EMACO® NanoCrete

European Standard EN 1504

A simplified, illustrated guide for all involved in concrete repair

BASF

The Chemical Company

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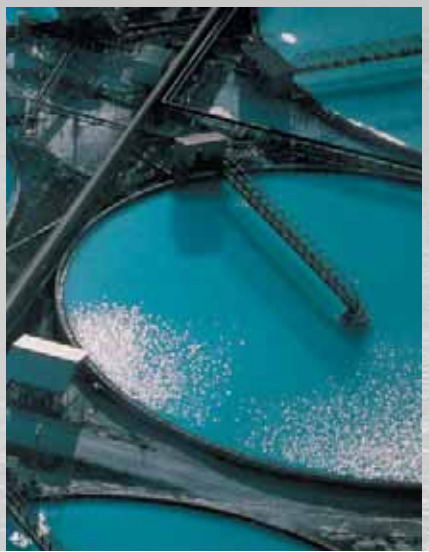


Concrete Repair Products and Systems

Over the past 30 to 40 years the industry's understanding of the technical performance requirements of concrete repair and protection products has increased significantly. The new European standard EN 1504 represents the culmination of over 15 years of consultation and committee work by professionals from all sectors of the concrete repair industry.

Repair and Protection of Concrete: An Overview of Current Practice

Concrete repair strategies – current practice

Proper maintenance of a concrete structure is essential in order to guarantee the designed lifetime, since there can be many causes of concrete deterioration. Therefore, concrete repair is a specialist activity requiring fully trained and competent personnel at all stages of the process.

Unsatisfactory understanding and diagnosis of concrete deterioration, incorrect repair specifications and choice of repair products / techniques, and the short-term “patch and paint” strategies have inevitably lead to dissatisfaction from structure owners.

A recent wide scale independent and anonymous research project clearly showed this level of dissatisfaction

“25 % of the structure owners are unhappy with the performance of the repair and protection materials within 5 years after the rehabilitation; 75 % are dissatisfied within 10 years!!!”

CONREPNET, November 2004

The European norm EN 1504 - “a recipe for success”

This new European norm EN 1504 will standardize repair activities and provide an improved framework for achieving successful, durable repairs and satisfied clients.

Accurate diagnosis and integrated solutions to meet clients' needs: a simple recipe for success!

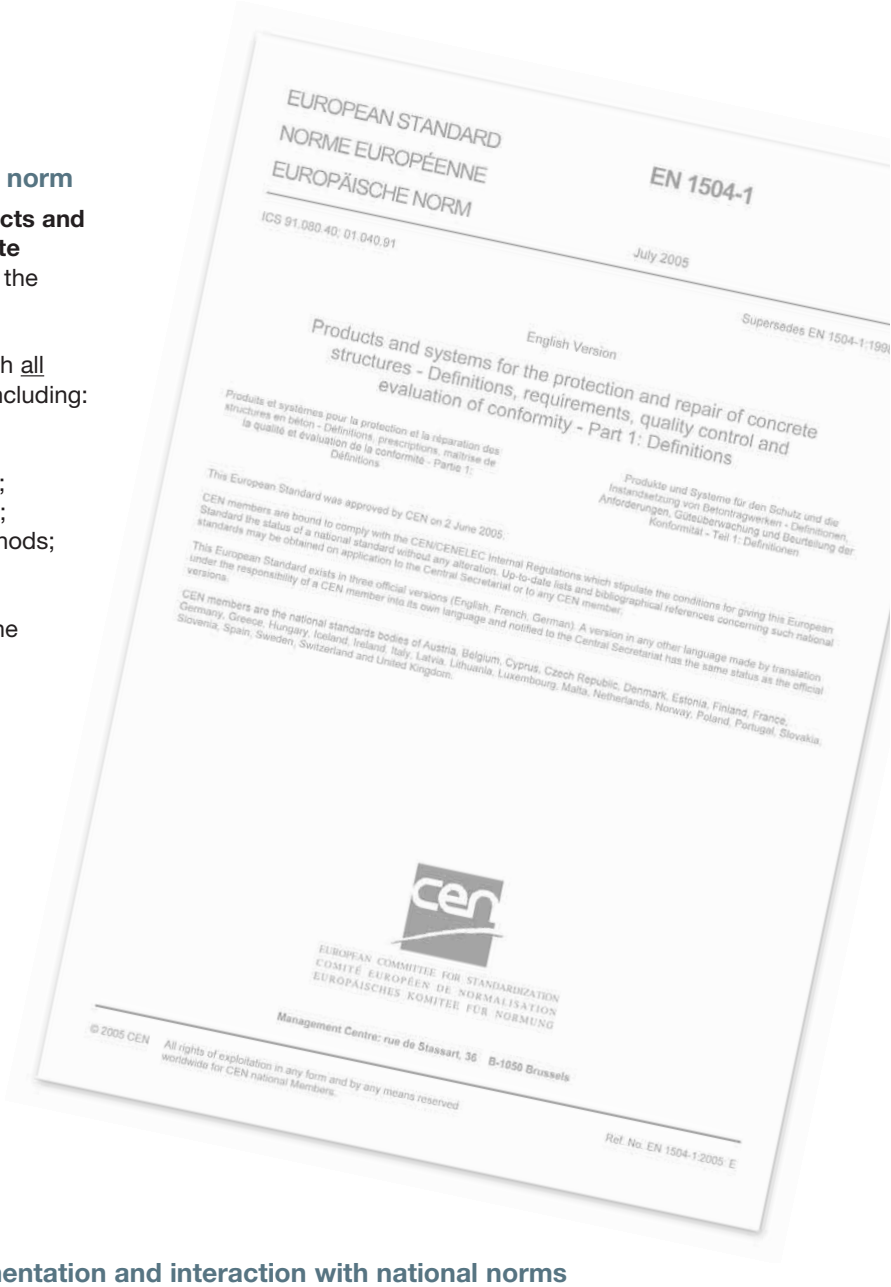
European standard EN 1504 – scope of the norm

The European standard EN 1504 is entitled: **Products and systems for the repair and protection of concrete structures,** and is aimed at all those involved with the repair of concrete.

For the first time in the industry, EN 1504 deals with all aspects of the repair and / or protection process including:

- definitions and repair principles;
- the need for accurate diagnosis of deterioration causes before specification of the repair method;
- detailed understanding of the needs of the client;
- product performance requirements and test methods;
- factory production control and evaluation of conformity, including CE marking
- site application methods and quality control of the works

When followed, this complex, but comprehensive document, should ensure good quality repair and protection work on the jobsite, which will result in increasing satisfaction of the building owners.



EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1504-1

ICS 91.080.40; 01.040.91

July 2005

Supersedes EN 1504-1:199

English Version

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

Produits et systèmes pour la protection et la réparation des structures en béton - Définitions, prescriptions, maîtrise de la qualité et évaluation de la conformité - Partie 1: Définitions

Produkte und Systeme für den Schutz und die Instandsetzung von Betontragwerken - Definitionen, Anforderungen, Güteüberwachung und Beurteilung der Konformität - Teil 1: Definitionen

This European Standard was approved by CEN on 2 June 2005.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

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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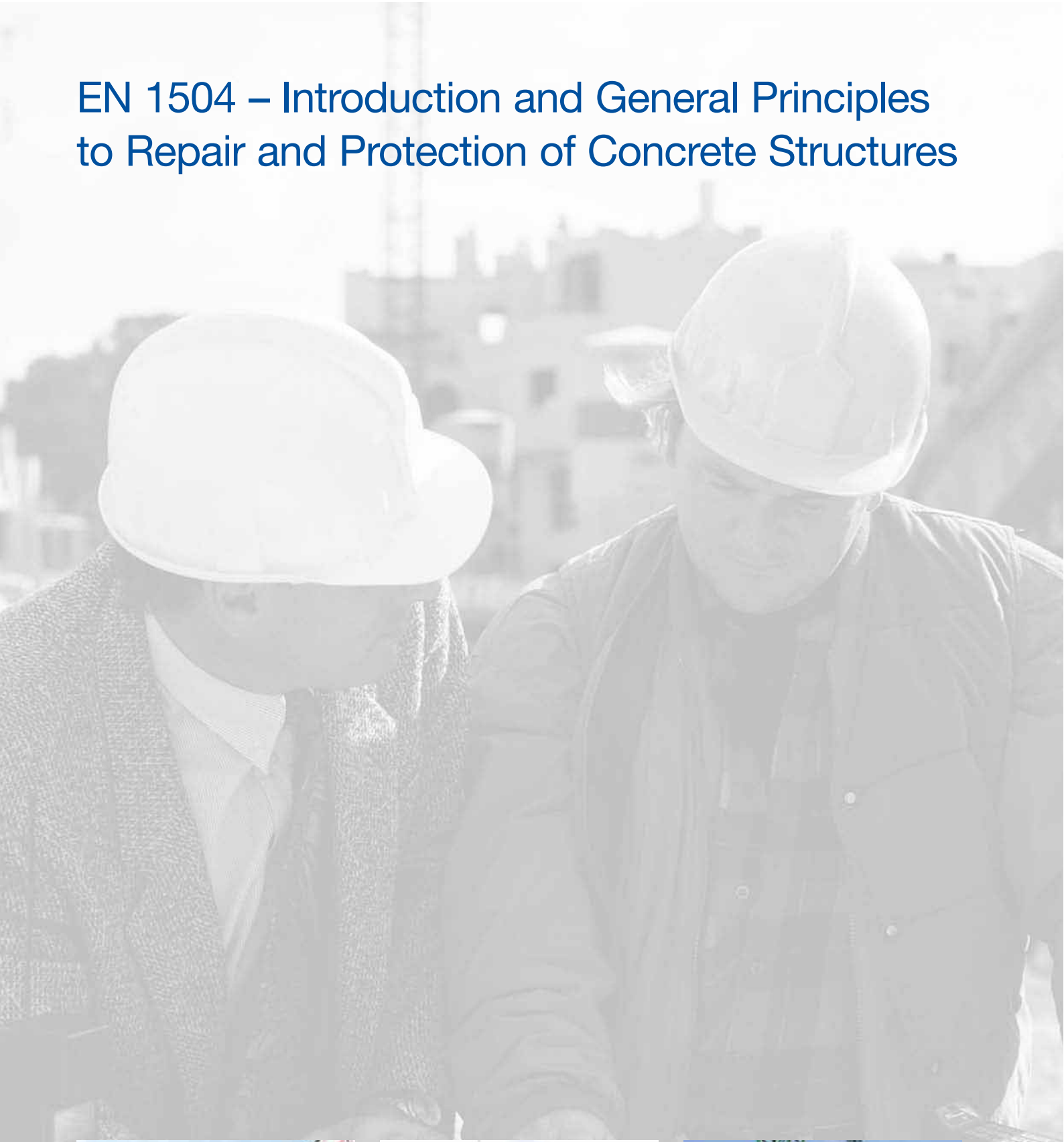
Ref. No. EN 1504-1:2005: E

Implementation and interaction with national norms

The European standard EN 1504 will be fully implemented by the CEN members (national standards bodies of 28 European countries) by January 1st, 2009.
All harmonized parts of the European standard shall be given the status of a national standard in the individual countries, and conflicting national standards shall be withdrawn by the end of the co-existence period, thus no later then December 2008.
Some local national application specifications may remain under the authority of the national specification bodies. The specification engineer needs to understand the requirements of the structure owner while meeting the local application guidelines as well as the requirements as set out by EN 1504.
Although the norm is to be implemented by the beginning of 2009, the concrete repair and protection industry has not yet fully recognized the importance of this European standard EN 1504.

This brochure will, hopefully, provide a useful, simplified overview of the standard and demonstrates BASF's commitment to supporting all our customers involved in the challenging field repair and protection of concrete.

EN 1504 – Introduction and General Principles to Repair and Protection of Concrete Structures



Reinforced concrete, has, since its first use at the end of the 19th century, become the most widely used building material and has made a huge contribution to global economic development. BASF's market and technology leading concrete admixtures allow architects and engineers to design structures with functionality, durability and aesthetic appeal.

However, even the best quality concrete subject to a wide range of atmospheric and environmental conditions requires periodic protection and repair in order to guarantee the design life of the structure. BASF's integrated repair and protection systems used as prescribed in the European standard EN 1504 are designed to provide simplicity, success and value.

EN 1504 – The Documents

The European standard EN 1504 consists of 10 parts, each covered by a separate document. This provides a resource which helps specifying engineers, contractors as well as material manufacturing companies.

It will give the structure owner an increased level of confidence as, for the first time, all issues of concrete repair and protection are addressed by a single integrated European standard.

Document No.	Description
EN 1504 - 1	Describes **terms** and **definitions** within the standard
EN 1504 - 2	Provides specifications for **surface protection products / systems for concrete**
EN 1504 - 3	Provides specifications for the **structural and non-structural repair**
EN 1504 - 4	Provides specifications for **structural bonding**
EN 1504 - 5	Provides specifications for **concrete injection**
EN 1504 - 6	Provides specifications for **anchoring of reinforcing bars**
EN 1504 - 7	Provides specifications for **reinforcement corrosion protection**
EN 1504 - 8	Describes the **quality control** and **evaluation of conformity** for the manufacturing companies
ENV 1504 - 9	Defines the **general principles** for the use of products and systems, for the repair and protection of concrete
EN 1504 - 10	Provides information on **site application of products and quality control of the works**

Each document in the standard is structured in a similar way:
- foreword
- introduction
- scope of the document
- normative references
- terms and definitions

Documents which specifically relate to products and systems deal with product specifications.
- Performance characteristics are defined, as:
  a) for **“all intended uses”**: this provides the minimum technical performance parameters which have to be met for each and every application,
     or
  b) for **“certain intended uses”**: these characteristics ensure that the repair system can withstand the many harsh conditions which may have caused the original defects
- Performance requirements define the minimum quantitative values that a product must achieve when tested under standardised test methods and conditions.

Some documents in the standard (e.g. part 8) are aimed at the product manufacturer and the CE-certification bodies:
- sampling of products
- evaluation of conformity (e.g. factory production control, certification of conformity by external notified bodies, etc.)
- marking and labelling

ENV 1504, Part 9 – General Principles

Basic considerations

This part of the EN 1504 European standard specifies the basic principles which shall be used, separately or in combination, where it is necessary to protect or repair concrete structures, above or below ground or water.

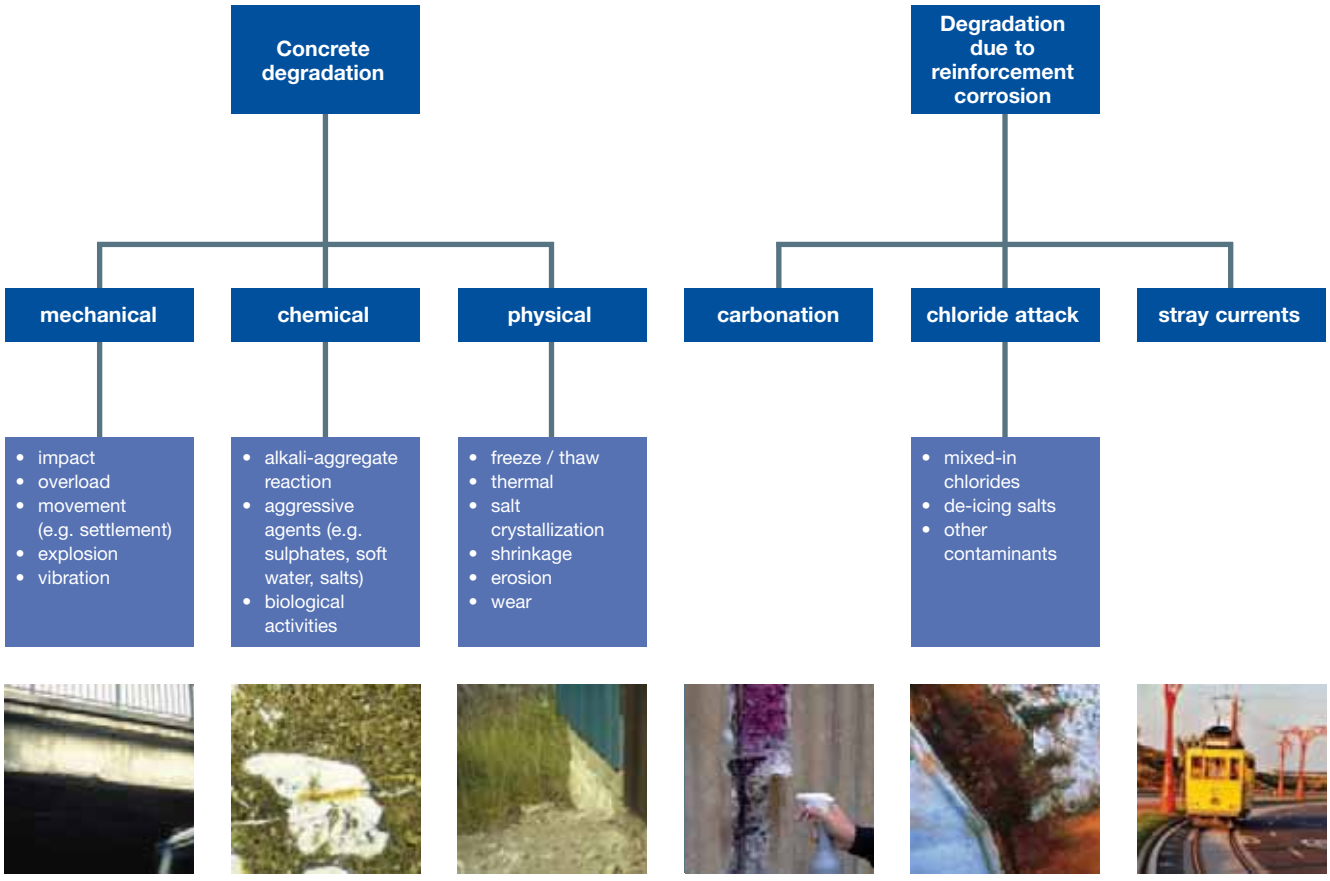
Successful repair of a structure starts with a correct condition assessment and identification of the cause of degradation. All other stages in the repair and protection process depend on these matters. ENV 1504, part 9 explicitly stresses the importance of these issues and identifies the following key stages:

- **assessment of the conditions of the structure**
- **identification of the cause of the deterioration**
- **deciding the objectives of protection and repair together with the structure owners**
- **selection of the appropriate principle(s) of protection and repair**
- **selection of methods**
- **definition of properties of the products and systems (described in EN 1504-2 to 7)**
- **specification of maintenance requirements following protection and repair**

As obvious as it may seem, EN 1504 is to be applauded for clearly stating that any repair project must identify the goals and objectives of the building or structure owners, before work commences. This includes life expectancy, future use and budget consolidation.

Common causes of defects

The nature and causes of defects, including combinations of causes, shall be identified and recorded. Many defects result from inadequate design, specification, execution and materials. Common causes of defects are represented below:



ENV 1504, Part 9 – Principles and Methods

The methods and principles described in the norm are based upon best practice and those methods shown to have a successful track record over many years. However, it must be noted that other methods may be used, or may be necessary in certain specific conditions. The methods for the repair and protection of concrete structures detailed in ENV 1504, part 9 are grouped in 11 principles which relate to

- degradation of the concrete matrix, or
- defects caused by reinforcement corrosion

Principles related to defects in concrete - principles 1 to 6

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 1 [PI]	**Protection against ingress** Reducing or preventing the ingress of adverse agents, e.g. water, other liquids, vapour, gas chemicals and biological agents.	**1.1 Impregnation**	**Masterseal®** 501
		1.2 Surface coating with and without crack bridging ability	**Masterseal®** F1120 / F1131 136 / 138 / 190 / 531 / 550
		1.3 Locally bandaged cracks (1)	**Masterflex®** 3000
		1.4 Filling cracks	**Concresive®** injection materials
		1.5 Transferring cracks into joints (1)	**Masterflex®** 462TF / 468 472 / 474 / 700
		1.6 Erecting external panels (1)(2)	*not applicable*
		1.7 Applying membranes (1)	**Conipur® / Conideck®** membranes

(1) These methods may make use of products and systems not covered by the EN 1504 series
(2) Inclusion of methods in this standard does not imply their approval

Method 1.2

Masterseal protective coatings: Available as rigid, flexible, acrylic, EP or PU material, protect against all kinds of ingress.

Method 1.4

Concresive crack injection: Rigid, flexible, foaming, EP or PU based.

Method 1.7

Conideck membranes: Chemical and wear resistant, EP, PU based, guarantee the highest level of protection.

* *Named products available in all European countries. For information on methods without listed products, or other local products contact our technical service department.*

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 2 [MC]	**Moisture control** Adjusting and maintaining the moisture content in the concrete within specified range of values.	**2.1 Hydrophobic impregnation**	**Masterseal®** 303
		2.2 Surface coating	**Masterseal®** F1120 / F1131 136 / 138 / 190 / 531 / 550
		2.3 Sheltering or overcladding (1)(2)	*not applicable*
		2.4 Electrochemical treatment (1)(2)	*not applicable*

(1) These methods may make use of products and systems not covered by the EN 1504 series
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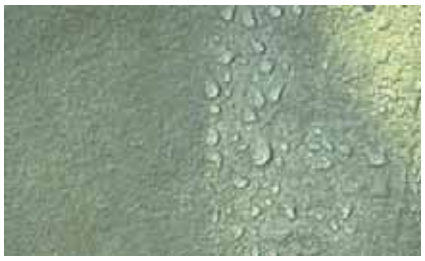
Method 2.1



Masterseal 303 hydrophobic treatment: Silane based emulsion, can be applied in many different situations or conditions.

Method 2.2

Humidity or moisture in the concrete can be controlled with Masterseal protective coatings acrylic, EP, PU based, rigid or flexible.

Method 2.2

Masterseal waterproofing coatings: Cement based, rigid or flexible.

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 3 [CR]	**Concrete restoration** - 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**	**Emaco® Nanocrete** R4 / R3 / R2 / FC
		3.2 Recasting with concrete	**Emaco® Nanocrete** R4 Fluid
		3.3 Spraying concrete or mortar	**Emaco® Nanocrete** R4 / R3
		3.4 Replacing elements	*not applicable*

Method 3.1

Emaco Repair mortars: Emaco Nanocrete R4 / R3 / R2 / FC hand applied.

Method 3.3

The highest quality and ease of application can be achieved with Emaco repair mortars, Emaco Nanocrete R4 / R3 spray applied.

Method 3.1

Emaco repair mortars: Emaco Nanocrete R4 Fluid recasting of elements.

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 4 [SS]	**Structural strengthening** 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**	**Masterflow®** grouts
		4.2 Installing bonded rebars in preformed or drilled holes in the concrete	**Masterflow®** 920SF
		4.3 Plate bonding	**MBrace®** systems and **Concresive®** adhesives
		4.4 Adding mortar or concrete	**Emaco® Nanocrete**
		4.5 Injecting cracks, voids or interstices	**Concresive®** injection materials
		4.6 Filling cracks, voids or interstices	
		4.7 Prestressing - (post tensioning) [1]	*not applicable*

(1) These methods may make use of products and systems not covered by the EN 1504 series

Method 4.3

MBrace structural strengthening: Glass, carbon, aramid sheets, laminates or rods.

Method 4.5 & 4.6

Concresive injection products: Used for force transmitting filling (load transfer) of cracks.

Method 4.1 & 4.4

Structural strengthening with Emaco Nanocrete R4 Fluid.

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 5 [PR]	**Physical resistance** Increasing resistance to physical or mechanical attack.	**5.1 Overlays or coatings**	**Mastertop®** flooring systems **Emaco®** resurfacing mortars
		5.2 Impregnation	*not applicable*

Method 5.1

Mastertop flooring systems: Cement, EP, PU based, considerably increase the physical resistance of the concrete.

Method 5.1

Mastertop coatings: Abrasion resistant, and much more.

Method 5.1

Increased physical or mechanical resistance can be obtained with Emaco resurfacing mortars.

* *Named products available in all European countries. For information on methods without listed products, or other local products contact our technical service department.*

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 6 [RC]	**Resistance to chemicals** Increasing resistance of the concrete surface to deterioration by chemical attack.	**6.1 Overlays and coatings**	**Conipur® / Conideck®** coatings **Ucrete®** flooring **Masterseal®** 136 / 138 / 185 / 190
		6.2 Impregnation	*not applicable*

Method 6.1

Masterseal 136, 138, 185, 190 chemical resistant coatings.

Method 6.1

Masterseal systems: 138, 190 – epoxy / 136 – polyurethane / 185 - epoxy-cement.

Method 6.1

Ucrete: PU-cement, chemical and temperature resistant flooring.

Principles related to reinforcement corrosion – principles 7 to 11

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 7 [RP]	**Preserving or restoring pasivity** Creating chemical conditions in which the surface of the reinforcement is maintained in or is returned to a passive condition.	**7.1 Increasing cover to reinforcement with additional cementitious mortar or concrete**	**Emaco® Nanocrete** R4 / R3 / R4 Fluid
		7.2 Replacing contaminated or carbonated concrete	**Emaco® Nanocrete** R4 / R3 / R4 Fluid
		7.3 Electrochemical realkalisation of carbonated concrete (1)	*not applicable*
		7.4 Realkalisation of carbonated concrete by diffusion	**Masterseal®** 550 / 588
		7.5 Electrochemical chloride extraction (1)	*not applicable*

(1) These methods may make use of products and systems not covered by the EN 1504 series

Method 7.1

Increasing reinforcement cover with spray applied Emaco Nanocrete R4.

Method 7.4

Realkalisation by diffusion: Using cement based Masterseal 588.

Method 7.2

Emaco Nanocrete R4 / R3: used to replace chloride contaminated concrete.

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 8 [IR]	**Increasing resistivity** Increasing the electrical resistivity of the concrete.	**8.1 Limiting moisture content by surface treatments, coatings or sheltering**	**Masterseal®** 136 / 138 / 190 / 303 / 550 **Conipur® / Conideck®** membranes

Method 8.1

Masterseal waterproofing and protective coatings.

Method 8.1

Conipur waterproofing systems: Eliminate water penetration and allow the concrete to dry out.

Method 8.1

Hydrophobic treatment using Masterseal 303.

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 9 [CC]	**Cathodic control** 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** (2)	**Masterseal®** 136 / 138 / 190 **Protectosil® CIT**(3)

(2) Inclusion of methods in this standard does not imply their approval

Method 8.1

Corrosion at the cathodic areas of the reinforcement is inhibited by the use of Protectosil CIT.

Method 8.1

Masterseal: 136 / 138 / 190 coatings limit the oxygen transport through the concrete.

Method 8.1

Masterseal coatings applied directly on the concrete to protect the underlying reinforcement.

(3) Protectosil CIT is a registered trade mark of Evonik Degussa GmbH

* *Named products available in all European countries. For information on methods without listed products, or other local products contact our technical service department.*

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 10 [CP]	**Cathodic protection**	**10.1 Applying electrical potential** [(1)]	**Emaco®** CP 10 **Emaco®** CP 30 **Emaco®** CP 60 **Emaco®** CP 15 Grout

(1) These methods may make use of products and systems not covered by the EN 1504 series

Method 10.1

Emaco CP 60 spray applied, conductive anode system: Used since 1991 in all kind of cathodic protection situations, has an expected life of > 25 years.

Method 10.1

The conductive coating Emaco CP 30: Cathodically protects reinforced concrete without significant additional dead load.

Method 10.1

Activated titanium anodes are embedded in Emaco CP 10: Specially designed for optimum compatibility with the CP anode.

Principle Nº	Principle definition	Methods based on principle	Recommended products*
Principle 11 [CA]	**Control of anodic areas** Creating conditions in which potentially anodic reactions of reinforcement are unable to take part in the corrosion reaction.	**11.1 Painting reinforcement with coatings containing active pigments**	**Emaco® Nanocrete** AP
		11.2 Painting reinforcement with barrier coatings	**Emaco®** Epoxiprimer BP
		11.3 Applying inhibitors to the concrete [(1)(2)]	**Protectosil® CIT** [(a)]

(1) These methods may make use of products and systems not covered by the EN 1504 series
(2) Inclusion of methods in this standard does not imply their approval
(a) Protectosil CIT has been independently tested in-situ by internationally accepted methods and shown to repassivate already corroding reinforcement

Method 11.1

Active corrosion protection with Emaco Nanocrete AP.

Method 11.3

Protectosil CIT, corrosion inhibitor technology.

Method 11.2

Emaco Epoxiprimer BP forms an impermeable barrier for corrosive agents.

EN 1504 – Individual Parts / Documents
Product Characteristics and Requirements

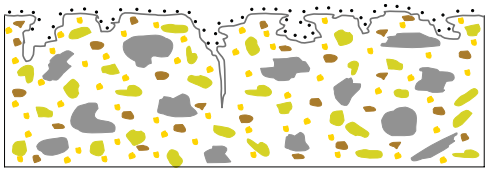
For the first time in the field of concrete repair, product performance can be compared because the European standard EN 1504 not only specifies minimum performance requirements, it also specifies and standardises testing methods.
In many situations, it is essential that products have been tested for the correct intended use and that these minimum performance criteria have been met or exceeded.

EN 1504, Part 2 – Surface Protection Systems for Concrete

The European standard gives specifications for the following surface protection systems:

Hydrophobic impregnation (H):

- is a treatment of the concrete to produce a water-repellent surface
- the pores and capillaries are internally coated, but they are not filled
- there is no film on the surface of the concrete
- there is little or no change to the appearance of the concrete
- active compounds may be, e.g. silanes or siloxnes



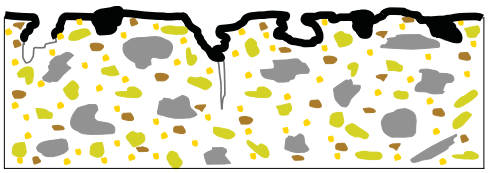
Performance characteristics for hydrophobic impregnations related to the "principles" as defined in ENV 1504, part 9

Performance characteristics	Principle 1 Ingress protection	Principle 2 Moisture control	Principle 8 Increasing resistivity	Minimum requirements (Table 3 in EN 1504, part 2)
Resistance against freeze/thaw stress (determination of mass loss)	□	□	□	Mass loss delayed with minimum 20 cycles compared to untreated
Depth of penetration	■	■	■	Class 1: < 10 mm Class 2: ≥ 10 mm
Water absorption and resistance against alkali test	■	■	■	Water absorption < 7.5 % Resistance to alkali < 10 %
Drying rate	■	■	■	Class 1: > 30 % Class 2: > 10 %
Diffusion of chloride ions	□			Subject to national standards and national regulations

■ for all intended uses □ for certain intended uses

Impregnation (I):

- is a treatment of concrete to reduce the surface porosity and strengthen the surface
- the pores and capillaries are partially or totally filled
- treatment leads usually to a discontinuous, thin film on the surface
- binders may be, e.g. organic polymers



Performance characteristics for impregnations related to the "principles" as defined in ENV 1504, part 9

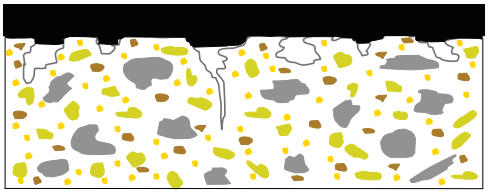
Performance characteristics	Principle 1 Ingress protection	Principle 5 Physical resistance	Minimum requirements (Table 4 in EN 1504, part 2)
Abrasion resistance		■	at least 30 % improvement in comparison with a non impregnated sample
Permeability to water vapour	□		Class I: S_d < 5 m Class II: 5 m ≤ S_d ≤ 50 m Class III: S_d > 50 m
Capillary absorption and permeability to water	■	■	w < 0.1 kg/m²·h$^{0.5}$
Freeze-thaw cycling with de-icing salt immersion	□	□	After thermal cycling / Ageing: a) No blistering, no cracking, no delamination b) Adhesion strength by pull-off - vertical: ≥0.8 N/mm² - horizontal without mechanical loads: ≥1.0 N/mm² - horizontal with mechanical loads: ≥ 1.5 N/mm²
Thunder-shower cycling (thermal shock)	□	□	
Thermal cycling without de-icing salt impact	□	□	
Clause 4.1: Ageing: 7 days at 70 °C	□	□	
Chemical resistance	□		No visible changes after 30 days exposure
Impact resistance		■	After loading no cracks, no delamination Class I: ≥ 4 Nm Class II: ≥ 10 Nm Class III: ≥ 20 Nm
Adhesion strength by pull-off test	□	■	- vertical: ≥ 0.8 N/mm² - horizontal without mechanical loads: ≥ 1.0 N/mm² - horizontal with mechanical loads: ≥ 1.5 N/mm²
Reaction to fire test	□	□	Euro classes
Slip / Skid resistance	□	□	Class I: > 40 wet tested (inside wet surfaces) Class II: > 40 dry tested (inside dry surfaces) Class III: > 55 wet tested (outside) or according national regulations
Depth of penetration	■	■	≥ 5 mm
Diffusion of chloride ions	□		Subject to national standards and national regulations

■ for all intended uses □ for certain intended uses

** for all details and special notes please consult the complete EN 1504, part 2 document for explanation of "all intended" and "certain" intended uses please refer to page 8*

Coating (C):

- is a treatment to produce a continuous protective layer on the surface of the concrete
- thickness is typically of 0.1 to 5.0 mm
- particular applications may require higher thickness than 5 mm
- binders may be, e.g. organic polymers, organic polymers with cement as a filler or hydraulic cement modified with polymer dispersion



Performance characteristics for coatings related to the "principles" as defined in ENV 1504, part 9*

Performance characteristics	Principle 1 Ingress protection	Principle 2 Moisture control	Principle 5 Physical resistance	Principle 6 Chemical resistance	Principle 8 Increasing resistivity	Minimum requirements (Table 5 in EN 1504, part 2)
Linear shrinkage	□	□	□	□	□	≤ 0.3 % (appropriate only for rigid systems with application thickness ≥ 3 mm)
Compressive strength			□	□		Class I: ≥ 35 N/mm² (polyamide wheels) Class II: ≥ 50 N/mm² (steel wheels)
Coefficient of thermal expansion	□	□	□	□	□	Rigid systems for outside application: $\alpha_T \leq 30 \cdot 10^{-6} K^{-1}$ (only for coatings with a thickness ≥ 1 mm)
Abrasion resistance			■			Weight loss less than 3000 mg wheel H22/1000 cycles/load 1000 g
Adhesion by cross-cut test	□	□	□	□	□	Cross cut value: ≤ GT2
Permeability to CO_2	■					S_d > 50 m
Permeability to water vapour	■	■			■	Class I: S_d < 5 m Class II: 5 m ≤ S_d ≤ 50 m Class III: S_d > 50 m
Capillary absorption and permeability to water	■	■	■	□	■	w < 0.1 kg/m²·h$^{0.5}$
Freeze-thaw cycling with de-icing salt immersion	□	□	□	□	□	After thermal cycling / ageing: a) No blistering, no cracking, no delamination b) Adhesion strength by pull-off crack bridging flexible systems or rigid systems - without trafficking: ≥ 0.8 N/mm² ≥ 1.0 N/mm² - with trafficking: ≥ 1.5 N/mm² ≥ 2.0 N/mm²
Thunder-shower cycling (thermal shock)	□	□	□	□	□	
Thermal cycling without de-icing salt impact	□	□	□	□	□	
Clause 4.1: Ageing: 7 days at 70 °C	□	□	□	□	□	
Resistance to thermal shock	□		□	□		
Chemical resistance	□					No visible changes after 30 days exposure
Resistance to severe chemical attack				■		loss of hardness (Buchholz or Shore) < 50 % Class I: 3 days without pressure Class II: 28 days without pressure Class III: 28 days with pressure
Crack bridging	□	□	□	□	□	Depending on classes and test conditions (e.g. climate, crack widths and dynamic movement)
Impact resistance			■			After loading no cracks, no delamination Class I: ≥ 4 Nm Class II: ≥ 10 Nm Class III: ≥ 20 Nm
Adhesion strength by pull-off test	■	■	■	■	■	crack bridging flexible systems or rigid systems - without trafficking: ≥ 0.8 N/mm² ≥ 1.0 N/mm² - with trafficking: ≥ 1.5 N/mm² ≥ 2.0 N/mm²
Reaction to fire test	□	□	□	□	□	Euro classes
Slip / Skid resistance	□	□	□	□	□	Class I: > 40 wet tested (inside wet surfaces) Class II: > 40 dry tested (inside dry surfaces) Class III: > 55 wet tested (outside) or according national regulations
Clause 4.2: Behaviour after artificial weathering	□	□	□	□	□	After 2000 h artificial weathering: no blisters, no cracks, no delamination
Antistatic behaviour	□	□	□	□	□	Class I: >10^4 and <10^6 Ω (Explosives) Class II: >10^6 and <10^8 Ω (Explosion hazardous substances)
Adhesion on wet concrete	□	□	□	□		After loading: a) no blisters, no cracks, no delamination b) Adhesion strength ≥ 1.5 N/mm² with the failure mode for more than 50 % in the concrete
Diffusion of chloride ions	□					Subject to national standards and national regulations

■ for all intended uses □ for certain intended uses

EN 1504, Part 3 – Structural and Non-Structural Repair of Concrete Structures

The European standard specifies requirements for the identification, performance (including the durability of the materials) and safety of products and systems to be used for the structural and non-structural repair of concrete structures.

EN 1504, part 3 covers repair mortars and concretes, possibly used in conjunction with other products and systems, to restore and / or replace defective or contaminated concrete and to protect reinforcement, in order to extend the service life of a concrete structure exhibiting deterioration.

The fields of application covered are in accordance with ENV 1504, part 9 as follows:

Principle 3	Concrete restoration	Method 3.1	Applying mortar by hand
		Method 3.2	Recasting with concrete
		Method 3.3	Spraying mortar or concrete
Principle 4	Structural strengthening	Method 4.4	Adding mortar or concrete
Principle 7	Preserving or restoring passivity	Method 7.1	Increasing cover to reinforcement passivity with mortar or concrete
		Method 7.2	Replacing contaminated concrete

Mortar classification according EN 1504, part 3

The European standard defines 4 classes of repair mortar **R4, R3, R2, R1**. These are then divided between structural and non-structural repairs, i.e. those applications where load transfer has to be considered in the design of the repair specification, or alternatively for cosmetic works. Furthermore the standard classifies the repair products for each type of application, in a high strength or high E-modulus and low strength or low E-modulus mortar.

This approach has been developed as a result of 30 years experience in the use of cement mortars for concrete repair. It allows the specifying engineer to select the right quality of repair material for the jobsite specific concrete quality, in order to repair “like with like”. It is well known that incompatibilities between repair mortar and host concrete can lead to premature failure, e.g. through differential thermal expansion / contraction.

The different classes do not imply bad, mediocre, good or excellent performances of the repair products. All repair materials meeting the norm are of a high quality. The norm only indicates which repair mortar class should be used for which kind of application. e.g.

- high strength concrete exposed to heavy loads should be repaired with a high strength / high E-modulus repair product, thus a class R4 mortar
- a lower strength concrete exposed to loads should be repaired with a structural repair mortar with medium strength and / or E-modulus, thus class R3
- all concretes in a non-structural situation, i.e. where loads are not to be transferred through the repair zone, can be repaired with a higher quality non-structural repair mortar, class R2

In addition to considering the appropriate classes, it is of utmost importance to recognize and specify the exposure conditions to which the product will be exposed. These exposure classes and the relevant repair mortar testing will determine the durability of the applied mortar systems. e.g.

- a mortar tested for restrained shrinkage / expansion only can not be used on structures exposed to freezing and thawing
- a mortar approved for use in freeze / thaw conditions (including salt exposure) can be used in all conditions

These additional commonly needed performance requirements, e.g. freeze / thaw resistance, should be specified, for each and every jobsite, from the performance characteristics list named “certain intended uses” in the standard.

Performance characteristics of structural and non-structural repair products*

Performance characteristics	Repair principle			
	3	3	4	7
	Repair method			
	3.1; 3.2	3.3	4.1	7.1; 7.2
Compressive strength	■	■	■	■
Chloride ion content	■	■	■	■
Adhesive bond	■	■	■	■
Restrained shrinkage / expansion	■	■	■	■
Durability - carbonation resistance	■	■	■	■
Durability - thermal compatibility freeze / thaw; thunder / shower; dry cycling	□	□	□	□
Elastic modulus	□	□	■	□
Skid resistance	□	□	□	□
Coefficient of thermal expansion	□	□	□	□
Capillary absorption (water permeability)	□	□	□	□

■ for all intended uses □ for certain intended uses

Major notes:
- carbonation resistance is not required when the repair system includes a proven carbonation resistant surface protection system
- restrained shrinkage / expansion not required if durability – thermal cycling is undertaken
- choice of thermal cycling test depending on the exposure conditions, e.g. exposure to freezing and thawing, drying and wetting, hot and cold etc.

Performance requirements for cementitious structural and non-structural repair products*

Performance characteristics	Test method	Requirement (Table 3 in EN 1504, part 3)			
		Structural		Non-Structural	
		Class R4	Class R3	Class R2	Class R1
Compressive strength	EN 12190	≥ 45 MPa	≥ 25 MPa	≥ 15 MPa	≥10 MPa
Chloride ion content	EN 1015-17	≤ 0.05%		≤ 0.05 %	
Adhesive bond	EN 1542	≥ 2 MPa	≥ 1.5 MPa	≥ 0.8 MPa	
Restrained shrinkage / expansion	EN 12617-4	Bond strength after test			No requirement
		≥ 2 MPa	≥ 1.5 MPa	≥ 0.8 MPa	
Durability - carbonation resistance	EN 13295	d_k ≤ control concrete		No requirement	
Durability - thermal compatibility freeze / thaw	EN 12617-4	Bond strength after 50 cycles			Visual inspection
		≥ 2 MPa	≥ 1.5 MPa	≥ 0.8 MPa	
Durability - thermal compatibility thunder / shower	EN 12617-4	Bond strength after 30 cycles			Visual inspection
		≥ 2 MPa	≥ 1.5 MPa	≥ 0.8 MPa	
Durability - thermal compatibility dry cycling	EN 12617-4	Bond strength after 30 cycles			Visual inspection
		≥ 2 MPa	≥ 1.5 MPa	≥ 0.8 MPa	
Elastic modulus	EN 13412	≥ 20 GPa	≥ 15 GPa	No requirement	
Skid resistance	EN 13036-4	Class I: > 40 units wet tested Class II: > 40 units dry tested Class III: > 55 units wet tested		Class I: > 40 units wet tested Class II: > 40 units dry tested Class III: > 55 units wet tested	
Capillary absorption	EN 13057	≤ 0.5 kg/m²·h$^{0.5}$		≤ 0.5 kg/m²·h$^{0.5}$	No requirement

** for all details and special notes please consult the complete EN 1504, part 3 document*

EN 1504, Part 4 – Structural Bonding

Part 4 of the European standard specifies requirements for the products and systems to be used for the structural bonding of concrete to concrete and the bonding of the strengthening materials to an existing concrete structure.

This document covers:

1. The bonding of external plates of steel or other suitable materials (e.g. fibre reinforced composites FRC) to the surface of a concrete structure for strengthening purposes, including laminating of plates in such applications.
2. The bonding of hardened concrete to hardened concrete, typically associated with the use of pre-cast units in repair and strengthening.
3. The casting of fresh concrete to hardened concrete using adhesive bonded joints where it forms a part of the structure and is required to act compositely.

Performance characteristics for structural bonding (limited to "for all intended uses")*

Performance characteristics	Principle 4 Structural strengthening			
	Repair method 4.3 Plate bonding		Repair method 4.4 Bonded mortar or concrete	
	For all intended use	Requirement (Table 3.1 in EN 1504, part 4)	For all intended use	Requirement (Table 3.2 in EN 1504, part 4)
Suitability for application application on wet substrate	—	—	■	
Adhesion plate to plate	■	Pull off test bonded joint ≥ 14 N/mm²	—	—
plate to concrete (a)	■	Pull off test bonded joint ≥14 N/mm²	—	—
hardened concrete to hardened concrete	—	—	■	Failure in concrete
fresh concrete to hardened concrete	—	—	■	Failure in concrete
Durability of composite system thermal cycling	■	a. Plate to concrete: failure in concrete b. Steel to steel: no failure	■	**After the test:** Compressive shear load at failure of concrete (hardened or fresh concrete bonding) specimens ≥ the lowest tensile strength of either the bonded or original concrete
moisture cycling	■		■	
Material characteristics for the designer				
open time	■	Declared value ± 20 %	■	Declared value ± 20 %
workable life	■	Declared value	■	Declared value
E-modulus in compression	■	≥ 2000 N/mm²	■	≥ 2000 N/mm²
compressive strength	—	—	■	≥ 30 N/mm²
shear strength	■	≥ 12 N/mm²	■	≥ 6 N/mm²
glass transition temperature	■	≥ 40 °C	■	≥ 40 °C
coefficient of thermal expansion	■	≤ 100 * 10^{-6} per K	■	≤ 100 * 10^{-6} per K
shrinkage	■	≤ 0.1 %	■	≤ 0.1 %

— Not required or relevant

* *for all details, performance characteristics for "certain intended uses" and special notes please consult the complete EN 1504, part 4 document*

(a) a value of 14 N/mm² in plate to concrete situation cannot be measured as the concrete will fail. Should be proven directly in contact with plate

EN 1504, Part 5 – Concrete Injection

Part 5 of the European standard specifies requirements and conformity criteria of injection products for repair and protection of concrete structures, used for:
- ductile filling (D) of cracks, voids and interstices in concrete
- force transmitting filling (F) of cracks, voids and interstices in concrete (i.e. situations with structural load transfer)
- swelling fitted filling (S) of cracks, voids and interstices in concrete

Crack widths considered in this EN 1504, part 5 are in the range of 0.1 mm to 0.8 mm, measured on the surface.

N.B. This part of the standard does not cover the treatment of cracks by widening and sealing them with an elastomeric sealant, external filling of cavities or preliminary injection works to temporarily stop water passage.

Concrete injection as defined in ENV 1504, part 9 is used in the following principles and methods:

Principle 1 (PI)	Protection against ingress	Method 1.4	Filling cracks
Principle 4 (SS)	Structural strengthening	Method 4.5	Injecting cracks, voids or interstices
		Method 4.6	Filling cracks, voids or interstices

The objectives of a concrete injection, as covered by this document are:
- to achieve impermeability and hence watertightness
- to avoid penetration of aggressive agents
- to strengthen the surface by strengthening the concrete

A general guide to typical chemical bases of the injection products used, (but not limited to) are as follows:
(D) Polyurethanes and acrylics
(F) Epoxies, polyesters and cement based products
(S) Polyurethanes and acrylics

Performance characteristics for ductile filling (D) of cracks (limited to "for all intended" uses") *

Performance characteristics		Requirements (Table 3.b in EN 1504, part 5)
Basic	Adhesion and elongation capacity of ductile injection products	Adhesion: declared value Elongation: > 10 %
Workability	**Injectability into dry medium** Determination of injectibility Injection between concrete tile	**Injectability class: Time to fill standard volume with standard sand** < 4 min (high injectability) for crack width 0.1 mm < 8 min (at least feasible) for crack widths 0.2 – 0.3 mm
	Injectability into non dry medium Determination of injectibility Injection between concrete tile	**Injection between concrete tile:** degree of crack filling: > 90 % (for crack widths of 0.5 – 0.8 mm)
	Viscosity	declared value
Reactivity	Workable life	declared value
Durability	Compatibility with concrete	No failure by compressive testing Lost deformation work < 20 %

Note: Only reactive polymer binder systems can be considered for "D" injection.

** for details, performance characteristics "for certain intended uses" and special notes please consult the complete EN 1504, part 5 document*

EN 1504, Part 5 – Concrete Injection (continued)

Performance characteristics for force transmitting filling (F) of cracks (limited to "for all intended" uses") *

Performance characteristics		Requirements (Table 3.a in EN 1504, part 5)
Basic	Adhesion by tensile bond (H,P)	H: > 2.0 N/mm² > 0.6 N/mm² for void filling P: cohesive failure in concrete
	Volumetric shrinkage (P)	< 3 %
	Bleeding (H)	< 1 % of initial value after 3 hours
	Volume change (H)	-1 % < volume change < +5 % volume of initial volume
Workability	**Injectability into dry medium (H,P)** Determination of injectibility and splitting test Adhesion by tensile bond	**Injectability class: Time to fill standard volume with standard sand** < 4 min (high injectability) for crack width 0.1 mm < 8 min (at least feasible) for crack widths 0.2 – 0.3 mm **splitting test:** > 7 N/mm² (P) > 3 N/mm² (H) **Injection between concrete tile:** degree of crack filling: > 90 % (for crack widths of 0.5 – 0.8 mm) adhesion requirements fulfilled as for basic characteristic
	Injectability into non dry medium (H,P) Determination of injectibility and splitting test Adhesion by tensile bond	
	Viscosity (P)	declared value
	Time to efflux (H)	declared value
Reactivity	Workable life (H,P)	declared value
	Tensile strength development of polymers (P)	> 3 N/mm² at 72 hrs at lowest allowed application temperature, thus depending on manufacturers declaration with respect to minimum application temperature and / or crack movement. Hence declared value
	Setting time (H)	declared value
Durability	Adhesion by tensile bond strength after thermal and wet drying cycles (H,P)	H: loss of adhesion: < 30 % of initial value P: cohesive failure in the concrete
	Compatibility with concrete (H,P)	H: loss of adhesion: < 30 % of initial value P: cohesive failure in the concrete

(H) Injection product formulated with hydraulic binder (P) Injection product formulated with reactive polymer binder

Note: Glass transition temperature shall be considered if the temperature of the hardened product (formulated with a reactive polymer binder) in the crack can be higher than 21 °C. Requirement: Glass transition temperature > 40 °C

Performance characteristics for swelling fitted (S) of cracks (limited to "for all intended" uses") *

Performance characteristics		Requirements (Table 3.c in EN 1504, part 5)
Basic	Watertightness	Watertight at $2 \cdot 10^5$ Pa (normal applications) Watertight at $7 \cdot 10^5$ Pa (special applications)
Workability	Expansion ratio and rate by water storage	declared value
	Viscosity - workability	≤ 60 mPa·s degree of crack filling > 95 %
Reactivity	Workable life	declared value
Durability	Sensitivity to water: expansion ratio caused by water storage	The expansion ratio shall reach a constant level during the water immersion
	Sensitivity to wet-drying cycles	After the wet - drying cycling, no change to the expansion rate after water immersion
	Compatibility with concrete	The strength properties compared to the water immersed specimens shall not differ more than 20 %. The strength properties are measured by applying a compressive load with a speed of 100 mm/min on the specimen with a stamp with conical head (Ø 20 mm; angle 60 °). The load / deformation curve is reported.

Note: Only reactive polymer binder systems can be considered for "S" injection

** for details, performance characteristics "for certain intended uses" and special notes please consult the complete EN 1504, part 5 document*

EN 1504, Part 6 – Anchoring of Reinforcing Steel Bars

Part 6 of EN 1504 European standard specifies requirements for the identification, performance (including durability) and safety of products to be used for the anchoring of reinforcing steel (rebar) as used for structural strengthening to ensure the continuity of reinforced concrete structures.

This part of the norm covers those applications as specified by Principle 4 (structural strengthening) – method 4.2 “Installing bonded rebars in preformed or drilled holes in the concrete” in document ENV 1504, part 9.

EN 1504, part 6 rightly assumes that a proper structural assessment of the structural elements to be repaired is carried out by qualified engineers, and that the choice of the products and systems to be used are based on this assessment.

To grout reinforcing steel rebars in hydraulic concrete structures, the following products are typically used:
- hydraulic binders (cement based materials)
- synthetic resins
- or, a mixture of these
  in either fluid or thixotropic consistency.

Performance characteristics of anchoring products for all intended uses *

Performance characteristics	Requirements (Table 3 in EN 1504, part 6)
Pull-out	Displacement ≤ 0.6 mm at load of 75 kN
Creep under tensile load (1)	Displacement ≤ 0.6 mm after continuous loading of 50 kN after 3 months
Glass transition temperature (1)	≥ 45 °C or 20 °C above the maximum ambient temperature in service, whichever is the higher
Chloride ion content	≤ 0.05 %

(1) For polymers (synthetic resins) only

** for details and special notes please consult the complete EN 1504, part 6 document*

EN 1504, Part 7 – Reinforcement Corrosion Protection

Part 7 of the European standard specifies requirements for the identification and performance (including durability aspects) of products and systems used for the protection of existing steel reinforcement in concrete structures under repair.
Two types of products are described: active and barrier coatings

Reinforcement protection as described in ENV 1504, part 9 is dealt with by:

Principle 11	Control of anodic areas	Method 11.1	Painting reinforcement with coatings containing active pigments
		Method 11.2	Painting reinforcement with barrier coatings

The coating system shall be selected based on an assessment of the causes of deterioration (where appropriate) and consideration of the appropriate principles and methods for protection and repair specified in ENV 1504, part 9.

The two types of coatings are described as follows:

- Active coatings for reinforcement:
  Are coatings, which contain Portland cement or electrochemically active pigments, which may function as inhibitors or which may provide localised cathodic protection. Portland cement is considered to be an active pigment due to its high alkalinity.

  Typical products: cement based reinforcement primers.

  The standard describes reinforcement preparation: Sa2 according EN ISO 8501-1, as specified in EN 1504, part 10 for use with this type of coating.

- Barrier coatings:
  Are coatings which isolate the reinforcement from pore water in the surrounding cementitious matrix.

  Typical products: polymer based reinforcement primers.

  Required reinforcement preparation for this type of coating: Sa2½ according EN ISO 8501-1, as specified in EN 1504, part 10.

NB This document does not cover the corrosion protection of pre-stressed or stainless steel.

Performance characteristics of corrosion protection products *

Performance characteristics	Requirements (Table 3 in EN 1504, part 7)
Corrosion protection: coated rebars coated plate / uncoated edge	 coated rebar free of corrosion rust creep at plate edge < 1 mm
Glass transition temperature	10 K above the maximum service temperature
Shear adhesion (coated steel to concrete)	Bond stress at a displacement of △0.1 mm: bond stress of coated rebar at least 80 % of uncoated rebar

Note: Only corrosion protection products which are known to be resistant to the alkalinity of the surrounding cementitious matrix shall be used.

** for details and special notes please consult the complete EN 1504, part 7 document*

EN 1504, Part 8 – Quality Control and Certification of Conformity

Part 8 of the European standard is specially addressed to the manufacturer and the certification institute, the so called “notified body”.

EN 1504, part 8 specifies procedures for quality control, evaluation of conformity (including initial type testing), CE-marking and labelling of the products.

Concrete repair and protection products used in buildings and civil engineering works require a system of attestation of conformity **2+**.

The conformity requirement **2+** means the following minimum tasks should be performed:

Tasks	
Manufacturer	Factory production control (FPC)
	Initial type testing
Notified body	Inspection of factory **and** of FPC
	Continuous surveillance, assessments and approval of FPC

BELGIAN CONSTRUCTION CERTIFICATION ASSOCIATION
BCCA
Rue d'Arlon 53
B – 1040 BRUXELLES

CE

EC-CERTIFICATE OF FACTORY PRODUCTION CONTROL

0749 – CPD

BC2-563-0013-0002-001

Products and systems for the protection and repair of concrete structures

Structural and non-structural repair

placed on the market by

BASF Construction Chemicals Belgium N.V.
Nijverheidsweg 89
B - 3945 HAM

and manufactured at the factory located at

BASF Construction Chemicals Belgium N.V.
Nijverheidsweg 89
B - 3945 HAM

EN 1504-3

Example of attestation of conformity certificate

Based on the above, the notified body issues a “certification of conformity”, whereas the manufacturer is responsible for the “declaration of conformity”. The manufacturer is also responsible for the affixing of the CE-marking, e.g. on the packaging, and / or product data sheets, delivery notes, etc.

- CE conformity marking, consisting of the “CE”-symbol

- Identification number of the notified body
- Name or identifying mark and registered address of the producer
- Year in which the marking was affixed
- Certificate number as on the attestation certificate

- Number of the European standard
- Description of the product

- Information on regulated characteristics

This example shows an extended version (**significantly more** than the **minimum** requirements as stated in the norm for “**all intended uses**”) of the full range of tests which have been completed.

Only classes or minimum requirements can be listed, no actual values.

CE

0749

BASF Construction Chemicals Belgium NV
Nijverheidsweg 89, B3945 Ham

06

0749 - CPD
BC2-563-0013-0002-001

EN 1504-3
Concrete repair product for non-structural repair
PCC mortar (based on hydraulic cement, polymer modified)

Compressive strength	class R2
Chloride ion content	≤ 0,05 %
Adhesive bond	≥ 0,8 MPa
Restrained shrinkage	≥ 0,8 MPa
Thermal compatibility - Freeze-Thaw - Thunder Shower - Dry cycling	 ≥ 0,8 MPa ≥ 0,8 MPa ≥ 0,8 MPa
Capillary absorbtion	≤ 0,5 $kg \cdot m^{-2} \cdot h^{-0,5}$
Reaction to fire	A1
Dangerous substances	complies with 5.4

Example of a typical CE-label

EN 1504, Part 10 – Site Application and Quality Control of the Works

For the first time, EN 1504 covers, not only product performance, it also extends into the application of the products and the complete execution of the repair works.

All successful concrete repair and protection projects are characterised by:
- careful diagnosis of the underlying causes of deterioration
- correct choice of repair method to counter the causes and reinstall the structure in line with the needs of the owner
- thorough surface preparation of the concrete substrate and reinforcing steel
- proper application of the chosen products meeting the performance requirements of the selected repair principle and method statement by trained, experienced operators
- adherence to health, safety and environmental issues before and during application

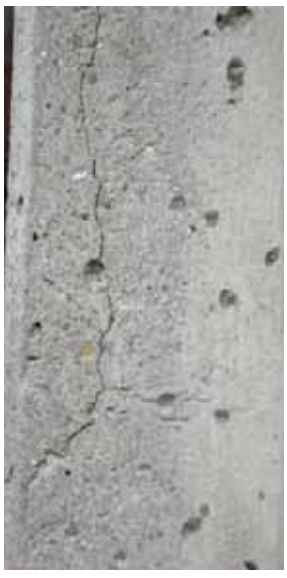
Diagnosis of the underlying causes

A full description of the methods of diagnosis is impossible, however these are the most commonly found:

1. Non destructive, physical testing
   - visual inspection: looking for cracking, rust staining, spalling etc.
   - hammer / sound testing: location of hollows or delamination
   - cover meter testing: location of, and determination of depth of cover over reinforcement
   - half-cell potential mapping: provides probability predictions of condition of reinforcement
   - corrosion current measurement: directly measures the rate of corrosion of steel
   - cracks and strain gauges: measures condition and stability of cracks

2. Chemical testing
   - carbonation depth analysis using phenolphthalein indicator solution
   - chloride ion content measurement performed on samples sourced from different locations and depths
   - microscopic analysis to determine the potential AAR activity

3. Destructive testing
   - coring samples to establish concrete strengths



Surface preparation

Concrete should be clean and sound. Soundness can be tested in-situ by direct tensile strength measurements.

Hydrodemolition at pressures ranging from 400 – 2000 bar (depending on the water quantity used) is the most effective and technically superior method for preparation as the concrete surface is left clean, textured, saturated but with no surface damage as is typically caused by high-impact methods such as bush hammering. It also avoids vibration injuries caused by long term use of hand tools. Horizontal surfaces can easily be prepared using vacuum grit blasting techniques, followed with an appropriate cleaning of the surface prior to the application of the products.

Patch repairs should be delineated with saw cuts at 90° - 135° to the minimum depth required by the repair mortar (Emaco Nanocrete products require only 5 mm).

Steel should be best cleaned to Sa2 according EN ISO 8501-1 for active primers and Sa2$^{1}/_{2}$ for two component epoxy barrier primers. The full circumference should be cleaned and the repair should extend 20 mm beyond the area of visible corrosion. Care should be taken to remove chloride / salt contamination from pitted steel.

Application of products

Manufacturers instructions must be followed in particular regarding:

- storage of goods
- necessary protection before, during and after application
- climatic conditions of temperature, humidity and dew point (especially for coatings)
- curing times and method

Trained professional operators and companies should be employed

Quality control and health & safety

A repair project must include onsite inspection and control before, during and after installation.

In-situ testing in critical situations may include:

- inspection of preparation works
- pull off tests to determine adhesive bond or surface soundness before application of the materials
- measurement of reinforcing steel
- coating inspection of wet and dry film thickness and continuity of protection
- sampling of site batched materials, etc.

When large areas of concrete are removed care must be taken to ensure structural stability and safety, by providing temporary shoring and support as necessary.
The execution of the works shall comply with the relevant local requirements for health & safety, environmental protection and fire regulations.

EN 1504 – Principles and Methods in Action: Some Typical Environments and Examples

Many repair solutions require a wide range of products. Product compatibility and performance can best be achieved by sourcing materials from a single, trusted supplier. This section gives several detailed examples of the use of the BASF range of concrete repair and protection products in accordance with the principles and methods outlined in the European standard EN 1504. In each example you will find the following:

1) Recommended investigation / diagnostic procedure (to thoroughly understand the causes of deterioration).
2) Typical expected defects to be found in the environment in question.
3) Recommended surface preparation procedures.
4) Recommended material application method statements using BASF systems with reference to the EN 1504 principle which is most appropriate for the situation described.

Indicative guidelines only. Space restrictions do not allow full specification or application methods to be given. For additional information please contact your local office of the Construction Chemicals division of BASF

Highway Bridge Structures:

Recommended investigation / diagnosis:

- Visual inspection and / or hammer testing to identify existing spalled or delaminated areas.
- Determination of condition of reinforcement especially loss of steel diameter.
- Half-cell potential (or other electronic NDT method) mapping to assess active corrosion.
- Concrete sampling to determine chloride levels and depths of contamination.
- Determine requirements of client: budget, life expectancy of repair, future loading requirements, practical considerations e.g. traffic management, access problems etc.

Typical defects found in this situation:

- High structural loading.
- Chloride contamination from de-icing salts - visible red rusting and large scale spalling.
- Joints and decking requiring waterproofing.
- Large scale surface damage of concrete crash barriers caused by freeze-thaw action.
- Structural or traffic carrying capacity inadequate.

Supporting Columns, Beams, Crash Barriers, Joints and Waterproof Decking

Possible repair strategies and recommended products:

Surface preparation

- Delineate repair zones by saw-cutting to 5 mm.
- Remove damaged and / or contaminated concrete by high power water-jetting or similar.
- Clean steel in exposed areas to Sa2 (EN ISO 8501-1).

Material application

- Replace any steel where > 30 % loss of profile using **Masterflow®** resin anchors (Principle 4 of ENV 1504 part 9). (NB do not use resin anchors if structure is to be CP protected)
- Restore passivity to steel by use of active primer **Emaco® Nanocrete AP** or high pH, impermeable, repair mortar **Emaco® Nanocrete R4** (Principle 7).
- Structural repair columns and beams: Option 1: Spray apply high strength, high modulus, expansive cement based mortar to required profile: **Emaco® Nanocrete R4.** Option 2: In areas of heavy congested reinforcement, or for enlarged areas, erect watertight formwork and recast using high flow, self compacting fluid repair mortar **Emaco® Nanocrete R4 Fluid** (Principle 3).
- Reprofiling crash barriers: Apply skim coat repair mortar: **Emaco® Nanocrete R3 / R2** (Principle 3).
- Protect and beautify with **Masterseal®** protective coating (Principle 1 & 2).
- Renew deck waterproofing where necessary with **Conideck®** elastomeric deck membrane system (Principle 1).
- Renew jointing system. Repair concrete nosings with **Emaco® SFR** or **Emaco®** T as appropriate.

Optional extra treatments / alternative systems

- Protect rest of structure by reducing corrosion rates of the steel using spray applied corrosion inhibitor (**Protectosil® CIT**) (Principles 2 & 11).
  **NB: because Protectosil® CIT prevents the formation of ring-anodes, only actual spalled or delaminated areas need to be repaired*
- Or apply appropriate **Emaco® CP** cathodic protection for 25+ years of maintenance free life (Principle10).
- Where appropriate strengthen structure with **MBrace® FRC** strengthening systems (Principle 4).
- Add additional capacity by broadening traffic lanes and strengthening cantilever, using **MBrace® Laminate** or **MBrace® MBar** Carbon fibre bars (Principle 4).

Residential or Commercial Buildings:

Recommended investigation / diagnosis:

- Visual inspection and / or hammer testing to identify existing spalled or delaminated areas.
- Determination of condition of reinforcement especially loss of steel diameter.
- Concrete sampling to determine depths of carbonation.
- Determine requirements of client: budget, life expectancy of repair, practical considerations e.g. resident access times, disruption during repair process.

Typical defects found in this situation:

- Relatively low strength concrete +/- 35 MPa.
- Carbonation in thin section pre-cast concrete panels due to low cover.
- Existing balcony deck badly designed with inadequate falls causing severe water ponding.
- Balcony deck cracked through settlement.
- Balcony decking requiring waterproofing and anti-slip coatings.
- Poor details on hand rail causing extensive spalling either because of water ingress or bi-metallic corrosion.
- Existing tiled and screed areas badly damaged.

Façade and Balcony Repair

Possible repair strategies and recommended products:

Surface preparation

- Delineate repair zones by saw-cutting to 5 mm.
- Remove damaged and / or contaminated concrete by high power water-jetting or similar.
- Clean steel in exposed areas to Sa2 (EN ISO 8501-1).

Material application

- Replace any steel where > 30 % loss of profile using **Masterflow®** resin anchors (Principle 4). (NB do not use resin anchors if structure is to be CP protected)
- Restore passivity to steel by use of active primer **Emaco® Nanocrete AP** (Principle 7).
- Reprofile balcony edge and facade areas: Option 1: Apply fibre reinforced, shrinkage compensated mortar **Emaco® Nanocrete R3 / R2** (Principle 3). Option 2: Reprofile balcony edge by erecting grout and watertight formwork. Recast using high flow, self compacting, shrinkage compensated repair mortar **Emaco® Nanocrete R4 Fluid** (Principle 3).
- Protect against CO_2 with **Masterseal® F1131** protective coating (Principle 1).
- Fill non-moving cracks with **Concresive®** epoxy injection systems (Principle 4).
- Replace defective screeds and / or re-create adequate falls with **Mastertop® 560** fast-setting screeding systems (EN 13813).
- Reset handrails ensuring no contact with reinforcing steel. Grout with non-shrink epoxy from **Masterflow®** range.
- Apply waterproof **Conideck®** elastomeric deck membrane system.

Optional extra treatments / alternative systems

- Protect structure by reducing corrosion rates of the steel using spray applied corrosion inhibitor **Protectosil® CIT** (Principles 2 & 11).
  ** NB: because Protectosil® CIT prevents the formation of ring-anodes, only actual spalled or delaminated areas need to be repaired.*
- Many residential buildings were constructed in the boom years of the 60's and early 70's with chlorides in the concrete to accelerate the construction process. Such structures can be cathodically protected using **Emaco CP** systems (Principle 10).

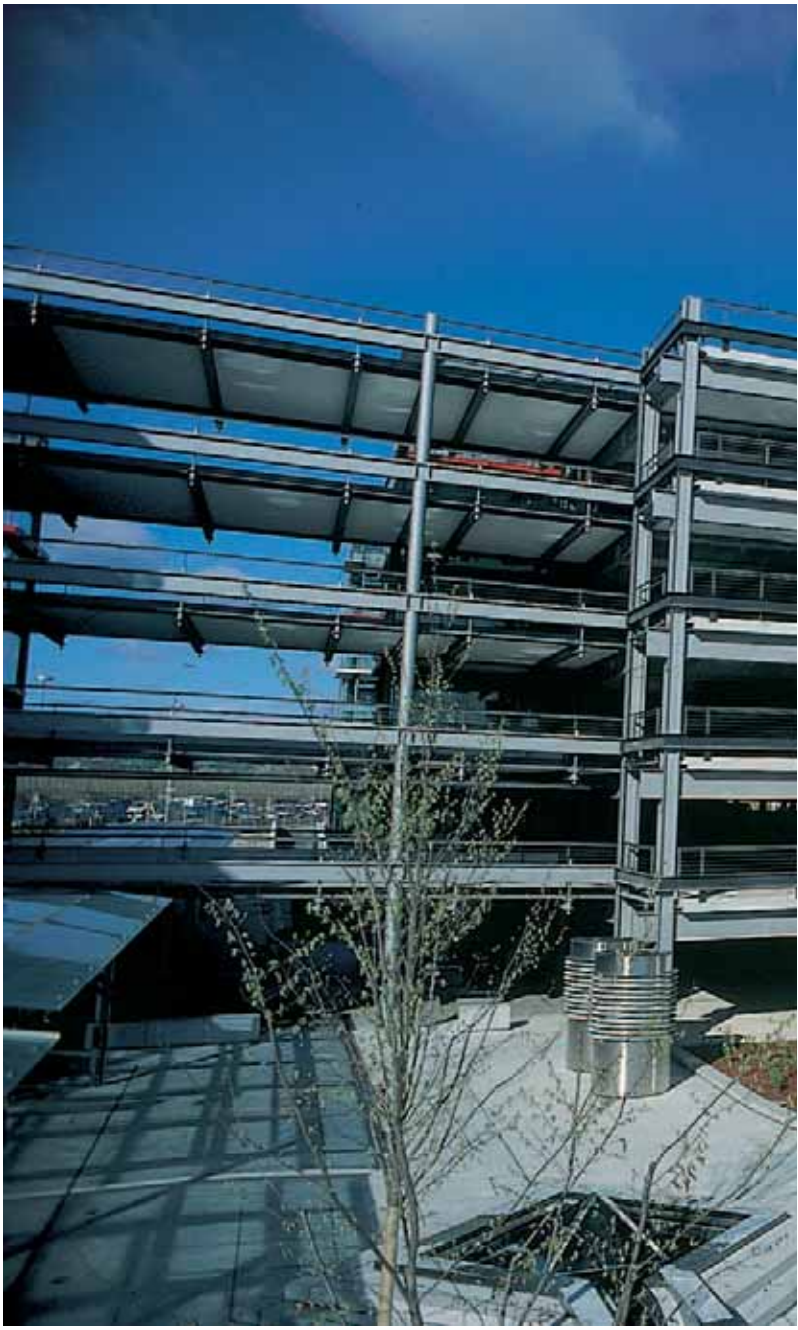
Multi-storey Car Park Structure:

Recommended investigation / diagnosis:

- Visual inspection and / or hammer testing to identify existing spalled or delaminated areas.
- Determination of condition of reinforcement especially loss of steel diameter.
- Half-cell potential (or other electronic NDT method) mapping to assess active corrosion.
- Concrete sampling to determine chloride levels and depths of carbonation.
- Determine requirements of client: budget, life expectancy of repair, practical considerations e.g. traffic management, access times / loss of revenue while car park closed etc.

Typical defects found in this situation:

- Chloride contamination from de-icing salts – visible red rusting and large scale spalling on lower levels and ramps.
- Large scale corrosion because of carbonation in thin section pre-cast concrete panels.
- Joints and decking requiring waterproofing and anti-slip coatings. Water ingress into ground floor retail units.
- Existing car park very dark and subject to constant graffiti attack.
- Existing car park is now too small.



Precast Façade Panels and Floor Slabs, Supporting Columns and Beams

Possible repair strategies and recommended products:

Surface preparation

- Delineate repair zones by saw-cutting to 5 mm.
- Remove damaged and / or contaminated concrete by high power water-jetting or similar.
- Prepare horizontal surfaces by captive grit blasting or similar.
- Clean steel in exposed areas to Sa2 (EN ISO 8501-1).

Material application

- Replace any steel where > 30 % loss of profile using **Masterflow®** resin anchors (Principle 4). (NB do not use resin anchors if structure is to be CP protected).
- Restore passivity to steel by use of active primer **Emaco® Nanocrete AP** or high pH, impermeable, repair mortar **Emaco® Nanocrete R4** (Principle 7).
- Reprofiling pre-cast panels and scab repairs: Apply shrinkage compensated, fibre reinforced, high build repair mortar **Emaco® Nanocrete R3 / R2** (Principle 3).
- Protect and beautify with **Masterseal®** anti-carbonation or anti-graffiti coating (Principle 1).
- Where necessary resurface and level large scale horizontal surfaces using Mastertop 544 (when over-coated) or **Mastertop 560 Rapid** (can be directly trafficed) fast setting high strength toppings (EN 13813).
- Provide crack bridging barrier waterproofing over retail units with **Conideck®** elastomeric deck membrane system (Principles 2 & 5).
- Protect intermediate decks with corrosion protection against water-borne chloride ingress with **Protectosil® CIT** (Principles 1, 2 & 11).
- Provide hard wearing, anti-slip intermediate deck coating **Mastertop® EP Coatings** (Principle 1& 5).
- Renew jointing system with **Masterseal® 474**.

Optional extra treatments / alternative systems

- Protect structure by reducing corrosion using spray applied corrosion inhibitor **Protectosil® CIT** (Principles 2 & 11).
  OR
- Apply appropriate **Emaco® CP** cathodic protection for 25+ years of maintenance free life (Principle10).
- Constructing additional storeys: Add additional local capacity, using **MBrace Laminate**, **MBrace® Mbar** or **MBrace® wet lay-up** FRC systems **(Principle 4).**

Marine Structures:

Recommended investigation / diagnosis:

- Visual inspection and / or hammer testing to identify existing spalled or delaminated areas.
- Determination of condition of reinforcement especially loss of steel diameter.
- Half-cell potential (or other electronic NDT method) mapping to assess active corrosion.
- Concrete sampling to determine chloride levels.
- Determine requirements of client: budget, life expectancy of repair, practical considerations of access times / loss of revenue while structure is out of commission etc.
- Agree repair option is viable rather than demolish and rebuild.

Typical defects found in this situation:

- Chloride contamination from seawater - visible red rusting and large scale spalling on underside of superstructure.
- Splash / tidal zone and immediately below water level heavily damaged by erosion and impact damages plus some corrosion spalling.
- Existing crane rail needs to be upgraded with new rails and anchoring / grouting systems.

Jetties, Sea Walls and Desalination Plants

Possible repair strategies and recommended products:

Surface preparation

- Delineate repair zones by saw-cutting to 5 mm.
- Remove damaged and / or contaminated concrete by high power water-jetting or similar.
- Clean steel in exposed areas to Sa2 (EN ISO 8501-1).

Material application

- Replace any steel where > 30 % loss of profile using **Masterflow®** resin anchors (Principle 4).
  (NB do not use resin anchors if structure is to be CP protected)
- Restore passivity to steel by use of the active primer **Emaco® Nanocrete AP** or of high pH, impermeable, repair mortar **Emaco® Nanocrete R4** (Principle 7).
- Structural repair to superstructure columns and beams: Spray apply high strength, sulphate resistant, expansive cement based mortar **Emaco® Nanocrete R4** to the required profile (Principle 3).
- Repair and protect columns below water level and in splash / tidal zone with **Wabo® A.P.E. (Advanced Pile Encapsulation) System (Principle 1, 5)**.
- Install new crane rail and fenders with chemical resistant, high strength, epoxy grout capable of high dynamic loading, e.g. **Masterflow® 648 CP Plus**.

Optional extra treatments / alternative systems

- To heavily chloride contaminated structure, spray apply 8 - 12 mm **Emaco® CP 60 Anode** cathodic protection for 25+ years of maintenance free life (Principle10).
- To lesser contaminated structures provide additional protection with **Protectosil® CIT** spray applied silane based corrosion inhibitor (Principle 11).

Industrial Buildings:

Recommended investigation / diagnosis:

- Visual inspection and / or hammer testing to identify existing spalled or delaminated areas.
- Visual inspection of surface appearance, especially on chemical attack.
- Determination of condition of reinforcement especially loss of steel diameter.
- Half-cell potential (or other electronic NDT method) mapping to assess active corrosion.
- Determination of the carbonation depth.
- Concrete sampling to determine chloride levels and depths of contamination.
- Determine requirements of client: budget, life expectancy of repair, future loading requirements, practical considerations of access times / loss of revenue while structure is out of commission etc.

Typical defects found in this situation:

- Carbonation in areas with low reinforcement cover due to complex formwork (and installation method) during casting of the concrete.
- Acid attack due to exhaust fumes of the industrial chimneys.
- Constantly wet / humid conditions.
- Deterioration due to soft water which is formed during water condensation in the cooling towers.
- Loss of surface hardness showing a powdery or non-cohesive surface due to chemical attack on the cement matrix.
- Cracking of the concrete in chimneys, requiring external structural strengthening.

Cooling Towers, Silo's and Chimneys

Possible repair strategies and recommended products:

Surface preparation

- Delineate repair zones by saw-cutting to 5 mm.
- Remove damaged and / or contaminated concrete by high power water-jetting or similar.
- Clean steel in exposed areas to Sa2 (EN ISO 8501-1).

Material application

- Replace any steel where > 30 % loss of profile using **Masterflow®** resin anchors (Principle 4).
  (NB do not use resin anchors if structure is to be CP protected)
- Restore passivity to steel by use of the active primer **Emaco® Nanocrete AP** or of high pH, impermeable, repair mortar **Emaco® Nanocrete R4** (Principle 7).
- Structural repair: Spray apply high strength, sulphate resistant, expansive cement based mortar **Emaco® Nanocrete R4** to the required profile (Principle 3).
- Where necessary, install **MBrace sheets** or **MBrace® MBar FRC systems** (Principle 4) in order to stiffen, strengthen or increase capacity of the structure.
- Protect the concrete from chemical attack using **Masterseal® 588** or **Masterseal® 185 / 190** chemical resistant membrane systems (principles 1 and 6).

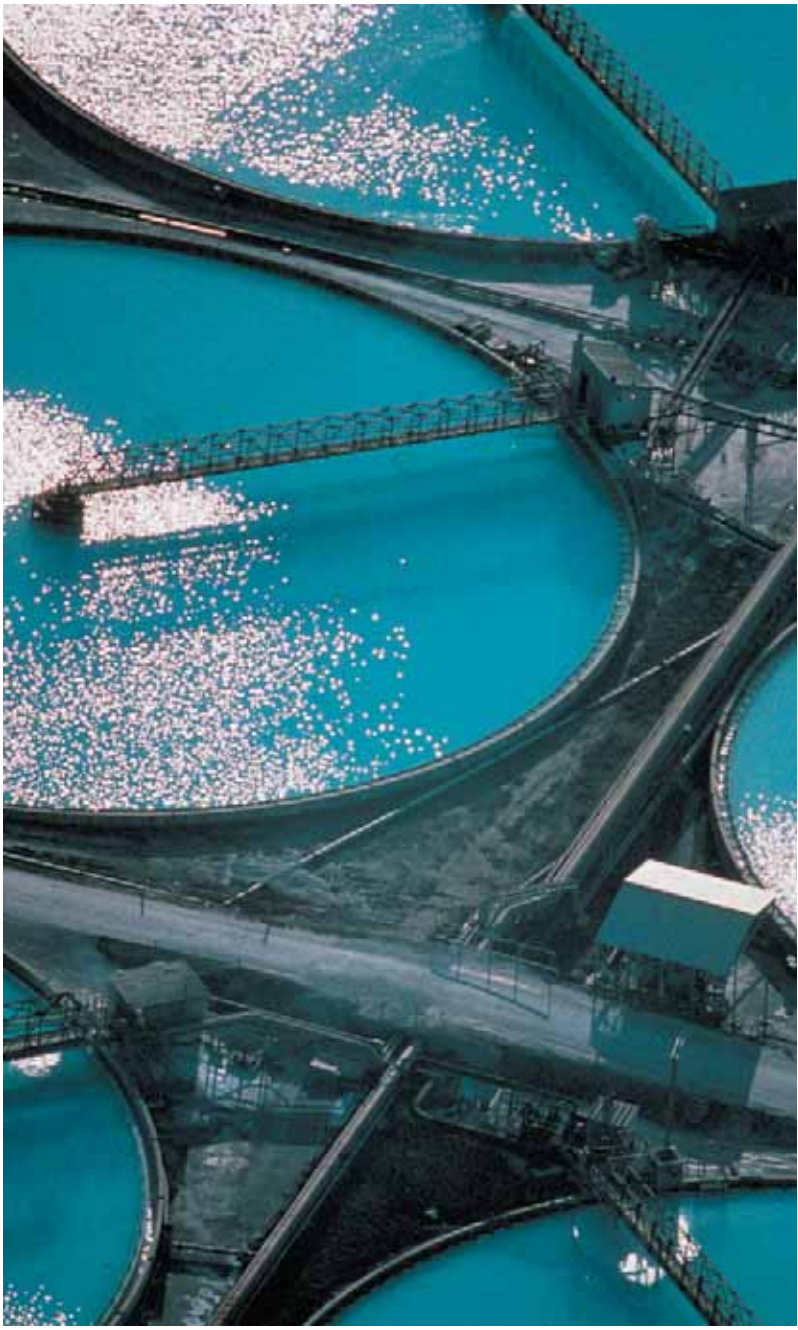
Optional extra treatments / alternative systems

- In areas of high chloride contamination, apply appropriate **Emaco® CP** cathodic protection for 25+ years of maintenance free life (Principle10).
- To less contaminated structures provide additional protection with **Protectosil® CIT** spray applied silane based corrosion inhibitor (Principle 11).

Dirty Water Industry:

Recommended investigation / diagnosis:

- Visual inspection and / or hammer testing to identify existing spalled or delaminated areas.
- Visual inspection of surface appearance, especially on chemical attack.
- Water analysis and possible changes over time.
- Determination of the water tightness of the structure, e.g. active leaks through the concrete, leaking joints etc.
- Determination of the type of degradation, i.e. organic or inorganic nature of the degradation.
- Determine requirements of client: budget, life expectancy of repair, future exposure requirements and drinking water issues, practical considerations of access times / loss of revenue while structure is out of commission etc.



Typical defects found in this situation:

- Chemical attack on the cementitious matrix of the concrete due to the low pH of the waste water.
- Sulphuric acid attack in sewage pipes or closed installations due to anaerobic transformation of sulphur dioxide gas by micro-organisms.
- Chemical degradation of the concrete due to chemicals dissolved in the waste water.
- Erosion of the concrete due to solids suspended in the water.
- Abrasion due to rolling wheels.

Waste Water Plants and Sewage Lines

Possible repair strategies and recommended products:

Surface preparation

- Delineate repair zones by saw-cutting to 5 mm.
- Remove damaged and / or contaminated concrete by high power water-jetting or similar.
- Clean steel in exposed areas to Sa2 (EN ISO 8501-1).

Material application

- Replace any steel where > 30 % loss of profile using **Masterflow®** resin anchors (Principle 4).
  (NB do not use resin anchors if structure is to be CP protected)
- Restore passivity to steel by use of the active primer **Emaco® Nanocrete AP** or of high pH, impermeable, repair mortar **Emaco® Nanocrete R4** (Principle 7).
- Structural repair to walls, floors and ceilings: Spray or hand apply high strength, sulphate resistant, expansive cement based mortar **Emaco® Nanocrete R4** to the required profile (Principle 3).
- Restore watertightness of the structure with **Masterseal®** waterproofing mortars and slurries (Principle 1 and 2) and **Masterflex® 700** or **462TF** joint sealing systems (Principles 5 and 6).
- Protect the concrete from chemical attack using **Masterseal®** protective coatings or **Conipur®** chemical resistant membrane systems (principles 1 and 6).

Optional extra treatments / alternative systems

- Install Masterseal® waterproofing linings / coatings which are approved for use in drinking water installations, where required (Principles 1 and 2).
- Cracks should be sealed with **Concresive®** injection materials before repair materials or protective coatings are installed.
- Local cracks or joints can also be bandaged with **Masterflex® 3000**, where necessary in combination with repair mortars from the **Emaco®** range.

BASF Integrated Concrete Repair Systems: Project References

Renovation of office building in Brussels (B):

Reprofiling of old concrete structure and repair of concrete beams of the balconies
Applied products: Emaco Nanocrete AP, Emaco Nanocrete R4 and Masterseal elastomeric coating

Waste water plant in Marseille (F):

Reprofiling of precast panels, waterproofing and joint sealing
Applied products: Emaco Nanocrete AP, R3 and R4, Masterflex joint sealing and Masterseal waterproofing solutions

Renovation of bridge structure in Castellòn (E):

Repairing of columns, piers and cross beams
Applied products: Emaco Nanocrete AP and Emaco Nanocrete R4

Cooling tower (SK):

Structural concrete repair and reprofiling
Applied products: Emaco Nanocrete AP and Emaco Nanocrete R4

Renovation of apartment building in London (GB):

Reprofiling of concrete structure and levelling of balcony soffits
Applied products: Emaco Nanocrete R2 and Emaco Nanocrete R3

Renovation of entrance stair of a private building (CH):

Repairing, reprofiling, waterproofing and tiling of stair steps
Applied products: Emaco Nanocrete R2, waterproofing and tiling products from BASF

EN 1504 – Product Selection Based on the Principles and Methods

Principle 1, method 1.2
Masterseal protective coatings: Available as rigid, flexible, acrylic, EP or PU material, protect against all kinds of ingress.

Principle 4, method 4.3
MBrace structural strengthening: Glass, carbon, aramid based.

Principle 7, method 7.1
Increasing reinforcement cover with spray applied Emaco Nanocrete R4.

Principle 11, method 11.3
Corrosion at the cathodic areas of the reinforcement is inhibited by the use of Protectosil CIT.

** Named products available in all European countries. For information on methods without listed products, or other local products contact our technical service department.*

Principle Nº	Principle definition
Principle 1 [PI]	**Protection against ingress** Reducing or preventing the ingress of adverse agents, e.g. water, other liquids, vapour, gas chemicals and biological agents
Principle 2 [MC]	**Moisture control** Adjusting and maintaining the moisture content in the concrete within specified range of values.
Principle 3 [CR]	**Concrete restoration** - 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.
Principle 4 [SS]	**Structural strengthening** Increasing or restoring the structural load bearing capacity of an element of the concrete structure.
Principle 5 [PR]	**Physical resistance** Increasing resistance to physical or mechanical attack
Principle 6 [RC]	**Resistance to chemicals** Increasing resistance of the concrete surface to deterioration by chemical attack.
Principle 7 [RP]	**Preserving or restoring pasivity** Creating chemical conditions in which the surface of the reinforcement is maintained in or is returned to a passive condition.
Principle 8 [IR]	**Increasing resistivity** Increasing the electrical resistivity of the concrete.
Principle 9 [CC]	**Cathodic control** Creating conditions in which potentially cathodic areas of reinforcement are unable to drive an anodic reaction.
Principle 10 [CP]	**Cathodic protection**
Principle 11 [CA]	**Control of anodic areas** Creating conditions in which potentially anodic reactions of reinforcement are unable to take part in the corrosion reaction.

Methods based on principle	Recommended products*
1.1 Impregnation	**Masterseal®** 501
1.2 Surface coating with and without crack bridging ability	**Masterseal®** F1120 / F1131 136 / 138 / 190 / 531 / 550
1.3 Locally bandaged cracks	**Masterflex®** 3000
1.4 Filling cracks	**Concresive®** injection materials
1.5 Transferring cracks into joints	**Masterflex®** 462TF / 468 / 472 / 474 / 700
1.6 Erecting external panels	*not applicable*
1.7 Applying membranes	**Conipur® / Conideck®** membranes
2.1 Hydrophobic impregnation	**Masterseal®** 303
2.2 Surface coating	**Masterseal®** F1120 / F1131 / 136 / 138 / 190 / 531 / 550
2.3 Sheltering or overcladding	*not applicable*
2.4 Electrochemical treatment	*not applicable*
3.1 Applying mortar by hand	**Emaco® Nanocrete** R4 / R3 / R2 / FC
3.2 Recasting with concrete	**Emaco® Nanocrete** R4 Fluid
3.3 Spraying concrete or mortar	**Emaco® Nanocrete** R4 / R3
3.4 Replacing elements	*not applicable*
4.1 Adding or replacing embedded or external reinforcing steel bars	**Masterflow®** grouts
4.2 Installing bonded rebars in preformed or drilled holes in the concrete	**Masterflow®** 920SF
4.3 Plate bonding	**MBrace®** systems and **Concresive®** adhesives
4.4 Adding mortar or concrete	**Emaco® Nanocrete**
4.5 Injecting cracks, voids or interstices	**Concresive®**
4.6 Filling cracks, voids or interstices	injection materials
4.7 Prestressing - (post tensioning)	*not applicable*
5.1 Overlays or coatings	**Mastertop®** flooring systems / **Emaco®** resurfacing mortars
5.2 Impregnation	*not applicable*
6.1 Overlays and coatings	**Conipur® / Conideck®** coatings **Ucrete®** flooring **Masterseal®** 136 / 138 / 185 / 190
6.2 Impregnation	*not applicable*
7.1 Increasing cover to reinforcement with additional cementitious mortar or concrete	**Emaco® Nanocrete** R4 / R3 / R4 Fluid
7.2 Replacing contaminated or carbonated concrete	**Emaco® Nanocrete** R4 / R3 / R4 Fluid
7.3 Electrochemical realkalisation of carbonated concrete	*not applicable*
7.4 Realkalisation of carbonated concrete by diffusion	**Masterseal®** 550 / 588
7.5 Electrochemical chloride extraction	*not applicable*
8.1 Limiting moisture content by surface treatments, coatings or sheltering	**Masterseal®** 136 / 138 / 190 / 303 / 550 **Conipur® / Conideck®** membranes
9.1 Limiting oxygen content (at the cathode) by saturation or surface coating	**Masterseal®** 136 / 138 / 190 **Protectosil CIT**
10.1 Applying electrical potential	**Emaco®** CP 10 **Emaco®** CP 30 **Emaco®** CP 60 **Emaco®** CP 15 Grout
11.1 Painting reinforcement with coatings containing active pigments	**Emaco® Nanocrete** AP
11.2 Painting reinforcement with barriercoatings	**Emaco®** Epoxiprimer BP
11.3 Applying inhibitors to the concrete	**Protectosil CIT**

EMACO® NanoCrete

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MBrace® - Composite Strengthening Systems
Masterflow® - Precision and Structural Grouts
Masterflex® - Joint Sealants
Masterseal® - Coatings and Waterproofing
Concresive® - Resin Based Mortars, Adhesives and Injection Systems
Conica® - Sports Flooring
Conideck® - Hand and Spray Applied Waterproofing Systems
Coniroof® - PU Based Roofing Systems
Conibridge® - PU Based Membranes to Protect Bridge Decks
Mastertop® - Decorative and Industrial Flooring Solutions
Ucrete® - Flooring Solutions for Harsh Environments
PCI® - Tile Fixing, Cement Underlays and Waterproofing Systems

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