CON REP NET
OVERVIEW OF A THEMATIC NETWORK ON PERFORMANCE BASED REMEDIATION OF REINFORCED CONCRETE STRUCTURES

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ABSTRACT

With over 50% of Europe’s annual construction budget being spent on refurbishing and remediating existing structures, the owners of buildings and infrastructure now require greater certainty in the performance of rehabilitated concrete structures in order to manage their assets more effectively. This has generated a requirement for industry to deliver more durable and effective repairs to concrete structures.

To help address these issues, a thematic network on the performance based remediation of reinforced concrete structures has been established, known as CON REP NET. This European-funded network was launched in Madrid in February 2003. It aims to improve the performance of rehabilitated concrete structures by looking at past, present and future circumstances.

Information about concrete durability and remediation issues has been collected from industry and research. Problems and barriers to achieving durable rehabilitated concrete structures are being identified, which will allow new avenues for industry and researchers to pursue to be proposed.

This paper describes the objectives of the network, how it is being delivered, and how members have been participating in the ongoing work of the network.

1. INTRODUCTION

Economic and social development is placing increasing demands on Europe’s infrastructure, yet there are resource and budgetary limits to how much new construction can take place. Remediation and refurbishment of existing buildings, structures and facilities is therefore critical to maintaining an effective operational infrastructure. It is estimated that over 50% of Europe’s annual construction budget is spent on the remediation and refurbishment of existing structures; a figure that is certain to increase as the existing infrastructure ages. One aspect of these works is the repair and remediation of concrete structures.

Unfortunately premature failure of some repairs and lack of certainty in some aspects of the performance of rehabilitated concrete structures increases the difficulty for building and infrastructure owners managing their assets. There is a desire to improve aspects of the durability and effectiveness of repairs to concrete structures. A better balance must be struck between ensuring longevity (with the attendant impacts on cost, environmental and societal issues etc) and shorter-term financial considerations. These are issues that exist for all construction materials.
Concrete can be subject to a number of deterioration processes. Problems caused by the corrosion of reinforcement in deteriorating concrete structures are widely encountered across Europe and are recognised as a major limitation upon durability of many existing structures. Other forms of deterioration due to processes such as frost action and alkali-silica reaction are less widespread in their occurrence, but no less significant in their effects. Premature failure of repairs and lack of certainty in the durability and performance of some repaired concrete structures affects Europe and many parts of the world.

There is a need for reliable information on which remediation processes are most effective and to allow identification and promotion of current best practices. It is also necessary to devise improved remediation strategies and methods in order to get better value for the money spent and the resources applied.

Furthermore there is a need to undertake cost-effective remediation of large numbers of public buildings and other national facilities. For example, in the Czech Republic alone it is estimated that works on dwelling blocks will cost some €2.5 billion over the next 25 years. This situation provides both a challenge and an opportunity to the European concrete remediation industry.

By recognising and encouraging the take-up of the most effective remediation processes and by promoting current best practices, the network should encourage the more cost effective application of resources to the task of extending the useful life of existing concrete structures.

The adoption of a performance-based approach to remediation would provide a more rational approach that should not inhibit innovation and could provide a strong stimulus to future development. There are potentially large gains to be made. For example, it has been estimated that the application of performance concepts to new construction could reduce total construction costs by as much as 25% in the long term (PEBBU Project, Competitive and Sustainable Growth Programme, 2000).

To help address these issues the European Commission, under its Framework Programme 5, has given financial support for a period of 4 years (2002 – 2006) to establish the CON REP NET thematic network on the performance based remediation of reinforced concrete structures. This paper provides an overview of the scope and focus of the project and aims to increase awareness of the thematic network.

2. NETWORK OBJECTIVES AND ACTIVITIES

Collaborative working within the network is helping foster technological co-operation between research centres, universities, knowledge and industrial organisations and property owners primarily within Europe, but also with participants from around the world. This approach is helping marshal expertise from different technical disciplines and backgrounds to address the technical and socio-economic problem of improving European-wide delivery of durable and effective repairs to concrete structures.
Such collaborations are encouraging the transfer of technology and knowledge, enhancing focus on customer requirements and should contribute to improvements in the level of European technology applied to these matters.

The network is seeking to achieve delivery of improvements in the performance of rehabilitated concrete structures by looking to the past, at the current and to future circumstances by:

- Involving stakeholders throughout the supply chain.
- Cataloguing the performance of previously rehabilitated concrete structures and seeking to identify the technical, environmental, cultural, commercial and process issues influencing this.
- Mapping RTD activities concerned with the remediation of concrete structures.
- Improving understanding of current industry practice and drawing together the state-of-the-art in research in this area.
- Working to develop benchmarks for performance of rehabilitated concrete structures and current industry practices.
- Exploring performance-based concepts to improve the delivery of durable repairs.
- Seeking to develop links at national, European and international levels to aid progress on these issues.
- Working to identify future research technology and development (RTD) actions required to support implementation of performance-based concepts for the remediation of concrete structures.
  - Examining and seeking to find ways to promote the introduction of performance-based concepts into future European and ISO standards.
  - Raising awareness of the work being undertaken and by disseminating the findings as they come available by a wide variety of methods.

3. WORK PROGRAMME

The programme of work for the network is grouped into five work packages (WP) each running for different periods within the four year project:

**WP1: Network management** (September 2002 – August 2006)
Provides the basic infrastructure needed to operate the network by means of the steering committee, secretariat, web site, communications infrastructure etc.

Focuses upon the creation of a catalogue of past performance, reviewing problems in achieving durable remediation of concrete structures, identification of success factors in creating durable repairs and remediation, benchmarks, and other factors such as value for money. Activities include the development of a Methodology for Monitoring and Assessing Performance of Repair and Remediation Interventions on Concrete Structures, which is expected to make an important contribution to WP4.
This addresses current industry practice and draws together a state-of-the-art research overview. Work is proceeding upon the identification of best practice guidance and benchmarks, along with the mapping of RTD activities and standards & regulations.

WP4: **Future performance based concepts** (December 2003 – March 2006)
The focus here is upon identification of new and improved remediation strategies and methods of delivering these. The WP is examining client aspirations for durable remediation of concrete structures, the development of an industry response to these and ways to deliver these. These steps should lead to the development of a vision for performance concepts to achieve durable remediation of concrete structures, the identification of future RTD needs, potentially providing an outline framework for the co-ordination of RTD and other activities, standardisation and CPD issues.

WP5: **Dissemination, Communication, RTD exploitation & IPR** (September 2002 – August 2006)
This is concerned initially with raising awareness of the thematic network and then upon the promotion of the findings from the technical activity areas (WP’s) to the target audiences by means of a programme of free and charged-for activities, materials and publications. This WP is intended to facilitate the transfer of information and understanding through the supply chain and from research to practice.

4. **COMPOSITION OF THE NETWORK**
The network is operating with three groups of members:
- A consortium of 7 principal partners, including BRE as the network co-ordinator.
- Members (now over 40) who have been contributing their expertise to the target issues through member domain network activities and events.
- Participants (target 300) benefiting from public network activities and events.

The consortium of principal partners comprises:

1. Building Research Establishment (BRE) of the UK is a research organisation with acknowledged expertise in most aspects of building and construction, and the prevention and control of fire. BRE acts as network co-ordinator and overall catalyst for many technical aspects of the project.

2. Gifford & Partners of the UK is a company of consulting engineers specialising in bridge design and the repair of concrete structures of all types. They are managing WP2 on the past performance of repairs, providing leadership to the other Partners’ contributions on this topic.

3. Belgian Building Research Institute (CSTC) is concerned with building research – structural testing, concrete remediation, non-destructive evaluation. CSTC is managing WP3 on current practices and has gathered data on these activities by means of questionnaires.

4. Institute of Construction Science “Eduardo Torroja” of Spain is a research centre involved in construction and corrosion science. It is taking a leading role in WP2 in the development of a Methodology for Monitoring and Assessing Performance of Repair and Remediation Interventions on Concrete Structures and also in WP4 on future performance-based concepts.

5. Freyssinet International of France is a repair specialist in construction, including structural maintenance and remediation, and is strongly involved in bringing the contractor’s perspective to the project and to the development of WP4 concerning future performance-based concepts.
6. STÚ-K is a small company of consulting engineers in the Czech Republic specialising in design, assessment and repair of concrete structures. They lead WP4 on future performance-based concepts and are also bringing an SME’s and an Eastern European perspective to the project.

7. CT Koulutus Oy (CT Centre) of Finland is a materials supplier involved in the repair and renovation of buildings and other structures, concrete repair technology & materials development, training and education in the concrete repair field. They are leading WP5 on dissemination, RTD exploitation, training and IPR issues.

The members of the network come from across Europe and include research organisations, asset owners, consultants, repair specialists and contractors. There are also a number of “observing” members from various countries around the world, including Canada and Japan.

5. NETWORK LAUNCH - MADRID, FEBRUARY 2003

The first event involving network members was the network launch in Madrid on 6 and 7 February 2003 hosted by the Institute Eduardo Torroja. This highly successful event was attended by 40 members from 13 European countries. A brief report on the outcomes of the event is available in the CONREPNET electronic newsletter (see project website), but the following gives a flavour of the discussions and the way forward after the meeting.

The meeting kicked-off by reviewing members’ expectations for the network, their role and what they hoped to get from participation. This process gave clarification of what they desired to see delivered via the network through the combination of their efforts and those of the principal partners. The technical discussion sessions then lead onto consideration of past, present and future performance issues. Topics of immediate focus included practical matters such as the suitable sources of key data required on the performance of rehabilitated concrete structures, the specification for data to be collected, methods of collection and peer-review criteria, as well as obtaining agreement for access to this. The partners and members review seeks to ensure that key actors, materials, systems, methods and remediation practices are included. Dissemination plans and actions were reviewed.

Members have contributed data and other information to work packages 2 and 3, and are now in the process of providing their insight and expertise to help take work package 4 forward.

6. WP2: PAST PERFORMANCE OF REPAIRED CONCRETE STRUCTURES

The data gathered on the past performance of existing structures has as far as possible been peer-reviewed and has now been entered into a web-accessible database. This was studied to identify the roles of factors such as those listed below, together with any lessons that might be drawn from the experiences.
• Accuracy of diagnosing the causes of problems in the first place.
• Selection and use of suitable repair materials.
• Quality of workmanship in making the repairs.
• The construction / remediation operations and processes employed.
• Date of construction, time to failure, repair, failure of repair etc.
• Local environment.
• Standards and available technical guidance.
• Nature and quality of training given / experience available to those involved in the remediation work.
• Accessibility of appropriate information to undertake the remediation work.

Clearly there has been a need to recognise the influence of changes in procedures, materials, standards and systems over time and to seek to establish the importance of these factors upon the review and conclusions drawn. It is also important to understand the context within which the remediation works were performed. The output is a catalogue of durability issues, past performance and case histories. Work is continuing to finalise a Methodology for Monitoring and Assessing Performance of Repair and Remediation Interventions on Concrete Structures which is expected to make an important contribution to WP4.

7. WP3: CURRENT PERFORMANCE AND PRACTICES

Two sets of data have been collected for WP3. The first set has enabled current industry practices in Europe to be reviewed. A comparison of industry practice with current guidance is being made. The second set of data has enabled an overview of the state-of-the-art in research on the remediation of concrete structures to be prepared.

Current industry practice involves:

• A review current industry practices in European for remediation of concrete structures.
• Comparison of industry practice with current guidance / recommended approaches.
• Establishing industry’s position in respect of current and developing national, European and international standards for remediation of concrete structures; in particular limitations to achieving durable repairs.

The state-of-the-art research overview:

• Details recent and ongoing research on the remediation of concrete structures.
• Seeks to identify recent successful adoptions of research outcomes by industry.

High pressure water jetting to strip away the concrete from the steel reinforcement
8. WP4: FUTURE PERFORMANCE BASED CONCEPTS

To achieve the goal of more durable repaired concrete structures there is a need to utilise repair and remediation techniques and procedures that are appropriate to the deterioration mechanism(s), environmental conditions and structural circumstances which exist for the particular structure or part of the structure under consideration. There is a need to take a wider and longer term view upon these matters.

It is postulated that the management of concrete structures could be improved by:
- Early intervention, before damage is visible
- Proactive monitoring and maintenance in support of this
- Correct diagnosis of the problem and mechanism(s) causing the deterioration
- Effective repair systems

The adjacent figure (left) illustrates the underlying concept, taking the situation steel reinforcement embedded in the concrete and the circumstances leading to corrosion. A very simple two stage corrosion model (after Tuutti) has been adopted. In the early life of the structure (the initiation phase) the ingress of aggressive species occur through the cover concrete (eg. carbon dioxide, chlorides). After some time the surface of the reinforcement becomes depassivated permitting corrosion to begin. The corrosion propagation phase is entered and corrosion products are produced, with cracking of the concrete and spalling following at some later time.

Reactive maintenance is likely to be instigated only once visible indications appear (eg cracking or spalling of concrete), with an intervention being made to slow the rate of deterioration and extend the length of the useful service life of the structure. Proactive maintenance, such as the early application of a coating to slow the ingress of the aggressive species, could potentially delay the onset of corrosion and extend the useful service life.

Proactive maintenance could:
- Reduce the resources necessary to repair / remediate
- Reduce the disruption time
- Reduce the overall cost of ownership

![Simplified Corrosion Model (after Tuutti)](image)

Reactive and proactive approaches to the maintenance of structures

![Proactive Solutions for Maintenance of Structures](image)

Alternative solutions for maintenance of structures
The Prescriptive Approach

Over history architects and builders etc have developed experience of what forms of construction seemed to work satisfactorily and produce a durable building or structure, with their experience being expressed in terms of materials used and styles of building that suited the particular geographic region or the function of the building concerned. Over time prescriptive codes and standards emerged from that experience. This type of document has the advantage that they are generally easy to understand and to control. There has been similar experience with the process which has evolved guidance and recommendations for concrete repairs.

So if this approach has proved to be satisfactory and successful, why is there any desire or need to change from the prescriptive approach? The following illustrate some of the difficulties experienced with the prescriptive approach:

- Inflexible and so difficult to change
- Problematic and restrictive for innovation
- Has led to a poor match between true User / Client requirements and what has been delivered by the construction process
- There is the perception that the construction industry has a poor ability to meet User / Client expectations and has provided low value for money. The issue of snagging – that is work not done correctly or satisfactorily first time – illustrates the underlying problems and issues.

Performance Based Approach

Perhaps surprisingly, performance based approaches are not new.

King Hammurabi of Babylon, who reigned from BC 1955 to 1913, is credited with the first recorded building regulation. The intent and the penalties for failure to perform are clear. This stated:

The builder has built a house for a man and his work is not strong and if the house he has built falls in and kills a householder, that builder shall be slain.

It can still be viewed today - inscribed on an obelisk housed in the Louvre Museum, Paris.

This work package (WP4) is currently exploring ways for developing strategies, techniques and processes for delivering durable and effective rehabilitation of concrete structures. This is being done by:

- seeking to understand client aspirations and needs
- developing an industry response for achieving them
- formulating a vision for performance concepts to achieve durable rehabilitation of concrete structures
- identifying future research, technology and development (RTD) needs
- co-ordinating a high level view on RTD and other activities
- examining the implications for European standardisation and the Construction Products Directive

9. PRINCIPAL PROJECT OUTPUTS

The network will produce some 25 deliverables and some of these are in the final stages of preparation. The key project technical deliverables are concerned with:

- A catalogue of durability issues, past performance and case histories
- The review of problems of achieving durable repairs
- A methodology for monitoring and assessing performance of rehabilitated concrete structures & implementation of web-based catalogue of durability issues, past performance and case histories
• Current European practice and benchmarks in the remediation of concrete structures
• Mapping of current industry practices and the state-of-the-art in research in the remediation of concrete structures
• Development of best practice guidance documents on remediation of concrete structures and associated benchmarks
• The vision and drivers for use of performance concepts to achieve durable remediation and encourage innovations and better solutions
• Creation of a strategy for developing performance concepts for durable remediation - vision to practice
• Identification of future RTD needs to deliver performance concepts for durable remediation
• Implications for the Construction Products Directive (CPD) and European standardisation of performance concepts

Public dissemination and communication activities include:

Free-access informative material, such as:

• Public web-site and electronic newsletters
• Links via other web-based dissemination of research and construction knowledge activities – such as E-Core
• Brief summary information upon technical topics, network technical reports and achievements, press releases, etc
• Presentations to selected organisations and parties
• Papers and project / topic overviews in technical press
• Links to other organisations and activities via the Internet
• Links to RTD projects and other activities sponsored by the European Commission and others – such as the REHABCON project
• Briefing materials for relevant international technical committees

Charged activities, materials and technical reports, upon topics and activities including:

• Pro-active events such as workshops, and potentially training events, summer schools and symposia
• Web-based arrangement for charged downloading / purchase of formal network technical outputs
• Formal network technical reports and outputs providing:
  • Peer reviewed experiences and identification of factors contributing to durable remediation
  • Benchmarks
  • Future performance concepts
10. DISSEMINATION ACTIVITY PROGRAMME FOR THE FIRST TWO YEARS

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<th>Breakdown of dissemination activities</th>
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<tr>
<td>Network launch - all</td>
<td>MM1</td>
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<td>Workshop on past and current performance</td>
<td>MM1A</td>
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<td>Specialist workshop - Clients/owners</td>
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<td>Specialist workshop - Consulting engineers</td>
<td>MM3</td>
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<tr>
<td>Specialist workshop - Repair specialists/material suppliers</td>
<td>MM4</td>
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<td>Workshop on performance concepts - all</td>
<td>MM5</td>
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<tr>
<td>Network close - all</td>
<td>MM5</td>
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<tr>
<td>Open events/meetings</td>
<td>PW1 - PW4</td>
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<td>Web-site (Public and Members Pages - see Note 1)</td>
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<td>Development</td>
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<td>Update</td>
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<td>Electronic newsletter</td>
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<td>Publications</td>
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<td>Produced by the network</td>
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<td>Deliverables</td>
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<td>Published through other bodies - eg. technical &amp; trade journals</td>
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<td>Education and training activities - see Note 2</td>
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<td>Links to Standards Organisations</td>
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<td>Links to Technical Organisations</td>
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<td>Links to national and international RTD projects</td>
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REFERENCES