

DURABLE TRANSPORT INFRASTRUCTURE IN ATLANTIC AREA

NETWORK



maintenance and repair of transport infrastructure

TECHNICAL GUIDE

Summary

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Summary

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

CONTRACT Nº: 2008-1/049

PROJECT TITLE: Durable Transport Infrastructure in the Atlantic Area
Network

ACRONYM: DURATINET

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General introduction

The main purpose supporting the preparation of this Technical Guide (TG) by the network DURATINET was to create a useful tool with relevant guidelines for the maintenance and repair of structures, which could be accessible to all end users involved in structures maintenance.

The TG contains the most relevant concepts and guidelines for steel and reinforced concrete structures, concerning the following aspects: general methodologies for managing and assessing structures; materials durability requirements; deterioration processes of structural materials and the damage/defects created; testing techniques for diagnose of deterioration and defects quantification, and the repair methods.

The establishment of requirements for materials durability in the structural conception and design, as their compliance during construction, is one of the most important aspects to improve the structures durability. The durability requirements and associated durability indicators are intrinsically dependent on the material and exposure conditions. The knowledge of the several deterioration processes and consequent distress and defects associated to each structural material is very important for a correct diagnosis and selection of adequate evaluation testing techniques. The evaluation of structures condition requires the use of specific methodologies and testing techniques. It is also very important to adopt an adequate system for classification of structures defects either due to deterioration or coming from construction faults not repaired before conclusion of construction works.

The classification of symptoms and defects adopted in this TG can be used not only for the identification and unambiguous classification of the defects observed during inspection of structures with different structural materials (steel, concrete, masonry...), but also to do damage quantification to support the structural assessment and decisions on structure maintenance/repair.

In this TG, the adopted classification method contains six basic types of defects or damage symptoms, which can be used for all type of structural materials.

The testing techniques for structures inspection for the correct diagnosis of deterioration processes concern the most relevant NDT to apply in-situ during routine or special inspections of structures, and DT tests to be performed in laboratory on samples collected from structures. The selection of testing techniques is mainly dependent on the deterioration process and respective damage progress present in each case and, in specific cases, it requires experts' advice.

The repair methods comprise several methods that have been developed for steel and reinforced concrete, aiming to mitigate the progress of deterioration and the effect of induced defects, to restore the original integrity of the structures and to protect against the recurrence of the defect. In addition to the several methods presented, some guidelines concerning the repair method selection are also given. Nevertheless, it must be emphasized that the repair methods selection may be a complex subject, requiring the materials durability expert advice to the structural repair designer.

Two versions of the TG were developed. One is an extended version for presentation in a book series or in a CD-ROM digital support with the development of detailed guidelines concerning each subject treated. The other is a user-friendly web version for a wide dissemination of the TG, with the objective of presenting the main guidelines treated in the extended version of the TG in an interactive format, especially designed for a web application, which has the following address: <http://duratinet.org/techguide>.

TG extended version

The Technical Guide (TG) extended version presents the guidelines concerning the maintenance and repair of infrastructure in a book series of 12 volumes or in a CD-ROM digital support. It is divided in four parts:

PART I - Introduction to technical guide

PART II - Structures Management

PART III - Steel Structures

PART IV - Concrete Structures

The subjects treated and the guidelines included in each part are described as follows:

PART I – Introduction to technical guide

It is composed by an introduction, in which the objectives of the network DURATINET are summarised and some evidences are presented to support the relevance of this network for the Atlantic Area. The general structure of the TG is presented and some relevant details are given concerning the two versions of the Technical Guide: the extended version of TG (prepared for hard copy or digital publication) and a short and interactive user-friendly version prepared for free internet access. It is also presented a list of the most frequently used keywords in the fields covered by the TG, their definition and respective translation into the other three official languages (French, Portuguese and Spanish) of the countries participating in the DURATINET consortium.

PART II – Structures Management

This part consists of two volumes containing general recommendations concerning the maintenance and structural assessment methodologies, mainly devoted to transport infrastructure:

Vol. 1 - General guidelines

This volume provides general guidelines for planning activities related with the inspection, maintenance, assessment and testing of steel and concrete structures within the framework of an infrastructure asset management system.

Vol. 2 - Maintenance and structural assessment

This volume intends to provide some general guidelines for addressing a multi-level hierarchical methodology for infrastructure management by managing risks, probabilistically expressed as the reliability of a structure over time. The probabilistic description of evolving risks takes account of uncertainties in: material properties, actions on the structure, lack of

knowledge regarding structural behaviour, measurements related errors and human fallibility. This uncertainty should be modelled probabilistically and quantified to assess its impact on final decisions. Engineering recommendations are focused on managing risks by managing the probability of failure. The consequences are broadly used for classification of the performance markers and the structure. Sometimes, additional socio-political or economic markers affect such decisions over which usually there is little engineering control. The key idea is to ensure the safety of a network of structures in its entirety above minimum prescribed levels of service at any given time within its lifespan.

PART III – Steel Structures

The Part III of the TG contains five volumes, each one concerning one of the following relevant topics associated with the maintenance and repair of steel structures.

Vol. 1 - Durability factors and requirements

This first volume contains general information about the main durability factors associated with exposure conditions influence and steel properties and describes the most relevant durability parameters for structural steel in different environmental conditions.

Vol. 2 - Deterioration

This volume presents a review of steel deterioration processes, including a general description of the two most important ones and the main factors and causes associated with each deterioration process along with the defects occurring in steel structures. The classification of defects and damage symptoms is presented for the defects associated to each deterioration process. Finally, the common faults associated with steel or protection systems observed in steel structures during their service life, especially in bridges, are also described. In the annex, a toolbox is present for each type of defect according with the classification system adopted in this TG.

Vol. 3 - Testing techniques

It presents the testing techniques applicable to the evaluation of steel and protection system conditions during inspections of steel structures for defects detection, for materials damage causes evaluation and to assess their relevance to the structural performance of the deterioration process installed. Non-destructive techniques (NDT), for *in-situ* application, or destructive (DT) or semi-destructive techniques for laboratory evaluation are considered. For the different testing techniques presented, the information provided comprises its adequacy and limitations, reliability and accuracy, the needed equipment, the training level of operators and also some data about costs and time of execution. Finally, some considerations are made concerning the main aspects to consider on the testing techniques selection for the steel structures assessment.

Vol. 4 - Repair methods

This volume presents in detail the repair methods employed in structural steel to repair steel defects or to limit the progress of some deterioration processes, in particular of those caused by fatigue or stress corrosion. Whenever possible, the reference to standard methods is presented. For each repair method, a general description of the method fundamentals is presented by discussing its adequacy and limitations in mitigating or repairing the defects induced by the main steel deterioration processes or by accidental damage actions. As a conclusion, this volume provides some guidance on the selection of the repair method, in accordance with the type of deterioration process and the defects induced, and also on the supervision requirements during application and monitoring of the service life.

Vol. 5 - Protection systems

It contains details on the methods used for steel protection against corrosion, in particular by coatings or cathodic protection. Where possible, reference is made to European Standards, for example, concerning coatings, reference is made to standard series EN ISO 12944 (part 1 to 8). Recommendations about steel surface preparation for coating application are also provided. For

each protection method, a general description of the fundamentals of the methods is presented and suggestions are made about their adequacy and limitations as regards steel protection according to environmental corrosivity class. As a conclusion, this volume presents some recommendations for the selection of the protection methods and makes some considerations about the repair of existing protection systems for steel structures according to the existent level of damage.

PART IV – Concrete structures

This part of the TG contains four volumes, each concerning a main topic relevant for the maintenance and repair of reinforced concrete structures.

Vol. 1 - Durability factors and requirements

It contains general information on the main durability factors, the environmental exposure conditions and the concrete properties related with relevant durability requirements for reinforced concrete, in accordance with harmonized European standards for concrete and EUROCODE 2. It also contains a short review of the national specifications developed in each of the five countries involved in DURATINET taking into account the specific local conditions. Some examples of the durability requirements adopted in the design of bridges recently constructed are also presented.

Vol. 2 - Deterioration

This volume presents a review of the main deterioration processes of reinforced concrete due to concrete deterioration or reinforcement corrosion, including a short description of the deterioration mechanisms and the main factors and causes associated with each deterioration process and the most common defects induced. The classification of defects and symptoms of damage adopted in this TG was also applied to reinforced concrete structures for the identification and classification of defects resulting from the several deterioration processes that occur during service life and also from design or construction defects. This classification can be used during inspections of reinforced concrete structures, mainly bridges, to support the

structural assessment and decision-making on structural maintenance and repair. In the annex toolboxes are present for each type of defects according the adopted classification.

Vol. 3 - Testing techniques

This volume contains short presentations of the most relevant testing techniques, classified as either non-destructive (NDT) or as destructive or semi-destructive requiring extraction of samples (DT), which can be useful on inspection of reinforced concrete structures to evaluate the defects and to quantify their distribution and extent of deterioration processes. For the different testing techniques presented, the following aspects were taken into account: adequacy and limitations; reliability and accuracy; the test equipment available; the training level of operators and some relative information about costs and execution time. Some general considerations are also made about the most relevant aspects to consider on the testing techniques selection for the structures condition evaluation.

Vol. 4 - Repair methods

It contains information about the repair and protection of reinforced concrete, mainly following the general methodology adopted by the EN 1504 standards series. Methods for preparation, removal and cleaning of concrete are also described. For each repair method or preventive protection technique, a general description of its fundamentals is presented and comments are made about its limitations in repairing the defects or in mitigating the degradation processes directly related with the concrete or the reinforcement. Some tentative guidelines are also given concerning the adequacy and repair method selection and the monitoring requirements during and after repair.

TG Web version

For a wide dissemination of the TG, a user-friendly and interactive web version was prepared based on the contents of the Technical Guide extended version, which has the following address: <http://duratinet.org/techguide>.

This web version presents a general organization similar to the TG extended version, but the several subjects are presented in a synthetic and interactive format adequate for an internet application. The home page and main structure of this interactive format are presented in Fig. 1.

After entering the application, the user has access to general information about the context of this TG and has the option to select subjects by keywords or to move along the application by choosing one of the three main options: structures management, concrete and steel structures. After choosing the type of structure, several options: deterioration, testing, repair and protection (this last only for steel), can be selected (Fig. 2). After choosing one of these main items, a list of several sub-titles is shown, from which one option could be selected by the user. If one of these sub-titles is selected, a toolbox is open, which contains a description of a defect, deterioration process, testing technique or of a repair or a protection method, depending of the option done. When a toolbox is open, two pages appear in the monitor the left page contains the main content of the toolbox and the right side page contains relevant pictures, videos or tables with data on the subject correspondent to the toolbox open. Fig. 3 presents an example of a toolbox with the two pages and the corresponding images. Each toolbox has zoom for better visualization and print options.

One group of toolboxes were prepared for each main option: deterioration process, defect, testing technique and repair or protection method. In each toolbox, it can be found links to other associated toolboxes (Fig. 4 and Fig.5) concerning one of the other alternative main options (deterioration, defects, testing techniques and repair). Each group of toolboxes corresponding to a main subject has one identification colour for easier access.



Fig. 1. Home and main enter pages of TG WEB version.



Fig. 2. Page layout after selection the structural material-steel.

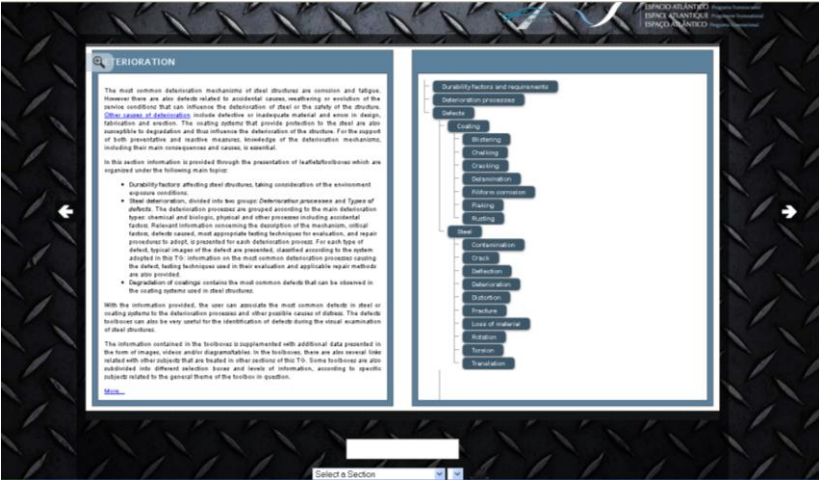


Fig. 3. Page layout after, e.g., the selection of steel structures and the options: deterioration and defects.

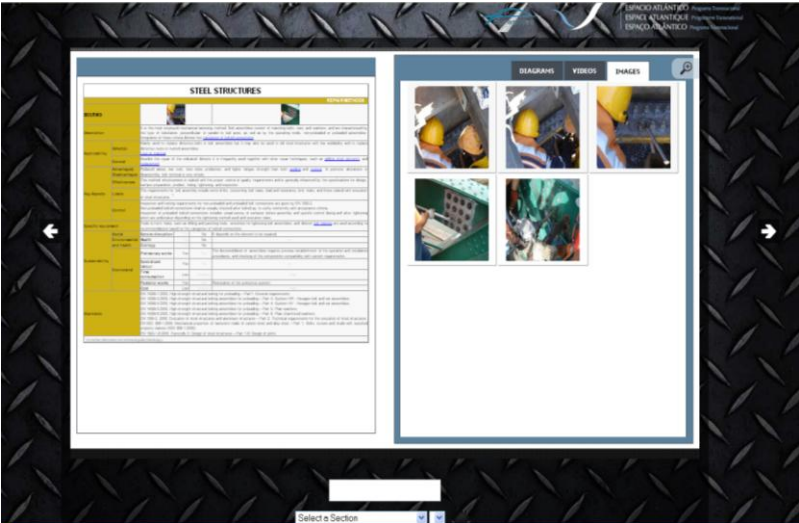


Fig. 4. An example of the presentation of a toolbox (corresponding to the selection order: steel structures/repair/methods for repairing damage in steel elements/bolting).

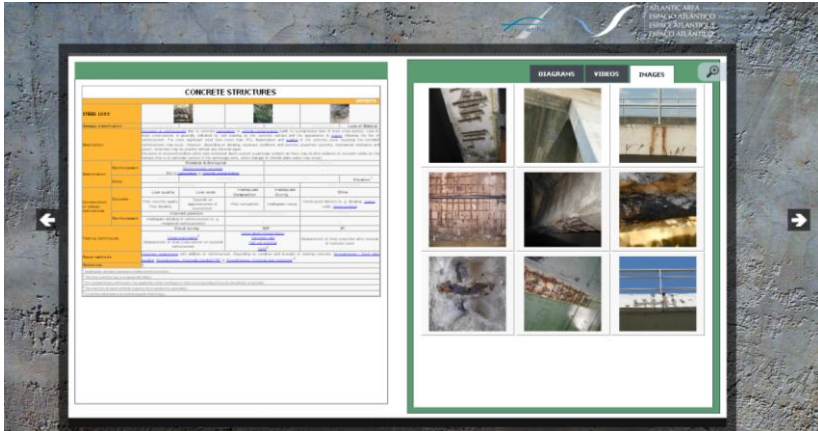


Fig. 5. An example of the presentation of a toolbox (corresponding to the selection order: concrete structures/deterioration/defects/steel loss).

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Selection of the repair methods

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