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# Critical Examination of European Standard EN 1504 for Products and Systems for Concrete Protection and Repair

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## ABSTRACT

The European Standard EN 1504 "*Products and systems for protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity*" can be considered a real milestone for the companies involved in the rehabilitation of buildings, bridges, piers, pipelines, and other civil or industrial concrete structures.

However in some cases the examination and, even more, the practical application of the proposed guidelines are made difficult by a complicated sub-division in principles and methods, and by a confusing and repetitive layout.

The paper deals in particular with the principles and methods for the rehabilitation of concrete damage due to reinforcement corrosion, often strictly connected, anyway, to those adopted in order to rehabilitate the concrete itself.

Suggestion are given for a possible future update of the Standard, based on the personal experience of the Authors.

## INTRODUCTION

In order to plan an intervention of protection and repair for a concrete structure, which is the declared pertinence of the EN 1504 European Standard ([*] EN 1504 European Standard has been published in 10 distinct sub-documents in 2004 (parts 2-5, 8); 2005 (parts 1, 3, 10); 2006 (parts 6, 7) and finally 2008 (part 9)), one single normative or recommendation is certainly not sufficient. However, following the guidelines of a similar standard should be useful to preventively design the overall sequence of the operating steps, with the primary goal of avoiding technical mistakes and minimizing time losses and economical misjudgements.

A company intending to carry out a repair, maintenance or rehabilitation intervention should have at its disposal understandable and comprehensive recommendations, that should inevitably refer to other current normative, more specific for each repair system or class of materials.

The European Standardization Body has made a very commendable effort to offer detailed and comprehensive guidelines in this field. In particular, the subject of the standard in exam covers the correct understanding of current damages in the degraded structure; the identification of causes for such damages; the methods for testing and interpretation; the repair materials selection; the repair techniques, and the methods of protection and maintenance.

The European Standard is, as today, the only comprehensive attempt that has ever been made to cover the whole process of concrete repair and maintenance (repair strategies, repair principles and repair methods). EN 1504 is progressively replacing all existing national standards (generally of more limited impact) in Europe. No such attempt has been conceived, to our knowledge, in the U.S. or in other countries; al least, no comparable standard has been published so far.

However, in spite of the recognition of the completeness and importance of the document, end-users, and the Authors of the present paper among them, have often manifested a certain uneasiness generated by the difficulty of identifying the appropriate final solutions among the very large number of technical and procedural details put together, according to the opinion of a number of operators, with some lack of order and coherence.

Some constructive criticism to the EU Standard 1504 has already been advanced by the Danish Standards Association [Danish Standards Association, 2004], that has tried with a certain success to re-organize the technical procedures aimed to select the best rehabilitation method(s) in a more easily understandable and user-friendly document.

Even though the effort made by the Danish Standards Association is certainly to be considered a very valuable improvement and was to our opinion headed in the correct direction, still the route to the identification of the final selection of the optimal repair method for a specific case of maintenance or rehabilitation remains extremely tortuous and complex.

This paper tries to offer some indications for a possible future revision of the existing standard. These modest suggestions should not be interpreted as a criticism or denigration of the work done by the Technical Committee in charge of the compilation of the standard, that has the undoubted value of trying to put an order to the immense technical and procedural material piled up in the last decades of advances in the field of reinforced concrete rehabilitation. They are proposed instead to a public assembly in the convincement that the best rules are those that are formulated and constantly updated according to the actual and shared exigencies of involved professionals and final users, and that none of these figures should feel inadequate to the process of their constant improvement.

## SUGGESTIONS FOR THE EN-1504 EUROPEAN STANDARD

First of all, let's consider the title: "*Products and systems for protection and repair of concrete structures*".

It is the opinion of the Authors the title itself does not give an immediate and unambiguous idea of the scope of the standard. This, in principle, should rather concern the "rehabilitation" of concrete and reinforced concrete structures. A correct definition of "rehabilitation", given by a current technical dictionary, is the following: "restoration of an entity to its normal or near

normal functional capabilities after occurrence of a disabling event". Therefore, this term could be more appropriately applied to indicate all the repair/maintenance interventions concerning concrete and reinforced concrete structures that have been affected by any type of damage.

In the past two decades three EU Projects were dedicated to the issue of the degradation of reinforced concrete structures: COST 509 "Corrosion and protection of metals in contact with concrete", COST 521 "Corrosion of steel in reinforced concrete structures", and COST 534 "New Materials and Systems for Prestressed Concrete Structures"; final conclusions of the actions are reported in [Cox et al. 1992], [Cigna et al. 2003] and [COST534, *in press*]. In those frames, all interventions aimed to maintain the structures in a safe and appropriate condition, thus assuring an adequate service life, were simply indicated as "maintenance". "Maintenance", as a general term, does not include but is indeed included within the term "rehabilitation", and therefore would not be totally adequate, even if more readily understandable than the terms "protection" and "repair". The word "protection", on the other side, does not seem to be the most appropriate, since it also includes all the so-called preventative measures that are suggested at the design stage in order to prolong as much as possible the service life of the structures, or to comply with the initial specifications.

Let's come now to the Standard layout: the document is sub-divided into 10 Sections:

*Part 1: Definitions.*
*Part 2: Surface protection systems for concrete*
*Part 3: Structural and non structural repair*
*Part 4: Structural bonding*
*Part 5: Concrete injection*
*Part 6: Anchoring of reinforcing steel bar*
*Part 7: Reinforcement corrosion protection*
*Part 8: Quality control and evaluation of conformity*
*Part 9: General principles for the use of products and systems*
*Part 10: Site application of products and systems and quality control of the works*

It can be easily observed that Part 1 only reports introductory definitions, while Parts 8 and 10 concern quality control and site application. Parts 2-7 describe the products and systems suggested for the repair and protection of the concrete structures. In fact, only Part 9 reports at last the general principles and the methods for the use of such products and systems.

It would have been much more useful and functional to the readability of the document to start with the indication of the principles and methods and then describe the products whose use is suggested for each method.

On the same line of the interesting comments and proposal made by the Danish Standards Association mentioned before, a proposal for a reorganization of the EN 1504 is described below.

**First step: Assessment of defects and their causes**

It seems that a very important issue in the overall process of rehabilitation is totally disregarded by the examined standard, that is the fundamental preliminary stage of damage identification.

The types of damage affecting a reinforced concrete structure should be identified through registration, analysis and evaluation of the present condition of the structure itself. In practice (reference to other relevant Standards should certainly be indicated) the most appropriate chemical, mechanical, structural, and electrochemical tests should be mentioned in order to identify the exact cause(s) of the damage. Moreover, wherever possible, the collection of background very important data for the assessment of the damage should be prescribed: age and typology of structure, structural details of the elements, results of loading tests and of periodical inspections, repairs already performed in the past can all represent a set of very valuable preliminary information.

It is important at this stage to classify the assessed damage causes in one or more of those reported, as a potential example, in the Table 1, very similar to that suggested by the Danish Standards Association.

**Second step: Options**

Undoubtedly very correct, even if unfortunately frequently disregarded by users, is the list of the options offered by the Standard to the person responsible for the structure, among which he needs to select the most convenient. The list of the options, integrated with some additions, as also suggested by the Danish Standards Association, is reported in the Table 2.

**Third step: Selection of the most convenient principles of rehabilitation**

Once it has been decided to proceed with the "strengthen and repair" option, the user should be guided to the selection of the most suitable principles of rehabilitation to be adopted for the specific type of damage.

Very useful, and in some way innovative, is the definition of all the potential principles of protection and repair (or rehabilitation) offered in the Table 1, Part 9, of the Standard, together with the specification of "Examples of Methods based on the Principle", and whose main column ("Principles") is reported here in Table 3.

**Table 1 – Classification of the causes of damage identified through the assessment of the defects**

| |
|---|
| Penetration of aggressive substances |
| Cracks due to load, shrinkage, etc. |
| Alkali-silica reaction |
| Freeze-Thaw |
| Collision, erosion, abrasion, etc. |
| Overloaded concrete |
| Too low pull-off strength |
| Lack of concrete cover |
| Reinforcement corrosion due to carbonation |

| |
|---|
| Reinforcement corrosion due to chloride ingress |
| Reinforcement corrosion due to stray current |

**Table 2 – List of the intervention options among which to decide after the assessment**

| |
|---|
| Abstain from immediate rehabilitation and wait for a (specified) period. |
| Renewed analysis, i.e. an evaluation based on a static calculation, e.g. a probabilistic analysis (probability analysis) of the load-carrying capacity of the concrete structure. This may lead to downgrading of the performance of the structure (reduce serviceability load). |
| Test loading of the structure components involved. |
| Prevent or reduce further decay (e.g. demolition of the concrete and corrosion of reinforcement) without actual improvement (i.e. strengthening) of the concrete structure. |
| Improve or strengthen the entire structure or some of its components. |
| Replace the entire concrete structure or some of its components. |
| Demolish and not replace the entire concrete structure. |
| Strengthen or repair and protect all or part of the concrete structure; |

**Table 3 – Principles of protection and repair proposed by the Standard (Table 1, Part 9)**

| **Principles of protection and repair related to defects in concrete** | |
|---|---|
| P1 | Protection against ingress |
| P2 | Moisture control |
| P3 | Concrete restoration |
| P4 | Structural strengthening |
| P5 | Increasing physical resistance |
| P6 | Resistance to chemicals |
| **Principles of protection and repair related to reinforcement corrosion** | |
| P7 | Preserving or restoring passivity |
| P8 | Increasing resistivity |
| P9 | Cathodic control |
| 910 | Cathodic protection |
| P11 | Control of anodic areas |

It is evident however that in the mentioned table, in spite of the caption stating: “Principles and methods related to defects in concrete”, there is actually no real connection between the listed

"Principles" and the specific type and cause of damage assessed for the structure. Thus, the unguided selection of the Principle is left to the operator, that will need to autonomously correlate the results of preliminary damage identification procedures with the potential optimal options for rehabilitation.

In order to fill the mentioned gap, we propose in Table 4, also laid up with the valuable aid of the report of the Danish Standards Association, the suggested combination, maybe still not complete, between the causes of damage and the principles proposed by the Standard, as it comes from the experience of the authors.

**Table 4 –Causes of damage and relevant principles suggested for the rehabilitation**

| | |
|---|---|
| Penetration of aggressive substances | P1, P3, P6, P7, P8, P10 |
| Cracks due to load, shrinkage, etc. | P1, P4 |
| Alkali-silica reaction | P2, P3 |
| Freeze-Thaw | P2, P3 |
| Collision, erosion, abrasion, etc. | P3 |
| Overloaded concrete | P4 |
| Too low pull-off strength | P5 |
| Lack of concrete cover | P7 |
| Reinforcement corrosion due to carbonation | P1,P2, P7, P8, P10 |
| Reinforcement corrosion to chloride ingress | P3, P4, P7, P8, P9, P10, P11 |
| Reinforcement corrosion due to stray current | P10 |

**Forth step – Selection of the most suitable method(s)**

As mentioned before, for each "Principle" to be adopted, several "Methods" are suggested, and are listed in the Table 1 of the Part 9, and very briefly discussed in the Annex A - (Informative) "Guidance and background information" of the same Part 9.

Only some of the Parts 2-7 that describe the products and systems make reference to the above "Methods" and this is certainly the most important deficiency of the Standard in its present form. This in fact creates serious disconformities between sections of the same document, generating confusion in the user. The document of the Danish Standards Association has attempted a correction to this inconsistency introducing in its Chapter 6 "Choice of repair materials and systems" a very quick description of all principles and methods. Here again, however, it seems that the title of the chapter is not entirely consistent (if the term "system" is given the meaning of "two or more products which are used together, or consecutively, to undertake repair or protection of concrete structures", as defined in the Part 1 of the EN Standard), since as a matter of fact most of the Methods refer to the choice of technical solutions rather then choice of materials. In the E-annexes of the mentioned document, the principles and methods are described in more detail, and the same approach should have bee used, to our opinion, in the EN 1504.

**The issue of sustainability: a hole in the standard.**

Some properties of the repair products and systems are indicated in the standard (part 9, point A.7) as "required for compliance with the principles of protection and repair". Among those, the standard mentions the issue of "Health, safety and environment" and states that "the specification for protection and repair shall comply with the requirements of relevant health and safety, environmental protection and fire regulations. Where there is a conflict […] use shall be made of alternative repair principles or methods".

No more specific reference is made in the standard to the issue of sustainability. No specific remind to the concept is made among factors to be considered when choosing a management strategy. Recycling demolition materials is neither suggested nor proposed as a potential approach.

## CONCLUSIONS

In conclusion, the end-user (owner, or maintenance/renovation company) could be much more comfortable if an European Standard could give an ordered and complete information concerning the decision making tree, that is concisely reported in the Figure 1.

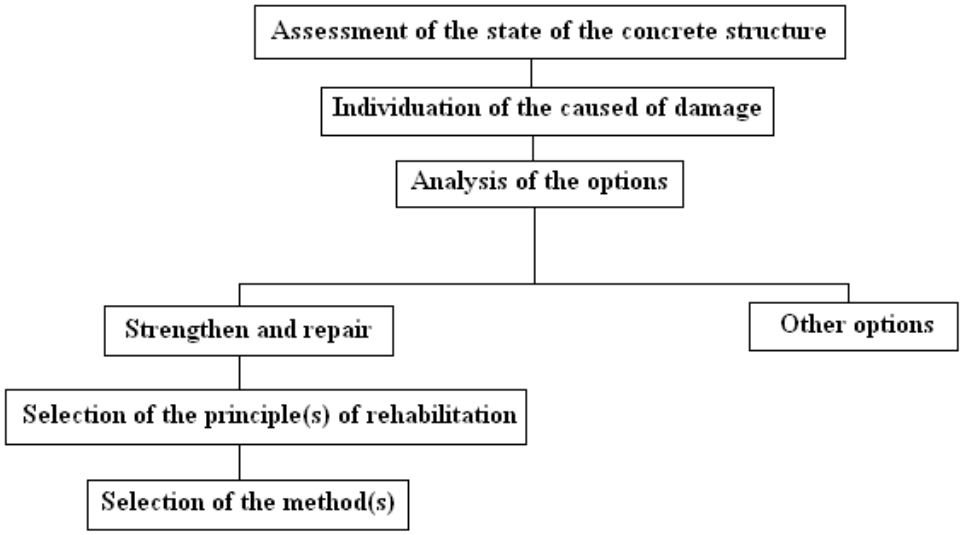


**Fig.1 – Decision Making Tree**

Since the Authors of this paper work passionately in the field of corrosion and protection of the concrete reinforcement, they found unsatisfactory the information concerning the interventions

for the repair of the reinforced concrete structures when the main cause of the damage has been recognized as corrosion.

In some cases, as for Methods 7.3 “Electrochemical realkalization of carbonated concrete”, 7.5 “Electrochemical chloride extraction”, and 10.1 “Applying an electrical potential” it can be sufficient refer to the existing relevant EU Standards. For the other methods, some of which are actually questionable or definitively known today as scarcely efficient (such as 11.3 “Applying corrosion inhibitors in or to the concrete”), a short description of the products and application should be given.

It is common experience that international standards concerning particularly complex issues, such as that dealt with in EN 1504, need a long time to be completed and a lot of constant work to be tested on site, upgraded and made ever more clear and easy to apply. In the present case, it is undeniable that the initial effort made by the experts in the compilation of the recommendations has been huge and that the document remains as of today the only existing operative guide to decision making in the wide field of maintenance and rehabilitation of reinforced concrete structures.

The brief and limited suggestions given in this paper arose from the very practical difficulties encountered in taking specific decisions for identifying on the basis of EN 1504 specific repair interventions in case of very particular real cases (columns of a church, beams, columns and slabs of several buildings).

Authors had the feeling that sharing their own difficulties and perplexities could have been useful to improve the process of ordering and outlining the scientific and technical knowledge available on the subject, thus more rapidly achieving results of common utility.

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