RILEM State-of-the-Art Reports

Denys Breysse *Editor*

Non-Destructive Assessment of Concrete Structures: Reliability and Limits of Single and Combined Techniques

State-of-the-Art Report of the RILEM Technical Committee 207-INR

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Volume 1

RILEM, The International Union of Laboratories and Experts in Construction Materials, Systems and Structures, founded in 1947, is a non-governmental scientific association whose goal is to contribute to progress in the construction sciences, techniques and industries, essentially by means of the communication it fosters between research and practice. RILEM's focus is on construction materials and their use in building and civil engineering structures, covering all phases of the building process from manufacture to use and recycling of materials. More information on RILEM and its previous publications can be found on www.RILEM.net.

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The information in this and similar reports is mostly pre-normative in the sense that it provides the underlying scientific fundamentals on which standards and codes of practice are based. Without such a solid scientific basis, construction practice will be less than efficient or economical.

It is RILEM's hope that this information will be of wide use to the scientific community.

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Foreword

The concrete infrastructure requires regular assessment in order to ensure public safety and cost-effective maintenance practice. Assessment efforts verify in place material condition, damage state, position and geometry of elements, and other important structural characteristics. But carrying out assessment using direct sampling and observation of the structure is not always possible, especially if the volume of interest is hidden from view (e.g. in the case of internal damage), or physical access to the structure of interest is restricted, or cost concerns limit the number of direct material samples that are collected.

Non-destructive assessment and evaluation (commonly referred to as NDE) methods offer the ability to infer material condition information where direct sampling and inspection cannot. And because of the inherent non-damaging nature of the tests, many data can be collected and analyzed without fear of adversely affecting the structure under inspection. In NDE, a specific test phenomenon is applied and the response observed. Many different types of phenomena are appropriate for application to concrete structures, including mechanical wave propagation, electromagnetic wave propagation, penetrating radiation, optics, magnetism, and heat transfer. Application of the phenomenon (test method) and observation of the observed phenomenological response (test data) is often made difficult by the nature of the concrete infrastructure: large size, difficult access and naturally inhomogeneous material makeup.

The nature of these different phenomena varies and the quality of the connection between the structural or material characteristic of interest also varies, depending on the particular phenomena employed and the characteristic of interest. After some processing, the observed test data, or in some cases judicious combination of distinct types of data, are normally related to the material property or structural condition of interest through some model. But in some cases, this connection is established by a normative rule set. For example, X-rays are less likely to be absorbed or scattered along paths within a solid that contain air-filled cracks and voids; thus we can infer that those paths that reveal higher X-ray intensity contain high amounts of such damage.

We see, though, that NDE relies on an indirect connection between the observed phenomena, and the quality of the NDE result depends as much on the appropriateness and rigor of this connecting model as on the quality of the observed phenomenological data themselves. Thus appropriate and effective use of NDE needs balance of requirements:

(i) hold suitable understanding of the underlying phenomenon,
(ii) deploy testing methods correctly, and
(iii) apply appropriate and accurate connecting models in the analysis.

This book aims to give the reader a solid basis in these three areas, with a particular focus on complimentary combinations of techniques to improve the assessment.

Chapter 1 introduces the basic concepts of NDE, lays out the associated challenges for concrete structures and offers some solution to these challenges through the combination of distinct techniques. Chapter 2 provides fundamental information about the underlying phenomenological basis and principles of individual NDE test methods. Chapters 3 to 7 are devoted to specific NDE applications: strength assessment, defect characterization, geometry (thickness or depth) determination, etc. The last chapter revisits the concepts of test method combination, thoroughly addressing the challenges associated with NDE and proposing future directions of development.

This book is authored and edited under the auspices of RILEM Technical Committee 207-INR, which is made up of internationally recognized experts in the field. From this book, the reader will obtain a thorough background in nondestructive assessment methods that is essential for effective application to concrete structures, representing technical progress in an important field.

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This book is the result of a five year work of RILEM TC 207-INR. More than thirty core members and corresponding members were involved in twelve meetings and contributed to this report. They contributed either as "main authors" coordinating a chapter of the book, as contributors to these chapters or as reviewers. Their list is following. The name of authors and contributors is specified at the beginning of each chapter.

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Contents

Chapter 1
Non destructive assessment of concrete structures: usual combinations of techniques

Denys Breysse[1]

1 Non-destructive assessment of concrete: objectives and key challenges

Condition assessment of building materials is critical when reassessing existing structures, since material ageing can result in performance loss, degradation of safety, and maintenance costs. For these reasons, the use of non destructive testing (NDT) has become more common to assess the condition of existing reinforced concrete structures. The first part of this book shows the range of NDT methods that are available, which show some sensitivity to concrete properties or defects. Their use has become more common to assess the condition of existing reinforced concrete structures. When detecting or suspecting of a possible pathology, e.g. after visual inspection, the usual approach with application of NDE is the following:

(a) to identify first the roots of the problem,
(b) to know if there is a possible evolution of damage and, if any, at what rate, and
(c) finally to know what is the severity level of the problem, its location and extent.

Much research has been aimed to developing techniques and data processing. Some standards have been developed for individual techniques and reference texts have been produced on individual problems, like strength assessment (EN 13791 2007). Some authors have also tried to synthesize the capabilities of techniques with

[1] Vincent Garnier, Martin Krause, Patrice Rivard, Felicita Pires and John Popovics have also contributed to this chapter.

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