increased to expose the whole bar depending on the repair specification. The clearance around reinforcement and the minimum distance between the reinforcement bar and the remaining substrate should be at least 15 mm or the maximum aggregate size of the repair material plus 5 mm whichever is the greater to allow proper compaction. Chloride contaminate concrete should be removed on all sides of the reinforcement for a minimum of 20 mm.

If there is no corrosion on the reinforcement, carbonated and or chloride contaminated concrete may remain if electrochemical methods are used or the concrete is sufficiently dry.

In thermal and mechanical removal of concrete, micro-cracks may occur in the concrete left in place. The layer containing micro-cracks should be removed using water blasting with or without abrasive or should be treated to restore its integrity if the surface tensile strength is not sufficient for the products and systems to be applied. Cracking can be detected by wetting the surface and allowing it to dry. Cracks retain water and can be seen as dark lines. If thermal processes are used to remove concrete, the introduction of heat must be carefully controlled to prevent damage and if damage occurs further removal carried out by other means to remove any contaminated concrete.

Hydrodemolition is a fast and effective way of removing concrete, keeping the removal of sound concrete to a minimum. No micro-cracks develop and unsound concrete is removed selectively leaving sound concrete intact. Selection is carried out around a mean removal depth. This procedure may be employed if it is carried out with equipment of known performance. The requirements to be met are to achieve the selection between sound and unsound concrete, to remove concrete without leaving shadows and only a small amount of low ridges underneath the reinforcement and to do the work without creating pits. Removal to a generally predetermined minimum depth is possible, but where concrete is locally weak, the depth of removal will be deeper.

The equipment normally used for selective hydrodemolition operates with a pressure of 60-110 MPa. In selective hydrodemolition, it is necessary to specify equipment prequalified for the method. Surface roughness may vary considerably and is affected by the distance between the nozzle and the substrate, water pressure, water flow, feed rate, equipment and concrete quality.

Water pressure, which is usually metered at the pump can be categorised as follows:

— Low Pressure Up to 18 MPa - Used for cleaning concrete and steel substrate;

— High Pressure 18 MPa - 60MPa - Used for cleaning steel substrate and for removal of concrete;

— Very High Pressure 60 MPa - 110 MPa - Used for concrete removal when low water volume are necessary.

Cutting with high pressure water is defined as cutting with a water jet so that a narrow slit or small hole is formed. The method is used, for example, to cut away parts or make holes in reinforced concrete. By adding abrasives to water, it is also possible to cut steel.

A.7.3.1 General

Structural performance may be changed by loss of section or pitting of the reinforcement.

A.7.3.2 Cleaning

For practical reasons, cleaning will normally be to the whole periphery of the bar. It will normally extend 50 mm or more beyond the extent of the corrosion along the length of the bar. Structural considerations may limit the amount of concrete which can be removed and the cleaning which can be carried out. Potential mapping may assist in detecting corrosion.

The standard of cleaning for method 11.1, using coatings with active pigment, is normally to Sa2, "thorough blast-cleaning". For method 11.2, using barrier coatings to Sa2½, "very thorough blast-cleaning", is normally specified. Cleaning may be difficult to achieve under site conditions.

Where access for cleaning is prevented or difficult due to bar congestion, contact between bars, proximity to the concrete substrate, or other bars or other factors, the method and standard of cleaning should be specified. If corrosion products and contaminants cannot be removed or, if the coating cannot be applied to all areas intended to be treated, the performance of the coating may be changed. Sa standards for blast-cleaning are given in ISO 8501-1. Any method of cleaning, including grit blasting, may be used.

Removal of chlorides on the surface of the steel or in pits in the steel can only be achieved by water under pressure, normally at low pressure below 18 MPa but if low volumes of water are required pressures up to 60 MPa may be necessary.

A.8 Application of products and systems

A.8.1 General

The temperature of the substrate and repair mortar or concrete should not differ materially to avoid the risk of loss of bond and loss of hydration.

Surface working of concrete or mortar may cause the formation of shrinkage cracks as the treatment may give rise to a cement rich surface layer.

A.8.2.1 Bonding

A rough surface profile is beneficial for the bond between old and new concrete and repair products and systems. This can be achieved by hydrodemolition or mechanical means. The roughness produced by hydrodemolition is considerably greater than that produced by mechanical hammers which is in turn greater than that produced by grit blasting. If hydrodemolition is used there is normally a good bond between the concrete substrate and the repair material and mechanical connection is not necessary for the transfer of shear and tensile stress less than 0.4 MPa.

A textured surface can be given to the surface of repair mortar or concrete before it has set to assist in the mechanical key for a subsequent layer.

Where cementitious or polymer repair products and systems are used it should be decided whether it is appropriate to apply a bonding primer. The use of bonding coats can reduce bond if the bond coat sets before the application of subsequent products.

Where cementitious repair products and systems are used without a bonding primer and the surface is to be pre-wetted as specified in 8.2.2, 8.2.3 or 8.2.4 for a minimum period, the surface should not be allowed to dry before application of the products and systems. However surface pores and pits should not contain water when the material is placed or bond may be diminished. An indication of this is the appearance of the surface which should be dark matt without glistening. The purpose of wetting the surface is to prevent the transfer of water from the repair product to the substrate detrimentally affecting the hydration of the repair product.

Polymer hydraulic mortars may set with a smooth polymer rich layer on the surface which is harmful to the bond of subsequent layers or surface treatment.

A.8.2.2 Hand applied mortar or concrete

Provision must be made to allow for the difference in properties between polymer mortar and concrete and cementitious products and systems. General polymer mortar and concrete have higher coefficients of thermal expansion and higher resistance to water vapour and lower resistance to fire or high temperatures than cementitious alternatives.

Polymer mortar and concrete may be used underwater or where high abrasion resistance is necessary, fast gain of strength or thin layers are required, or where it is impossible to provide curing for cementitious materials.

A.8.2.3 Sprayed concrete and mortar

Sprayed concrete and mortar can be applied by the wet or dry process

Sprayed concrete or mortar should be applied at an angle as close as possible to 90 degrees to the substrate, and at a distance of between 0.5 and 1.0m between the nozzle and the substrate.

If sprayed concrete is applied to a thickness greater than 70 mm it may be necessary to incorporate reinforcement within it to prevent the development of shrinkage cracking and to assist in mechanical bond

Care is required to avoid the formation of voids behind the reinforcement.

For sprayed concrete which has set between layers, that is not wet on wet, the surface should be cleaned by low pressure water or compressed air. Sprayed concrete does not normally require a bonding coat.

An additional non structural layer can be applied if there are special requirements for the surface of the repair material. e.g. if finished with rule or hand tools.

A.8.2.4 Cast mortar or concrete

Drainage layers on formwork surfaces prevent the formation of surface voids and decrease the water cement ratio of the surface layer.

A.8.2.5 Curing

Where it is important to avoid cracks caused by plastic or drying shrinkage, curing of hydraulic mortar and concrete (cc) is most effectively carried out by supplying an excess of water over the surface. If it is usually impractical to apply water manually throughout the required curing period but the use of perforated hoses to feed water to absorbent material (for example hessian) covered with transparent plastic sheeting is economical and very effective even under the most severe drying conditions.

During the hydration and hardening process of the concrete it is important that the temperature gradient throughout the structure is as flat as possible to avoid thermal cracking

Products and systems containing polymer modifiers (pcc) have special curing requirements because a balance must be struck between the need to retain moisture to cure the cement and the need to reduce moisture to allow film forming of the polymer component to gain strength.

A.8.2.6 Cracks and joints

[AC1] Filling cracks can be by injection, soaking or vacuum techniques. Before filling any cracks contamination such as oil or other contaminants must be removed. The tolerable amount of moisture or water in the cracks depends on the properties of the filling material. Cracks may be cleaned and dried by methods including the use of water and solvents and clean air under pressure. If cracks are injected, sealing of the cracks is usually necessary to ensure that injection can be completed without interruption. Parts of nozzles remaining in the structure should be of material which will not cause electrochemical reaction. Care must be taken that the pressure of injection does not produce further cracks or other detrimental effects to the substrate, other components or the environment. The use of thixotropic grouts may give rise to unacceptability high pressures. [AC1]

Surplus filling and sealing material is usually removed.

The equipment for soaking must ensure an adequate, uninterrupted flow of the crack-filling material until absorption has ceased.

Other methods of filling cracks are based on vacuum techniques.

If there are significant changes in crack-width during filling and hardening then the time of injection must be selected where possible to allow re-injection at the moment of maximum crack width and within the workability time of the product.

Crack filling is not appropriate if expansive reaction in the structure is likely.

Cracks should be completely filled if possible. The degree of filling can be established by taking and examining cores or ultrasonic testing - see Test No.33.

Complete filling of small cracks with a width of less than 0.1 mm is difficult to attain. Epoxy resins with a low viscosity and special fine cement/grout, may give good results. This should be proven in pre-tests.

Sealing of cracks with bandages may be preferable if cracks are contaminated, too small for filling or if longitudinal and/or shear movements are more than 25 % of the crack width. If no other information is available pre-tests may be necessary to determine the adhesion and tightness of bandages.

Cracks may require to be converted into joints if considerable changes in crack-width are expected, e.g. due to thermal effects or structural movement. New joints should be compatible with the existing joints. If reinforcement is to be cut, any harmful effects shall be taken into account, in particular with regard to the load bearing capacity and the corrosion risk. The design of the joint and use of material shall be in accordance with ENV 1992-2-4 or any other relevant EN or European Technical approval.

A.8.2.7 Surface coatings and other treatments

There is a danger of the occurrence of efflorescence when Electrochemical processes are used. Unless it is removed it interferes with the bond between the coating and the concrete.

Surface applied inhibitors can leave a surface deposit which may hinder bond of a subsequent coating.

Impregnation and hydrophobic impregnation can be applied by hand, spray, vacuum method or via a gel.

For Hydrophobic impregnation using a silane or siloxane the penetration can be improved by applying the material in two stages, wet on wet.

A.8.2.9 Plate bonding

Bonded external plate reinforcement may consist of mild steel or fibre reinforced composite or other material of appropriate standard capacity and durability. The use of stainless or high yield steel is not recommended.

Surface preparation of the concrete substrate is recommended as follows :

The surface tensile strength should be established. Weak, damaged and deteriorated concrete should be removed and replaced. Cracks wider than 0.1 mm should be filled with compatible structural repair material.

A.8.3.1 Coating reinforcement

Coatings for reinforcement are included in many repair systems. Coating on reinforcement can act as a barrier or can be used to prevent coated areas acting as an anode and so prevent corrosion of untreated reinforcement. Inhibition can also be achieved by surrounding the reinforcement with alkaline cement paste with or without a polymer modifier. If cement paste is used it should not be allowed to set before cementitious mortar or concrete is applied or placed or the bond between repair material and reinforcement may be adversely affected.

A.8.3.2 and A.8.3.3 Removal and replacement

Additional or replacement reinforcement can be fixed using mechanical connection, by welding, by lapping to existing reinforcement or by anchoring into the concrete substrate.

Reinforcement fixings or other attachments made from dissimilar metals embedded in reinforced concrete can cause rapid local corrosion of reinforcement if there is direct or indirect electrical contact between them. A similar problem can arise through electrical contact between items made from the same type of steel if they are in different environments, e.g. different concentrations of oxygen.

Care must be taken when removing or replacing reinforcement when using techniques involving the application of heat not to damage either the reinforcement or the concrete substrate.

A.9 Quality control

A.9.1 General

The personnel undertaking the execution of the protection and repair work should be suitably experienced and should possess written evidence of their competence where this is available to them.

As indicated in Clause 9 (Normative) site testing is a method of measuring the characteristics and quality required for products and systems on their arrival on site and for their performance during and after application. Site testing is also a method of measuring the condition of the structure and the substrate on which the products and systems are to be applied and the condition of the environment in which the products and systems are to be applied.

Test methods are described in EN standards but where no such standard exists tests should be carried out in accordance with ISO or National standards or in the tests or observations described in A.9.2.

A.9.2 Quality control tests and observations

Table A.2 - Guidance on acceptable maximum and minimum parameters for tests of characteristics is as follows

Test No	Characteristics	Method	Maximum and Minimum Parameter
10	Temperature of substrate	All	Depends on material but usually between 5° - 30 °C
23	Precipitation	All	Usually none but some materials can be applied to damp or wet surfaces
24	Wind strength	1.1, 1.2, 1.3, 2.1, 2.2, 5.1, 5.2, 6.1, 7.1, 8.1, 8.2, 9.1	Less than 8M/sec
25	Dew point	1.1, 1.2, 1.3, 2.1, 2.2, 4.3, 5.1, 5.2, 6.1, 7.1, 8.1, 8.2, 9.1, 11.1, 11.2	Depends on material but usually no application at temperatures less than 3 °C above dew point
33	Degree of filling of cracks	1.4, 1.5, 4.5, 4.6	80 % is normally acceptable
35	Adhesion Mortars and concrete	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.4	It depends but can never be greater than the surface tensile strength of the substrate. Site values within the range of 1.2 – 1.5 MPa for structural repair and a minimum value of 0.7 MPa for non structural repair are acceptable. Values for laboratory performance are given in prEN 1504-3:2001-03.
35	Adhesion Surface coatings	1.2, 2.2, 5.1, 6.1, 7.1, 8.1, 9.1	It depends on and can never be greater than the surface tensile strength of the substrate. Values for laboratory performance are given in prEN 1504-2:2000-03.
36	Compressive strength	3.1, 3.2, 3.3, 4.4, 5.1, 6.1, 7.1, 7.2, 7.3	Compatibility with the parent concrete is an important factor. Values for laboratory performance are given in EN 1504-3:2001-03.
44	Adhesion of crack filling material to substrate	1.5, 4.5, 4.6	It depends but can never be greater than the surface tensile strength of the substrate. Values for laboratory performance are given in prEN 1504-5:2002-01.

Description of quality control tests and observations

Test or Observation No.1. Delamination

Tapping or sounding on a concrete surface can be carried out with a light hammer or other impact echo equipment. The purpose is to detect delaminated areas of the concrete structure or loose single aggregates in the surface of the substrate.

Test or Observation No.2. Cleanliness

The surface should be checked visually for the presence of:

— hardened cement and spray fog;

— flaws, such as gravel pockets;

— efflorescence;

— powdering and sanding;

— loose particles such as dust or concrete spalling (e.g. above reinforcement);

— organic growths;

— contaminants such as oil, grease or paraffin;

— debonding agents, curing agents or residues of old coatings;

— debonding of mortar.

The presence of dust or contaminates on the surface of the substrate can be detected by visually wiping or scratching the concrete surface. An adhesive strip applied to the surface will indicate the presence of dust when removed

Test or Observation No.3. Surface Unevenness

Visual inspection will reveal the presence of cavities pores and pits on the surface of the substrate which would cause an interruption of an even thickness of a bonding or coating film.

Unevenness of substrate can be established using a steel straight edge.

Irregularities can be remedied as specified in Clauses 8.2.2, 8.2.6 and 8.2.7.

Test or Observation No.4. Roughness

The roughness may be determined with the use of a profile meter or using the Sand Area Method. This latter method is described in EN 1766 Clause 7.2. The surface texture profile method is described in EN ISO 3274 and EN ISO 4288.

Test or Observation No.5. Surface tensile strength of substrate

Surface tensile strength may be measured on site using a pull-off test analogous to EN 1542 or as given in BS 1881 Parts 201 and 207. It may be used directly on the surface to be tested or at a position on the surface which has been partially cored if strength at a specified depth beneath the surface is required. Care should be taken with the preparation of the surface and the number and position of tests so that they are properly representative.

Test or Observation No.6. Crack width and depth

Crack width may be measured by electrical or mechanical gauge on exposed structures, the most important crack characteristics (crack width and changes in crack width) are subject to weather related changes (see Test or Observation No.7). When these characteristics are determined, the following additional data should therefore be recorded:

1) date, time;

2) weather conditions i.e. air temperature, cloud cover/rain (including values on preceding days);

3) surface temperature of the component in the crack-relevant zones and in special cases also in the interior of the component.

Drilled cores can be used to determine the type and size of crack, the state of the crack and crack edges and any remedial previous measures. Drilling cores invariably represents a disturbance, and should therefore be restricted to necessary cases. Ultrasonic tests yield also good information on crack characteristics. They can be used only by properly trained and experienced personnel.

Test or Observation No.7. Crack movement

Crack widths may be measured with mechanical or electrical gauges and measurements should be given to an accuracy of at least 0.1 mm. It will usually be sufficient to compare the crack width visually with a calibrated line on a line-width rule. More experience is needed to use a crack magnifier.

Methods with differing sensitivity can be used to measure the changes in distance associated with changes in crack width as follows:

1) line width rule;

2) glass plates or strain gauges can be fixed over a crack (see BS 1881-206);

3) crack magnifier;

4) thin plaster markers can be applied by brush to the concrete surface. When the cracks in the concrete widen, cracks also appear in the plaster. Their width can readily be determined with the crack magnifier. Repeated readings to an accuracy of 0.01 mm can be used to follow slow changes in crack width, including long-term alterations. If necessary, a number of plaster markers may be applied at intervals to the same crack.

Where changes in crack width during the course of the day are observed, the relevant data must be recorded several times a day. Where changes in crack width are traffic-related, characterisation of the traffic may be necessary in order to allow more effective analyses of the results. The selected measuring periods should be such that adequate conclusions on short-term and daily changes in crack width at the planned filling time can be drawn from the results.

On superstructures of monolithic bridges and similar structures exposed to direct weathering, there are daily changes in crack width, in some cases dependent on insulation. The maximum changes are to be expected in cloudless days in the summer months, but not on days with high cloud cover and high air temperatures. At the crack width maximum, traffic influences also usually lead to extreme values of short-term crack width changes.

Test or Observation No.8. Vibration

When applying products or system it is important to observe vibration due to causes such as traffic, equipment or windy weather. To register the vibration one can use vibration measurement equipment e.g. an accelerometer. No restrictions on causes of vibration should be made if the vibration values are within the values for dynamic loads accepted by the product or systems during the application.

Test or Observation No.9. Moisture contents of substrate and cracks

The moisture content of the substrate may be evaluated by the following tests and observations:

1) Visual

The surface moisture may be observed using the following approximate guide:

- 'dry' - A freshly produced fracture surface with a depth of approximately 2 cm must not become visibly lighter in colour as a result of drying out;

- 'moist' - The surface has a matt, moist appearance with no shiny water film; the pore system of the substrate must not be water-saturated i.e. drops of water applied to the concrete substrate must be soaked up, leaving the surface matt again after a short time;

- 'wet' - The pore system may be water-saturated; there may be a surface shine on the concrete, but no free surface water.

A further visual indication can be obtained by covering the surface with a polythene film for 24 hours. If no moisture is evident the surface and sub surface can be considered dry;

2) with use of Relative Humidity Probes;

3) by measuring the electrical resistivity using the Wenner probe test and relating the measurements to absolute moisture content as measured in the laboratory. There is also a two pin conductivity test which can be related to absolute moisture content;

4) by taking site samples and testing in the laboratory.

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

Test or Observation No.10. Temperature of substrate

Measuring the temperature of a concrete or steel surface should be carried out with a thermometer made for measuring surface temperatures. If there is a need for exact measurement of the temperature of a substrate, after a suitable material for ensuring thermal contact with substrate has been applied, the measurement can be carried out as follows. The thermometer should be placed in the position for measurement in the middle of an insulating material such as a Styrofoam plate with the size of 0.5 square metre and 70 mm thick. The measurement should be carried out when the temperature is stable i.e. when the change of the temperature with the passage of time is less than 1 centigrade/5 minutes.

Test or Observation No.11. Carbonation testing

Use the test given in prEN 14630:2003-03.

Test or Observation No.12. Chloride content

The chloride content of concrete substrate may be obtained by obtaining dust samples and by subsequently testing in the laboratory by the method given in prEN 14629:2003-03.

Alternatively there are site test systems which can be used. These are based on electrochemical technology.

Test or Observation No.13 and No.14. Penetration of other contaminants and crack contamination

The concrete substrate and cracks may be contaminated by agents which cause deterioration of the substrate and repair products and systems and encourage corrosion of reinforcement. Such contaminants include carbon dioxide, chlorides, sulphates and other organic and inorganic substances. The history of the structure and its environment is likely to indicate possible contamination. If contamination is suspected samples may be taken by drilling or coring and tested in the laboratory to establish content and profiles.

Test or Observation No.15. Electrical resistivity

Resistivity of substrate and repair material may be measured by a method based on the Wenner 4 probe method of soil resistivity testing. Resistivity of repair material should be measured on the site applied material or on prepared specimens and is normally specified to be between 50 and 200 % of that of the substrate for electrochemical methods 7.3, 7.5 and 10.1.

Test or Observation No.16. Cleanliness of existing reinforcement

The required degree of cleanliness of steel reinforcement depends upon the method of repair selected. It is best judged by comparing the appearance of the cleaned steel with that defined in ISO 8501-1 eg. Sa2½ .

Test or Observation No.17. Size of existing reinforcement

The size of reinforcement should be measured mechanically to establish the cross section dimensions at positions where corrosion products have been removed to obtain the minimum cross sectional area so that structural calculations can be made and comparisons made with the specification.

Test or Observation No.18. Degree of corrosion of existing reinforcement

Loss of steel-area on reinforcement due to corrosion can be estimated by measuring mechanically. Special attention should be given to the detection of corrosion pits in the steel.

Epoxy or other impermeable coatings on reinforcement should be inspected closely as cracks or defects in the coating in combination with high chloride levels may give rise to increased corrosion at the damaged position and a reduction in bond of the coating. The reason for the corrosion is that the reinforcing steel is insulated by the coating from the protecting alkaline environment.

Corrosion can also be detected by potential mapping using half cell tests.

Test or Observation No.19. Cleanliness of reinforcing plates

Steel plates should be free of mill scale, rust, grease and other contaminants. The degree of cleanliness should be to Sa 2½ as defined in ISO 8501-1. Composite plates should be cleaned as specified.

Test or Observation No.20. Identity

Identity may by be established by means of marking and labelling in accordance with EN 1504-8:2000-10 or by written certificate. The purity of water can be established as detailed in EN 1008.

Test or Observation No.21. Ambient temperatures

Ambient temperature may be measured using thermometers. The accuracy of the reading should be at least plus or minus 1 °C.

Measurements should be made in the immediate vicinity of the works. The temperature sensor should not be exposed to direct solar radiation. Measurements should be taken sufficiently often to record changes of 2 °C and to record reducing or increasing temperature movement.

Test or Observation No.22. Ambient humidity

Ambient Humidity may be measured by the methods given is ISO 4677 1-2

Test or Observation No.23. Precipitation

Precipitation may be observed visually or if relevant recorded with the use of a gauge. It can include rain, snow, dew and spray.

Test or Observation No.24. Wind strength

Wind velocity should be measured by means of anemometer so that maximum values during application can be measured and work suspended if so specified.

Test or Observation No.25. Dew point

For the application of many polymer an other products the substrate must be dry and dew must be avoided unless otherwise specified. The dew point depends directly on the ambient relative atmospheric humidity and on the ambient temperature. It occurs only when the substrate temperature is lower than or equal to the dew point temperature.

The following table (extract of table given in ISO 4677 1-2) gives the temperatures of dew points, knowing the ambient dry temperature and the ambient relative atmospheric humidity.

Ambient dry-temperature	Dew point temperatures (°C) for ambient relative humidity between 40 and 100 % RH						
	40 %	50 %	60 %	70 %	80 %	90 %	100 %
35	19.4	23 0	26.1	28.7	31.0	33.1	35
30	15.0	18.5	21.4	23.9	26.2	28.2	30
25	10.5	13.9	16.7	19.6	20.1	23.2	25
20	6.0	9.3	12.0	14.4	16.5	18.3	20
15	1.5	4.2	7.3	9.6	11.6	13.4	15
10	-3.0	0.1	2.6	4.8	6.7	8.5	10
5	-7.0	-4.7	-2.0	0	1.9	3.5	5

The repair or protection product cannot usually be applied when the ambient dry temperature is less than 3 °C above dew point but this depends on the material (see Table A.2).

The air temperature is measured using a mercury or digital thermometer. The required accuracy is ± 0.5 °C.

For the surface temperature measurement digital electronic thermometers may be used.

Required accuracy : ± 0.5 °C.

For the air humidity assessment see Test No.22.

Test or Observation No.26. Wet thickness of coating

The method No.1 of ISO 2808 gives two methods for measuring a wet thickness: comb gauge and wheel gauge.

The first seems easier to adapt from its use for measuring paints and varnishes to use for measuring coatings of repair products. The gauge consists of a stainless steel comb, the outer teeth of which form a baseline. The inner teeth are progressively shorter so as to present a range of gaps between the teeth and the baseline, and the size of each gap can be read from a scale on the gauge. Immediately after the application of the product, the comb gauge is placed firmly onto the substrate in such a way that the teeth are normal to the plane of the surface and the gauge does not slip. The gauge is removed and the teeth are examined to determine which is the shortest one to touch the wet coating. Minimum three readings are taken in different places in a similar manner to obtain representative results over the repaired area.

A wheel gauge may also be used.

Test or Observation No.27. Consistency of concrete or mortar

In addition to the Slump, Vebe and Flow Test table test given in EN 12350 Parts 1-5 a test using a trough can be used to test the consistency of flowing concrete. Concrete mortar and grouts can be tested as specified in EN 13395-1-4.

Test or Observation No.28. Air content of fresh concrete

Use the test given in EN 12350-7.

Test or Observation No.29. Dry thickness of coating

The dry thickness of the surface coating can be measured by knowing the quantity of product applied by using ISO 2808, Method Number 2.

The thickness can also be measured by destructive means such as:

— profilemeter method given in ISO 2808;

— wedge cut method (a special apparatus is available which includes a microscope with illumination devices and cutting tool) given in ISO 2808 method 5B;

— drilling of core samples and measuring the film thickness (is more destructive and there is no standard).

Test or Observation No.30. Covering of coating

Gaps, holes and defects in the coating may be detected visually and as given in ISO 4628-1-6:2003-04.

Test or Observation No.31. Penetration of impregnation

The penetration of impregnation depends on the substrate porosity and on the product penetration ability. It is possible to get an estimation of it by knowing the quantity of product used. For that, EN ISO 2808 may be used (method No.2 : determination of dry-film thickness by calculation from film mass per unit area).

It is also possible to determine penetration by examination of cores.

Test or Observation No.32. Permeability of coating or repair material or filled cracks to water

The principle of the German Karsten Test, as for the French tests of NF P 84-402 or NF T 30-801, is to measure the volume or the weight of water penetrating per unit time into concrete by means of a glass calibrated tube previously sealed watertight to the tested surface. The diameter of the tube, depending on the standard used can be 20 mm, 50 mm, 100 mm. The height of the water column, depending on the standard used can be 100 mm, 150 mm, 200 mm.

The results obtained are:

— quantity of penetrating water during the time of the test (linear or not, limited or not);

— temperature conditions;

— moisture content of the test area.

Cracks which are filled to at least 80 % by volume and with a firm bond between concrete and sealing material can be visually taken as impermeable to water. In doubtful cases cores can be taken and penetration tests carried out as indicated EN 12390-8 and ISO 7031.

Test or Observation No.33. Degree of filling of cracks

Drilled cores are to be taken to assess the degree of filling. The cracks must be filled completely. This is defined if cracks visible on the surface of the drilled core are filled to a least 80 % by volume. Usually small-diameter cores (50 mm or less) are taken from representative sections of the filled cracks.

Ultrasonic test methods as given in prEN 12504-4:1998-07 and ISO 8047 can also give information about the state of filling. Present methods available demand expert skill and sophisticated test equipment to produce reliable results on site.

Test or Observation No.34. Thickness or cover of repair materials

Cover of concrete over reinforcement may be established by means of a cover meter which is a electromagnetic device. Accuracy expected in average site conditions should be within ± 15 % or 5 mm whichever is the greater for reinforcement cover less than 100 mm. The test methods is described in BS 1881 Part 204.

Concrete cover can also be established by taking cores and by removing repair material.

Test or Observation No.35. Adhesion of coatings, adhesive and repair material

Adhesion of coatings can be tested using the cross cut test as specified in EN ISO 2409-6 and for adhesion of repair materials a pull off test as specified in ISO 4624 and in BS 1881-201 & 207 or analogous to the laboratory tests in EN 1542. The cross cut test can be used for layers less than 0.5 mm in thickness and the pull off test for thicker layers.

Test or Observation No.36. Compressive strength

Compressive strength of original precast concrete and hardened repair concrete or mortar can be measured by means of taking cores and crushing them in accordance with Pr EN 12504-1 or with the use of a rebound hammer in accordance with EN 12504-2. When using the latter method care should be taken to ensure that the instrument is properly calibrated. The nature of the latter method and the possible variation in the surface of the concrete or mortar make it useful for indication of comparative strength rather than absolute values.

The strength of repair concrete can be established in accordance with EN 12390 1-3 using cube and crushing tests but for pc or pcc and hcc mortar it can be tested in accordance with EN 12190.

Test or Observation No.37. Density of hardened mortar or cement

[AC1] The density of hardened repair mortar or cement should be established using tests given in EN 12390-7. If the density of the original concrete is required it can be established by taking cores and measuring the weight and volume. [AC1]

Test or Observation No.38. Shrinkage, cracking in repair material

This may be observed visually and measured with a gauge. very fine cracking can be detected by wetting the surface and allowing to dry. As it dries the cracks can be seen as they retain water for a longer period then the uncracked surface.

Test or Observation No.39. Presence of cracks and voids in hardened repairs material

Voids including those caused by inadequate compaction, injection or filling and cracks may be detected by means of radiography reference BS 1881 Part 205, radar or ultrasonic pulse velocity measurement reference EN 12504-4:1998-07 and ISO 8047. Alternatively cores may be taken and visually examined.

Test or Observation No.40. Position of reinforcement

The position of reinforcement with respect to the outer surface of the concrete and to other reinforcement can be measured mechanically when concrete has been removed or by means of a cover meter as specified in BS 1881-204 when reinforcement is not visible.

Test or Observation No.41. Bond of reinforcement

The bond strength of reinforcement embedded in repair mortar or concrete may be determined using the appropriate aspects of prEN 1881:2003-06, ASTM A 944-599 of equivalent. Samples of reinforcement embedded in repair material may be tested in this way.

Test or Observation No.42. Presence of voids between bonded plates and substrate

The presence of voids may be detected by tapping or similar impact echo methods and by using ultrasonic testing as specified in EN 12504-4:1998-07.

Test or Observation No.43. Load tests

Site load tests may be required if the load bearing capacity of an element or structure has to be established after repair or strengthening.

Test or Observation Test No.44. Adhesion of crack filling material to substrate

There is no site test for measuring adhesion strength of crack filling material. However an indication of the adhesion can be established by taking cores and inspecting and by testing the cores to failure using the test specified in EN 12504-1.

Test or Observation No.45. Colour and texture of finished surface

The colour and texture of the finished surface of repairs should match as far as possible the original.

A.11 Health, safety and the environment

Particular care is advisable when dealing with dangerous and radioactive substances.

NOTE 1 Directive 92/57/EEG gives Minimum Health and Safety requirements for temporary and mobile construction sites and requirement of a health and safety plan.

NOTE 2 Construction Products Directive 89/106/EEC gives requirements for hygiene, health and safety and the environment for third parties.

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