CON REP NET
NETWORK NEWSLETTER
No.5
September 2005

Special Topic:
- Towards a Performance Based Approach

Index
- Review of Network Proceedings
- Towards a Performance Based Rehabilitation of Concrete Structures: The Industry Response
- Basic Concepts for Performance Based Approach
- Forthcoming Events

projects.bre.co.uk/conrepnet
The Network recently held meetings in Prague for CONREPNET members (Member Workshop MW5) and also for the public (Public Workshop PW2).

MW5 held on 22 June 2005 was attended by 30 Members and Partners. This workshop formed part of the Network's technical programme concerned with developing performance based concepts for the protection and repair/rehabilitation of reinforced concrete structures. The meeting was divided into three sessions.

- Session 1: The past and the present in concrete repair.
- Session 2: Tomorrow and beyond for concrete repair?
- Session 3: Next practice in concrete repair - A way forward?

The first two sessions of MW5 reported the findings of earlier work-packages addressed by the Network that is in respect of the performance of past repairs and current practice in the industry and contemporary research work. Members representing different aspects of the supply chain gave their insights into the work and their perspective on the findings. Session 3 was designed to gain input and Members thoughts and guidance on future activities relating to the next stages of work concerned with performance based concepts. This focused particularly on the issues concerned with the topics to be addressed by Deliverable D20, but also gained some input for D21 & D22 (see below for the titles of these reports). The article on reviewing the outcomes from MW5 will be in next Newsletter (NL6).

Public Workshop PW2, entitled The CONREPNET Conference, held on 23 June 2005 was an element of the Network's wider public dissemination activities. Most of the Members stayed on after MW5 for this event, some giving presentations on their work or related topics. Many engineers and others involved in concrete repair from the Czech Republic, and also from much further a field, participated in the day. In total almost 90 people attended the day, which was judged to have been highly successful.

The CONREPNET Conference was held in conjunction with the Czech Concrete Society, who were responsible for organising the venue and, amongst other matters, the preparation of a magnificent bound proceedings for the day accompanied by a CD copy of the proceedings. Although the Conference was held in English, simultaneous translation into Czech was available, illustrating the high standard of the organisation for the day.

The presentations given at The CONREPNET Conference are listed below. For further details of the presentations, together with authors, please see the CONREPNET website (see more below). In due course PDF versions of the presentations will also be posted on the CONREPNET Members website.
CONREPNET Presentations

- An overview of the TN CONREPNET
- Performance of past repairs
- Current practice
- Towards a performance based approach
- Methodology for monitoring and assessing performance

EN1504
- Overview of the EN1504 suite of concrete repair standards

Presentations by CONREPNET Members

- Repairs to highway and roads related structures
- Structural integrity of deteriorated and repaired concrete structures
- Corrosion risks after patch repairs to concrete
- Some aspects to be considered when replacing a damaged concrete cover with a new cover
- Qualitative and quantitative description and classification of rams (reliability, availability, maintainability, safety) characteristics for different categories of repair materials and systems
- The use of Pavix CCC100 as a reinforced concrete impregnate and as an alternative to silane
- Innovation in repair techniques
- Rehabilitation of reinforced concrete structures built in the soviet time along with correction of their constructing mistakes

To date the CON REP NET Thematic Network has now produced 9 complete / draft main technical outputs [NB. 14No technical outputs are planned for the project overall]. We have now also held 6No meetings for Network members and 2No for the public [11No planned for project overall]. The current status of these is detailed below.

<table>
<thead>
<tr>
<th>CON REP NET - Current Status of Technical Deliverables</th>
<th>Title</th>
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<tbody>
<tr>
<td>Completed or where an advanced draft has been prepared</td>
<td>Status</td>
</tr>
<tr>
<td>D10 Web-based catalogue of durability issues, past performance and case histories</td>
<td>Completed</td>
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<tr>
<td>D11 Catalogue of past performances and review of problems of achieving durable repairs</td>
<td>Completed</td>
</tr>
<tr>
<td>D12 Methodology for monitoring and assessing performance of rehabilitated concrete structures</td>
<td>Final draft</td>
</tr>
<tr>
<td>D13 Current European practice and benchmarks in rehabilitation of concrete structures</td>
<td>Final draft</td>
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<tr>
<td>D14 Research state-of-the-art in rehabilitation of concrete structures</td>
<td>Final draft</td>
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<tr>
<td>D15 Best practice and benchmarks in rehabilitation of concrete structures</td>
<td>Final draft</td>
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<tr>
<td>D16 Client aspirations for durable rehabilitation of concrete structures and their wider implications</td>
<td>Completed</td>
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<tr>
<td>D17 Discussion paper on the use of performance concepts to achieve durable rehabilitation of concrete structures</td>
<td>Final draft</td>
</tr>
<tr>
<td>D18 Industry response to meeting client aspirations</td>
<td>Final draft</td>
</tr>
<tr>
<td>D19 Vision and drivers for the use of performance concepts to achieve durable rehabilitation of concrete structures</td>
<td>Under Development</td>
</tr>
</tbody>
</table>
In addition, a special report was also produced especially for Member information as part of the recent Prague MW5 Members Workshop meeting. This report was entitled: CONREPNET: An overview of a thematic network on performance based remediation of reinforced concrete structures: June 2005 Edition

The front cover is illustrated on the right. The report was distributed to those attending the MW5 meeting in Prague.

Details are given in the following table (see blue shaded box below) of several technical deliverables on which work is just starting in support of the development of performance based concepts for the protection and repair/rehabilitation of reinforced concrete structures.

We are also looking towards a series of formal published outputs from the Network. Currently it is envisaged that these could potentially take the following form:

- Review of Problems of Achieving Durable Repairs
- Current European Practice and Benchmarks in Rehabilitation of Concrete Structures
- Research State-of-the-Art in Rehabilitation of Concrete Structures
- Performance Based Concepts for the Protection and Repair / Rehabilitation of Concrete Structures

<table>
<thead>
<tr>
<th>CON REP NET - Technical Deliverables on which work is just starting</th>
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<tbody>
<tr>
<td>Deliverable</td>
<td>Title</td>
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<tr>
<td>D20</td>
<td>Performance concepts for durable rehabilitation of concrete structures – from vision to practice</td>
</tr>
<tr>
<td>D21</td>
<td>RTD needs to deliver performance concepts for durable rehabilitation of concrete structures</td>
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</table>

Work is virtually complete on the technical work packages concerned with Past Performance of Concrete Structures (WP2) and also Current Practices (WP3). Previous editions of the Newsletter (see below) have given an overview of some aspects of the findings from these WP’s, as does the Overview report cited above.

Progress with our mapping activities was outlined on page 7 of Newsletter 3. However we still need your assistance and your technical information to populate the web-site which has been set up for this purpose. We still plan to contact you separately on this matter.

<table>
<thead>
<tr>
<th>CON REP NET Web Based Technical Deliverables That Require Input from CON REP NET Members [Have you registered for your Password?]</th>
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<tbody>
<tr>
<td>- Mapping: web-site access</td>
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The technical work activities have been complimented by an extensive dissemination programme (over 30 events so far). Initially this focused upon raising awareness about the project, but now (as described above) as project technical information becomes available, dissemination activities are concentrating upon the findings and outputs of the technical work packages.

Later in next electronic newsletter further details are given about the work done at MW5 in Prague as part of the process of addressing the challenging task of developing Performance Concepts (WP4). As previously described, the approach being used is to follow the supply chain, starting with the owners’ aspirations, trying to see how to translate these into engineering procedures and contractual activities.

Newsletter 3 reported on the discussion about industry response to owners’ future performance aspirations. This issue continues reporting on page 3 of this edition the discussions concerning a basis for a possible industry response to the owners’ aspirations for durable repaired concrete structures. As a contribution to performance based concepts, a prospective methodology for monitoring and assessing performance of repaired concrete structures is described in the Overview Report (see above) but was also outlined on page 8 of Newsletter 3.

Ongoing and future work upon performance based approaches to remediation of concrete structures (WP4) are detailed in the box below.

### Performance Based Approach to Remediation of Concrete Structures: Ongoing & Future Work [WP4]

**Performance concepts: from vision to practice.**
- Identify barriers to introduction of performance concepts into practice.
- Establish approaches to overcoming or modifying barriers, such as:
  - Seek to improve client practices by owner education
  - Achieve wider adoption of best practice working by industry
  - Consider the ability of industry to deliver these concepts.
- Prepare report on performance concepts protection and durable rehabilitation of concrete structures – from vision to practice [D20].

**RTD – future needs and co-ordination**
- Identification of RTD needs to support practical implementation of performance concepts.
- Consultation with research community and research funding organisations.
- Draw upon findings of mapping activities.
- Prepare report on RTD needs to deliver performance concepts [D21].

**Construction Products Directive (CPD) and standardisation issues**
- Identification of CPD and standardisation issues to support practical implementation of performance concepts.
- Consultation with representatives of relevant bodies.
- Prepare report on performance concepts - implications for Construction Products Directive and European Standardisation [D22].

As a Network member you should previously have received the three electronic newsletters shown below describing progress with the work and future activity plans – please remember to let us know if you have changed your email or job in your organisation.

Also a small reminder. We recently requested Members to forward their Cost Statements for travel and subsistence claims legitimately incurred in attending CON REP NET Member events in the third year period (October 2004 to end September 2005). I trust you will submit your claim promptly. Please note these are currently capped at 1000 Euro plus a 20% overhead contribution (overall total 1200 Euro per event).

Finally, important future Network activities are planned. Currently these are expected to include meetings in the following locations:
- Madrid in November 2005 at IETcc for Public Workshop PW3
- Garston / London in April 2006 at BRE for Members Workshop MW6
- St Malo, France in June 2006. It is proposed that this be held in conjunction with the international Concrete Solutions Conference (27 – 29 June 2006), at which CONREPNET is expecting to mount a one day parallel session (effectively our Public Workshop PW4).

See page 24 for further details. Please put these dates in your diary. We really hope that as CON REP NET Members you can be there with us, to hear about what has been achieved with you the information provided through your cooperation. Your contributions have been invaluable so far and we are extremely grateful to those that have been able to support us in this way. Thank you.
CONREPNET Network Launch
Introduction
General discussion on members’ expectations
Past performance
Current practice
Future performance
Dissemination of information
Review of dissemination activities

CONREPNET TN Interaction Meeting and Initial Results from Technical Tasks
Introduction
Past performance – the first results
Current practice – the first results
Meeting with owners, 13 November 2003
Mapping activities
Future performance: discussion on owners’ expectations
Forthcoming events

Future Performance - Discussion of Industry Response to Owners’ Aspirations
Mid term review
Future performance: discussion on industry response to owners’ aspirations
Methodology for monitoring and assessing performance
Forthcoming events

Towards a Performance Based Approach
Review of Network Proceedings
Basic Concepts for Performance Based Approach
Towards a Performance Based Rehabilitation of Concrete Structures: the Industry Response
Forthcoming events

Finally please remember to visit the CON REP NET web-site: www.projects.bre.co.uk/conrepnet and ensure that you have registered. We need technical details from you / your organisation to assist with the mapping exercise. More on this at a later time. Registering and contributing to the mapping activities will enable you to receive the downloadable technical outputs when they become available.
As part of the study of the performance of past repairs (undertaken within WP2) a web-based Concrete Repairs Database has been setup. This is accessible to CONREPNET Members via the CONREPNET website. The Search Page for the Concrete Repairs Database is illustrated below. The database can be interrogated by various fields including Structure Type (see below), Environment Type, Damage Type, Repair Type and Failure Type.
INTRODUCTION

Clients (or owners) are looking for repairs that are durable, economical, operational and aesthetical.

How are Consulting Engineers, Repair Specialists and Material Suppliers – in fact the industry – responding to these aspirations?

- Owners define/specify performance requirements
- Consultants turn performance requirements into design strategies and specifications
- Repair Specialists and Material Suppliers use correct materials and processes in order to meet the required performance levels.

Clients must set up a strategy for the management of their structures. This strategy should comply with European legal requirements if any. ENV 1504-9 has proposed a Flow Diagram with a selection strategy (Fig.1) and a Requirements Frame has then been established. Requirements are set at different levels and technical and non-technical requirements are considered at the same time (Fig.2).

PROCESS FRAME

1.1 Methodology

The idea of management and maintenance of structures is to keep the structures in an acceptable condition regarding function and safety in the economical most optimal way. Setting up, evaluating and comparing strategies are an important part of any management and maintenance systems.

A prescriptive approach according to EN 1504-9 is followed by the industry today.

EN 1504 has recognised three groups of remedial actions:
- Surface protection
- Repair
- Structural strengthening

Having established the reasons and mechanisms associated with the development of damage in a particular case, the following approach should be adopted for the selection of remedial options:

1. Choose option/approach to be adopted for the future management of structure
2. Adopt a principle for surface protection and/or repair and/or structural strengthening
3. Choose a method of surface protection and/or repair and/or structural strengthening
4. Choose a product or system to be employed.
5. Define future inspection and maintenance requirements.

Fig.1 illustrates this methodology which is followed by the industry to answer to Clients aspirations.
1.2 Flow Diagram

Minimum requirements for assessment of defects and their causes

- Present condition
- Original design approach
- Environment and contamination
- Conditions during construction
- Conditions of use
- History of structure
- Future use

Choose Option

- Do nothing for a certain time
- Re-analyse structural capability
- Prevent or reduce further deterioration
- Improve, strengthen or refurbish all or part
- Reconstruct all or part
- Demolish all or part

- Intended use, design life and service life
- Required performance characteristics
- Likely long-term performance of protection or repair works
- Opportunities for additional protection and monitoring
- Acceptable number and cost of future repair cycles
- Cost and funding of alternative protection or repair options, including future maintenance and access costs
- Properties and methods of preparation of existing substrate
- Appearance of protected or repaired structure

Choose Principle appropriate to the option chosen

Defects in Concrete
- Protection against ingress
- Moisture control
- Concrete restoration
- Structural strengthening
- Physical resistance
- Resistance to chemicals

Reinforcement corrosion
- Preserving or restoring passivity
- Increasing resistivity
- Cathodic control
- Control of anodic areas

Choose a Method

- Appropriate to type and cause or combination of causes and to the extent of the defects
- Appropriate to future service conditions
- Appropriate to protection or repair option chosen
- Compliance with the Principle chosen
- Availability of products and systems which comply with the EN 1054 series or any other relevant EN or European Technical Approval

Choose materials which comply with the standard

- Characteristics for all intended uses
- Characteristics for certain intended uses
- Characteristics may be considered for specific applications

Set out inspection and maintenance requirements

- Record of the protection or repair works which have been carried out
- Instructions on inspection and maintenance to be undertaken during the remaining design life to the repair part of the concrete structure

Fig.1: Overview of DD ENV 1504-9: 1997

1.3 Requirements frame

The selection of a strategy for repair and protection can never be taken on technical grounds alone. The following considerations can be taken into account:

- Economical and financial
- Social and cultural
- Environmental
- Functional
<table>
<thead>
<tr>
<th>Part</th>
<th>Primary Classification of Economical and Financial Requirement</th>
<th>Non-Technical (NTI) or Technical Issue (TI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Economic and Financial</td>
<td>Procurement and type of contract</td>
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<tr>
<td></td>
<td></td>
<td>Strength of local economy</td>
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<td></td>
<td>Improvement of asset values</td>
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<td>Effect on third parties</td>
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<td>Whole-life cost</td>
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<td>Cost versus benefit to society</td>
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<td>User cost</td>
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<td>Size and geometry</td>
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<tr>
<td>II.</td>
<td>Social and Cultural</td>
<td>Public confidence</td>
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<tr>
<td></td>
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<td>Target groups</td>
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<td>Education and training</td>
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<td>Aesthetics</td>
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<td>Social perception</td>
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<td>Consultation</td>
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<td>Social alarm</td>
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<td>Reputation</td>
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<td>Media and press</td>
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<td>Government policies and initiatives</td>
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<td>Labour union aspects</td>
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<td>Legal issues</td>
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<td>Insurance and future liabilities</td>
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<td>Working environment</td>
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<td>Repair time</td>
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<td>Political consequences</td>
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<td>Importance of a structure</td>
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<td>Management &amp; maintenance</td>
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<td>Location of a structure</td>
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<td>Kind of a structure</td>
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<td></td>
<td></td>
<td>Ownership</td>
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<tr>
<td>III.</td>
<td>Environment</td>
<td>Global environment</td>
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<td></td>
<td>Neighbourhood issues</td>
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<td>Internal environment</td>
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<td>IV.</td>
<td>Functional</td>
<td>Mechanical resistance and stability</td>
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<td></td>
<td>Safety in case of fire</td>
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<td>Safety in use</td>
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<td>Exposure requirement</td>
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<td>Loading requirement</td>
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<td></td>
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<td>Required service life</td>
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<td>Durability</td>
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<td>Other performance requirements</td>
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</table>

*Fig. 2 – Requirements Frame*

The CPD (Construction Product Directive) define provisions, including requirements, relating not only to building safety but also to health, durability, energy, economy, protection of the environment, aspects of economy and other aspects important in the public interest. The definition of Requirements is therefore an essential step in the process of management of an Asset of structures.
2. OWNERS’ ASPIRATIONS AND CONTRADICTIONS

2.1 Current approaches

In general, there is a variety of owners varying from those that are very knowledgeable (National authorities, Commercial organisations with relatively large number of structures) to generalists with low technical knowledge, reliant on advice from consultants very often having difficulties to raise adequate funding for maintenance. The approach is however invariably the same: after an inspection (more or less well done), a contractor is selected through competitive tendering. All owners have financial constraints which usually lead to acceptance of cheapest tenders but this does not necessarily turn out to best value.

Owners have to face external and non-technical factors, which influence the management of their structures: government policies, local political implications, strength of local economy, public attitude. And this complicates the situation and has a negative influence on the quality of the rehabilitation works.

2.2 Owners’ aspirations and contradictions

Owners are looking for repairs that are durable, economical, operational and aesthetical. It should first be recalled that the responses to these expectations are not always in the hands of the sole industry:

Dissatisfaction of owners with the performance of repairs founds its origin in the acceptance of cheapest tenders rather than best value for money.

Everybody realizes that a durable concrete repair must be based on the results of a serious inspection programme. This is not often the case. It seems that the importance of the assessment of a deteriorated structure is generally not sufficiently appreciated. In fact, the true question is: does the owner really know its structure?

Loss of operation can lead to loss of revenue. This criteria is paramount: repair works should be conducted after careful analysis of their interaction with the environment (economical, social and political).

It is demonstrated that pro-active maintenance will always end up with a lower overall cost. Even, if it is still unrealistic to speak today of whole-life costing for repair works, this principle remains applicable and would demand a new owners’ attitude in terms of management.

2.3 How owners define their aspirations with reference to the frame

With reference to the frame, their main requirement is the functionality (Part IV) of the repaired structure, which consists of:

- Mechanical resistance and stability
- Loading
- Safety in use
- Durability

Another concern is to have economical repair (Part I); in fact owners are fighting to find a sufficient budget to undertake the repair itself. The items listed in Part I of the frame are secondary for them.

As far as aesthetics is concerned, owners want to have the support of political authorities and public opinion: their desire is much rather to have an “acceptable rehabilitated structure” than a fancy architectural design. A deteriorated bridge pier with delaminated concrete and exposed rusty re-bars must be banned!
3. TRANSLATING OWNERS’ REQUIREMENTS INTO TECHNICAL REQUIREMENTS / SOLUTIONS

3.1 Current approaches

*Assessment
No doubt that there are weaknesses and failures to meet owners’ aspirations. However, the assessment of an existing structure is of primarily importance. It covers the analysis of inspection, the demand for further investigation (NDT and DT), the re-calculation of the structure and the final assessment of the origin of structural deterioration. The role of the Engineer during this phase, in close relationship with the Client, will be the key for the success of the repair project.

This aspect of the flow chart is not part of this document. But this is a key issue: owners must know their structure, and this has also a price which should not be forgotten.

* Product selection
The products and systems have then to be selected in accordance with the requirements of EN1504 –2 to EN 1504-7. However sometimes products and systems are not covered by EN 1504 series. Establishment of suitability results from specific ETA (European Technical Approval) of relevant National Standards. But the effective use of both new products and new techniques in a given remediation project is very rare. Cement based mortars continue to be commonly applied in spite of the development of polymer based mortars. We found the same attitude with barrier coatings versus modern impregnation techniques. This is true that there is a price difference but more than that, the introduction of new techniques and products in the practice is very slow. Durability has not been demonstrated, expertise for application does not exist: these could be the main reasons for explaining this long-term process. In fact:

There is a reluctance to use new materials: too many are present on the market and it is difficult to compare them.

Products and materials are tested with different standards.

Consequently consultants request:
- Classification of materials
- Classification of testing procedures
- Durability testing

Note: In France, a new product cannot be launched on the market without a qualification: ATEC (Avis Technique) and ATEX (Avis Technique d’Expérimentation) are provided by the CSTB (Centre Scientifique et Technique du Bâtiment).

* Workmanship
Most of the codes and standards did not address any comments on this matter; however, it has been recognised, today, that good quality workmanship is fundamental to the production of durable repair. This requires good procedures and appropriate training.

Each repair project is unique: it involves very often a series of techniques, which are applied in a specific order. Each structure has its specific environment characteristics. Structures have not been designed and built for being inspected and maintained under operations: accesses are sometimes extremely difficult. Consequently repair specialists able to master these various techniques are very limited.

For placing materials, suppliers may organize training course for repair specialist. Certification of workmanship is now developed in several countries but workers themselves – not only the firm they are working for – should be certified.

* Supervision of execution
Owners would like to be assured that their repaired concrete structures achieve their intended design life. To achieve this, the owners must take more control of the execution processes. The role of the Quality Assurance and Quality Control Programs within the project specifications for producing predictable durable repaired structures is essential.

Surprisingly, most owners rely mistakenly on good supervision of the repair work being sufficient to ensure that the product is durable. Some carry out inspections at the end of the first year but very few carry out acceptance testing.
3.2 The role of the different actors

The Professional Team
The owners need to commission different knowledgeable and skilled persons or organisations able to advise him and to carry out assessment, design and repair works of their structures. Depending upon the nature of the contractual relationship chosen by the owner, the professional team might include consultants, repair specialists and material suppliers.

The Owner
- They must be concerned about the management of their structures.
- They have responsibilities in terms of safety, functionality, service life, health and environment impact, aesthetics and other matters.
- They must be aware of the best practices.
- Consequently, they define and specify the performance requirements of their structures.

The Consultant
The primary role of the consultant covers the analysis of inspection, the demand for further investigation (NDT and DT), the re-calculation of the structure and the final assessment of the origin of structural deterioration. Once the assessment is done, the Consultant prepares this repair project (methods, technology and products to be used).

The Consultant specifies the standards and translates the owners’ requirements into technical and non-technical specifications.

Repair activity needs knowledge and experience: engineers must be concerned by the performance of repaired structures and the possible implication of poor design, specification and diagnosis.

The Consultant sometimes carries out the supervision of the construction.

Legal position and relative responsibility of engineers should be clarified.

The Repair Specialist
The repair specialists carry out the remedial operations according to standards and specifications prepared by the consultant.

As for the Consultant, knowledge and experience are required. Only a certified repair specialist should be retained to carry out repair works.

The repair specialist may offer proprietary system or techniques for such works. Contractual provisions should be developed to allow this.

The repair specialist should provide a guarantee of his works.

The Material Supplier
The material suppliers supply the materials meeting the standards and the specifications set up by the consultant and the general methods statements issued by the contractors.

His role is closely linked to the repair specialist. However, he should supply not only the products, but the application procedures and method statements.

Suitability testing and acceptance testing should be developed.

3.3 Limitations

* Work organisation

While looking at the classical way of the professional team establishment, it appears that there could be overlap between owners, consultants, supervisors and contractors responsibilities. There is a need to clarify their role.

Also the juridical status in each country has to be considered. Is it compulsory to use a Consultant? Are there any legal obligations? What are the responsibilities of the Consultant? This will affect the final scheme process, which is selected by the owner.

Sometimes owners do not realize the technical complexity of the repairs. They want their problem to be solved quickly and as cheap as possible. All actors who are taking part in repair activity should be educated (Development of training programmes and courses).
Standards

The owners require a level of performance for a given money. The difficulties lie in the definition of the performance and in its measurement. New approaches and monitoring tools have been developed.

Requirement for acceptance testing should also be considered. Very often standards address only the materials. Acceptance testing permits to appreciate the application; acceptance tests must be developed for each repair technique.

Responsibilities

The responsibilities of the Consulting Engineer, Repair Specialist and Material Supplier should be revised. Owners are looking for guarantees and for package approaches. Partnership between the different actors should be developed with this principle in mind:

- Owners define the performance requirements
- Consulting Engineers transform the performance requirements into design strategies and specifications
- Repair specialist and material supplier use appropriate material and processes to meet the required performance levels.

Introduction of Research results

Industry has realized that there is a real need for improvement and innovation. Technological advances in several countries are extremely significant. Research and Development programmes are underway everywhere. Education and knowledge should be an essential objective of the actors playing in this field: this implies the clients, the consulting engineers, the material suppliers and the repair specialists.

Research programmes have been carried out during the last 15 years with the following goals:

Concrete durability: general researches aiming at understanding the performance of concrete, its deterioration mechanisms and the impact that, those have on the expected service life of the structure. This class includes performance and behaviour of repaired structures, the preparation of the substrate and the action taken at the time of construction to enhance service life.

Repair materials and methods: in this class appears special research on well defined repair materials and methods. This can as well be the performance of impregnations as well as the possibilities of cathodic protection.

Inspection and assessment: all researches related to the inspection of a concrete structure and the evaluation of the results. To this class belong monitoring techniques prior to repair and the choice of repair methods.

Maintenance: all research aiming to improve the service life by appropriate management of concrete structures by well studied long time monitoring as well as the development of databases and software helping owners to better understanding the aging of their assets.

Strengthening: appearing regularly, either as research on the materials as on procedures for calculation, this could be a separate group.

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>CASE-HISTORIES</th>
<th>RESEARCH REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>The poor performances of repairs are attributed to a variety of causes</td>
<td>There would be benefits from more research on durability of repairs</td>
</tr>
<tr>
<td>Repair materials and methods</td>
<td>Failures were attributed to incorrect use of materials and there is no criticism of the materials</td>
<td>There is a requirement for materials that are more tolerant of misuse</td>
</tr>
<tr>
<td>Inspection and assessment</td>
<td>Only 15 per cent of inspections use NDT. Incorrect assessment is blamed for many of the failures.</td>
<td>Assessment would benefit from more research</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Corrosion and AAR continue to be difficult to manage.</td>
<td>Practical research and guidance related to field conditions is required</td>
</tr>
<tr>
<td>Strengthening</td>
<td>No problems identified.</td>
<td>More research is required on restoration of strength as opposed to upgrading</td>
</tr>
</tbody>
</table>

Table 1. Research requirements - identified from case histories.
4. USING PERFORMANCE BASED APPROACH WITH REFERENCE TO THE FRAME

4.1 Answers offered by running research

It is worthwhile to note that the following subjects are of primarily concern:
- Monitoring, surveillance and assessment
- Durability, maintenance and repair of structures
- Environmental impact of infrastructure
- New materials and technologies.

4.2 Standards and guidance documents

1. EN 1504

For the first time, there will be in Europe standards for selection of repair techniques and products. The objective is to:
- Specify minimum performance level
- Remove technical barriers to trade
- Provide reference to relevant performance tests
- Provide standardized approaches for design and execution.

However the European Norms need time to enter into application. Very often, the project specifications are essential. The following principle should not be forgotten:
- Raise the level of Standards,
- Define Quality Control and Quality Assurance programme,
- Define acceptance testing,
- Measurement of the repair,
- Certification of various actors.

2. National Standards

- British Standards
- Highways Agency
- BRE Specific Standards
- French Norms and Recommendations.

3. Other guidance documents

- fib Commissions reports
- ACI Structural Journal and Materials Journal
- ICRI (International Concrete Repair Association)
- Bi-monthly magazine: "Concrete Repair Bulletin"
- ISO standards
- Other CEN standards.

4.3 The partnership

* Principle

The owner must be intimately and effectively involved in the definition of performance requirements at the start of the construction procurement process.

Article 3.2 has shown that to achieve these goals, the owner will usually need the support of a team of professional advisers, which could comprise architects, engineers, contractors or others depending upon the nature of the task to be undertaken and the expertise held by the owner. Together they must be able to address the various technical and process matters relating to design, construction and maintenance and end of life issues that may arise.
It appears that new contractual relationship should be developed between the different actors involved in structure repair activities: owners – consulting engineers – repair specialist. There is a fragmentation of the different tasks and sometimes overlapping may be encountered; a partnership agreement should be established to overcome this fact. Every time it has been experienced, the result was extremely satisfactory. Of course, this is not possible to do that everywhere and for every project. At least, some principles should be considered and used as guidance. This is the case for the QA/QC programmes.

*Specific performances for the Owners*

The owner should define and specify the performance requirements according to Table 2 “Requirements frame”; these requirements should be:

- Economical and Financial
- Social and Cultural
- Environmental
- Functional

*Specific performances for the Consultants*

The consultants should turn the performance requirements into design strategies and specifications. In particular, the role of the Q/A and Q/C programmes within the project specifications for producing predictable durable repaired structures is essential.

* Specific performances for Repair Specialist*

The repair specialist should be bound by intermediate approval and corresponding acceptance testing for example:

- State of the support surface prior to application of products (surface finish)
- Definition of the treatment area
- Temporary stages during execution of the works are sometimes critical: general stability of the structure should always be checked (it is a step by step procedure)
- The repair specialist may be subject to certain obligations regarding the waste materials (re-cycling, deposit area)
- Finally there should be always acceptance testing to qualify the performance of the works
- Specific requirements may be very much demanding: take care of vibration, noise or dust problems since the structure will be under operations during the repair works.

* Specific performances for the Material Supplier*

The repair work requests several commitments from the Material Supplier such as:

- Materials approvals: ready mix concrete, cement, aggregates, admixtures, rebar, curing materials etc …
- Products approvals: their composition (mix), their workability.

4.4 Contractual relationships for procurement

Today Repair Specialists are usually selected with the objective of obtaining what is seen as best value for money through competitive tendering. Financial constraints invariably lead to acceptance of cheapest tender but this does not turn out to be best value. In fact, nobody could be satisfied with this method and the performance is poor.

The owner should develop a systematic approach to avoid, reduce, or control the risks (this is risk management). In fact, the course of action followed is to assess uncertainties by identifying and assessing hazards, by understanding and communicating risk issues.

This is why it is necessary to develop new contractual relationship: partnership between owner – consultant - and repair specialist should be investigated. The following is required:

- Prequalification of the different actors (references, certifications …)
- The repair specialist should be aware of the investigation results and strategy (better knowledge of the structure)
- The owner must set the performance requirement and the guarantees he is looking for. One serious difficulty exists: when repair works are carried out, it is quite simple to be responsible and to provide guarantees for the repair work itself. But the owner usually…. a guarantee for its structure.
Then come the difficulties:
- What are the effects of the repair on the structure as a whole?
- How are the structure members or elements, which have not been repaired? What is their level of deterioration?

When prequalification of contractors is carried out, the following should be requested:
- Past references
- Specific equipments and systems
- Qualification of workmanship (training programme, certification)
- Quality Assurance Programme
- Method statements of each proposed technique.

Better results are always achieved when there is a better knowledge of the state of the structure.

Two stages tender should be recommended:
- First tender for detailed investigation works
- Second tender for repair works, once the Consultant has established the assessment of the deterioration and the proposed repair project.

At the same time, ways has to be found to consider proprietary solutions and alternative proposals.

4.5 Quality Assurance and Quality Control Programme

Since the rehabilitation of concrete structures calls for various techniques which are not yet all codified in terms of method or control, the following principles must apply:
- The repair specialist contractor must prepare a Quality Assurance Programme (QAP) which will define:
  - general site organisation
  - main resources and equipments which will be used
  - internal control procedures.

The QAP will be given with the tender and will be finalised prior to the start of the works. It should be such that there is no room for improvisation.

- Control procedures definition

During the works there are several steps which deserve a specific attention. They could be classified as follows:
  - Sensitive point: a special care should be taken at that moment
  - Critical point: this step will require an internal quality control report submitted to the owner or its representative in charge of the external quality control
  - Stopping point: this is a critical point which needs the approval of the External Quality Control for continuation of the works.

- Characteristics of the Internal Quality Control testing regime
  - Proof testing: critical point (example: concrete mix for shotcreting)
  - Suitability testing: stopping point (example: site equipments and conditions on a representative sample (1 m²) of all techniques to be used)
  - Acceptance testing: critical point. This will concern: concrete (ready mix), cement materials and admixtures, protection coatings, reinforcement, curing products etc … This will concern also the definition of the area to be treated, checking of the reinforcement, checking of the surface.

- Execution Internal Quality Control
  - Sequence of each repair construction stage
  - Materials quantities to be used
  - Curing (cp)
  - Geometry (cp)
  - Bonding to the support surface (sp)
  - Final acceptance testing (sp).

- External Quality Programme

The owner has to prepare its external quality programme. Each step is carried out in accordance with the requirements of the contractor’s QAP.

It will cover:
  - Quality and quantity of workmanship
  - Equipment (idem)
  - Materials
  - Contractor QA/QC
  - Validation of all stopping …
Definition of PB concept

A prescriptive approach to evaluate construction materials can be defined as the set of test methods in order to know their main constituents, characteristics or properties. By opposing to this approach a performance based one tries to test the fitness for the function the materials fulfill in the final work. Therefore, a PBA does not try to identify the material by its characteristics or constituents but by the function or objective it complies with.

Another aspect that differentiates both approaches is that in the case of the prescriptive one, the tests do not need a specific goal or objective. They try simply to identify the product univocally. However, in the case of the performance, the goal or function to comply with is precisely the most important aspect when testing the product.

The verification of the fulfilling of the function is made by defining certain "requirements" which define the function or use in the final work. Then, the performance concept applied to construction products means that they should fit into the specific use by fulfilling some specific requirements. The products and systems are not evaluated by their compliance with certain pre-specified characteristics but to their ability to fulfill the functions described in the design phase.

A prescriptive approach is that defining the products by their constitutive characteristics with independence of the functions in the work-site along their service life. The prescriptive approach has been more commonly used in the past and therefore, can be considered traditional and as such, it is much easier to be followed and accepted by manufacturers and construction companies. Thus, a product is approved if it presents the required characteristics and reaches the values pre-required in its properties.

However, the performance approach requires an effort to identify the key parameters that control the fitness for use and the durability of the products. Once identified the controlling parameters to evaluate the compliance to the requirements, it is necessary to develop tests to quantify and make objective the evaluation.

The maintenance of a prescriptive approach represents the adoption of products always responding to predefined characteristics, while a performance approach opens the possibility to innovation by not fixing the constitutive characteristics but the functions required.

It should not be distinguished the prescriptive approach from the PB by saying that the last is better or more advanced because this may influence the choice in favour to the PB even when it may be premature its application. They are different manners of evaluating the products and should be used in parallel more than as alternatives. A "multilevel" approach by using the prescriptive standards to identify the products known by best traditional practice should be recommended to benchmark the different alternatives that may appear when a PBA is used.

The prescriptive approach adapts to any kind of product in any kind of industry. The PBA is especially suitable for the construction industry due to the diversity of situations and the fact that each work has unique characteristics not usually repeated in other climates or circumstances. Thus, for the car industry for instance, whether they use a prescriptive or a performance approach is more a commercial or cultural issue, however, for the construction industry the possibility to select the products by the function the fulfill in the final work is a clear advantage. Thus, a brick is more suitably defined by its resistance to frost or tightness than for its geometry of raw clay minerals.

The performance approach is not new as was commented and, in addition, many of the present standards contain tests to evaluate the products by their characteristics related to their function. What in CON REP NET project will make the difference between the prescriptive and the PBA is the integral methodology and not the standards themselves. A description of an integral methodology being all the steps based in the performance concept will be the difference to a prescriptive approach, for the sake of CON REP NET.
Clarity of Definition Required

A clarity in the identification of all steps of the integral methodology is required, otherwise, the PB approach can be only partly applied and therefore not resulting in a correct means to evaluate the products or creating confusion more than collaborating to a better assessment of the fitness for use of the products.

An important aspect of the definition is to realize that a PBA should lead into an identification of the product which will avoid the need to test it in each circumstance it will be used. This will aim, after a certain experience is reached, into the generation of a standard to test the fitness for use of the product. This type of standard has not to be misunderstood by saying that the PBA leads into a prescriptive one, as soon as the product is tested several times. The PBA leads into PB standards when they become enough experimented but, still these standards test the functions and do not try to find out the constituents of the product.

Although it is perceived sometimes as more advanced and complete alternative for the evaluation of products, the PBA has advantages and disadvantages. They are summarized in Table 1:

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prescriptive</strong></td>
<td></td>
</tr>
<tr>
<td>- Is the traditional and known</td>
<td>- Difficults innovation</td>
</tr>
<tr>
<td>- Is easier for manufacturers and construction companies</td>
<td>- Is very restrictive</td>
</tr>
<tr>
<td>- Has already the tests needed</td>
<td>- Is not comprehensive</td>
</tr>
<tr>
<td>Is objective</td>
<td></td>
</tr>
<tr>
<td><strong>Performance based</strong></td>
<td></td>
</tr>
<tr>
<td>- It promotes innovation</td>
<td>- Has not tradition</td>
</tr>
<tr>
<td>- Adaptive to the different work sites</td>
<td>- Tests are not developed</td>
</tr>
<tr>
<td>- Is related to the use of the work</td>
<td>- It promotes more expensive products</td>
</tr>
<tr>
<td>- Better in user interests</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Advantages & disadvantages of PB / prescriptive approaches

Process for a Performance Based Approach, PBA

When needing to decide on which product best suits a particular application, the process followed by the designer is illustrated in Figure 1:

A PBA is often described by means of a triangle having in its top the goal or target of the product understood as forming part of a building work. The main levels of a PBA are:

- Identification of the **goal** or objective of the product in the work.
- Definition of **requirements** (and the indicators as properties to be tested or calculated).
- **Verification** of requirements (by testing or calculation).

Next, the process depicted by Figure 1 will be followed in order to illustrate the characteristics of the three main steps: Assessment, Evaluation and On-site incorporation.
The Concept of Duality CEN AND EOTA

Both approaches, prescriptive and PB can be complementary; however the application of both simultaneously represents an overloading of testing and verification steps. This makes necessary to adopt one or other for each case, although can complement each other in certain steps.

The ideal duality is to offer both possibilities by defining “levels”, being level-1 or simpler the prescriptive one and level-2 a higher one needing more engineering intervention as was shown in Table 1.

This duality of concepts is in a certain manner represented by the two European organizations devoted to issue Standards (CEN) and Technical approach (EOTA). Both, CEN and EOTA deal with the evaluation of construction products as defined in CPD, but while CEN deals with traditional products which can be evaluated through prescriptions, specifications or performance standards, EOTA issues Technical Guides which evaluate more comprehensively the products focussing to their performance and intended use.

The European Commission defines the regulated characteristics by mandating the CEN and EOTA in order they deliver harmonized standards or technical Approvals, ETA’s, for the performance assessment of construction products. Thus the Directives of the “New approach” as is the CPD introduce a mandatory system of attestation of conformity in the whole chain of the construction sector. The CPD tries to be a manner to reach performance based works specifications and regulations.

Other Experiences and Studies

All around the interested world the PBA is attracting research and application examples. Some references are given at the end of this report. Two main initiatives have to be described: PeBBu and Lifecon Projects. Both have wider scopes than the addressed in present report but they are described for the sake of information. PeBBu Project, which its objectives are closer to the interest of CON REP NET, has produced several articles on different aspects of the application of PBA to construction products. Lifecon, which is more devoted to service life prediction also has produced some related deliverables of interest of CON REP NET.

Another project to be mentioned is REHABCON. Two of the partners of CON REP NET were also partners in REHABCON. It will be described too and some of the “decision tools” for optimum selection of the repair option will be used in CON REP NET.

Application of PBA to the Repair of Concrete Structures

The concept of PBA will be next tried to be applied to the particular case of the repair process being this understood as a part of the general management of concrete structures. For this general purpose, Figure 2 shows the steps in the repair process comparatively with the actors involved and the several important aspects related.

In order to maintain the design level of safety, functionality and aesthetic, the owners of the structures follow a maintenance strategy.
## General Framework

- The building of concrete structures represents an investment for the owners.
- Concrete structures are designed and built complying with the design requirements of safety, serviceability and aesthetic regulated in Eurocodes.

Concrete structures need a maintenance policy in order to comply with the essential requirements during the period of their service life. Figure 3 depicts the chain of steps with more detail than in Figure 2 of the management strategy of concrete structures. As definition of service life, the design of essential requirements has to be fulfilled in all the steps of the life of the structure.

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### Figure 2. General process of service life and repair / post repair components of the management of concrete structures

#### General Framework

- Economic and financial
- Social and cultural
- Environmental
- Functional

---

### Figure 3. General steps of the framework of concrete structures maintenance.
Maintenance Policy

- It consists in the planning of inspections with assessment reports in order to verify the fulfilment of the essential requirement by the structure.
- In the case the punctual condition of the structure shows values below the threshold in any of the essential requirements, repair work is necessary to restore the initial condition.

Delimitation of repair strategy: A repair strategy is composed of the following elements (Figure 4). It shows that there are at least two methods for the optimisation of the selection (benchmarking) of best repair option: that contained in the prEN standard 1504 and that developed in the REHABCON Project (Repair Index Methods; RIM)

![Diagram of repair strategy]

The selection of the best repair option consists mainly in:

- Identification of available repair methods suiting in the needed restoration of initial condition of the structure.
- Benchmarking or comparison of best repair methods.
- Selection of the optimum repair method.
- Definition of specifications of the repair work in order the repair structure fulfils again the design requirements by executing the selected repair method.
- Execution of the repair work.
- Monitoring of the efficiency of the repair.

The restoration of values above the threshold levels on the design requirements is an essential contribution to the updating of the economical value of the structure.

Requirements for the repair processes

The object of compiling the list of requirements is to define the possible range of technical and non-technical requirements that may need to be taken into account in identifying the optimum repair option. As considered before the requirements are grouped in four main headings:

- Economical and financial
- Social and cultural
- Environmental and
- Functional
The requirements influence each other and can even be contradictory. For example, durability influences aesthetics and safety and almost every requirement influences the economy.

One of the main requirements of the structure is that it shall maintain full function during the prescribed service life, defined by the owner. By function, it can be meant requirements for structural stability and safety or load-carrying capacity. And also it can be related to service life, durability and serviceability (operation and function), by which is meant the capability of the structure to fulfill requirements that are not directly coupled to structural stability like water tightness, appearance, deformation, cracking, serviceability, etc.

Quality control and monitoring

After the selection of the best repair option it is needed to prepare the tender for the execution and to assure a quality control during it and the monitoring of the post repair process. Figure 4 showed the steps needed that are now depicted in Figure 5.

The tender following a PBA may result complex and new. The use of innovative non-experienced products may aim in a lack of guaranty of their durability and long-term behaviour. The application of repair product should be verified in the work through a quality control scheme.

Conclusions

The use of Performance concepts is not new. It has been applied from many years by International Organizations dealing with the evaluation of innovative products or those not have classical prescriptive standards

What is new is the increasing interest in its application in a broader sense to the whole kind of the management of concrete structures and, in consequence, to the aspects related to service life prediction in general including the post repair periods.

These attempts are still in their preliminary steps and need much more practice in order to be a coherent and mature set of statements, which could be incorporated in the normal design of new structures and assessment of existing ones.

The PBA consists in the definition of the function that the product has to fulfill in the structure and by a set of Requirements its ability for the intended use is verified by calculation or testing. By opposing, a Prescriptive approach consists in defining the characteristics to be fulfilled by the product, which are calculated or tested a set of test methods in order to know their main constituents, characteristics or properties.

Therefore, the main difference is that the PA tries to find the characteristics of the product while the PBA does but with the performance indicators.

The application to the Repair process of concrete structures seems feasible although the identification of Performance Requirements and Performance Indicators is not an easy task due the lack of antecedents and experience. Regarding the whole repair process many aspects will require careful consideration in order to make the process of assessment an evaluation of the repair products through a PBA achievable.

References

OBJECTIVES FOR THE DAY
On behalf of Thematic Network CON REP NET and Instituto de Ciencias de la Construcción "Eduardo Torroja" we have a pleasure to invite you to the special seminar on CONCRETE REPAIR – SOLUTION OR PROBLEM?

LEARN ABOUT:
- the best practices on rehabilitation of reinforced concrete structures
- the developing rehabilitation methodologies and successful innovations in repair and maintenance
- the current Spanish topics and experiences in the field
- the results of the latest research on performance of past and current rehabilitation practices
- the new developments and visions for future performance based approaches

Forthcoming Events
3 November 2005, Madrid, Spain

- Open CON REP NET Seminar “CONCRETE REPAIR – SOLUTION OR PROBLEM?” for all network participants. See more information at CON REP NET website.

PROGRAMME

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<tr>
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<th>Event</th>
</tr>
</thead>
<tbody>
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<td>08:30</td>
<td>Registration &amp; Coffee</td>
</tr>
<tr>
<td>09:00</td>
<td>WELCOME, Prof Carmen Andrade, Instituto de Ciencias de la Construccion “Eduardo Torroja”[E]</td>
</tr>
<tr>
<td>09:15</td>
<td>WHAT’S WRONG: CONCRETE REPAIR – SOLUTION OR PROBLEM? Dr Stuart Matthews, Building Research Establishment Limited [UK]</td>
</tr>
<tr>
<td>09:45</td>
<td>PERFORMANCE OF PAST REPAIRS, Prof Graham Riley, Giffard &amp; Partners [UK]</td>
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<tr>
<td>10:10</td>
<td>CURRENT INDUSTRY PRACTICE, RESEARCH AND REPAIR Mr Josse Jacobs, Belgian Building Research Institute [B]</td>
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<tr>
<td>10:35</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>10:50</td>
<td>CURRENT BEST PRACTICE, ASSESSMENT AND INSPECTION AND MONITORING Dr Stuart Matthews, Building Research Establishment Limited [UK]</td>
</tr>
<tr>
<td>11:20</td>
<td><strong>REVIEWS OF SOME INNOVATIONS IN CONCRETE MAINTENANCE AND REPAIR</strong> Prof Graham Tilly, Gifford &amp; Partners [UK]</td>
</tr>
<tr>
<td>11:35</td>
<td>CASE HISTORY: CATHODIC PROTECTION AND SACRIFICAL ANODES, Paul Lambert [UK]</td>
</tr>
<tr>
<td>11:50</td>
<td>CASE HISTORY: EXPERIENCES WITH REPAIR METRICS, Freyssinet Spain</td>
</tr>
<tr>
<td>12:05</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>12:30</td>
<td>CASE HISTORY: ISSUES ON POST TENSIONING AND DURABILITY, Prof Graham Riley, Giffard &amp; Partners [UK]</td>
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<tr>
<td>12:35</td>
<td>Discussion</td>
</tr>
<tr>
<td>13:00</td>
<td>PRESENTATION OF THE MANUAL REPCOR, Garston [E]</td>
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<tr>
<td>13:45</td>
<td>Lunch</td>
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<tr>
<td>14:15</td>
<td>METHODOLOGY FOR MONITORING AND ASSESSING PERFORMANCE Prof Carmen Andrade and Dr Isabel Monfray Saino, Instituto de Ciencias de la Construccion “Eduardo Torroja”[E]</td>
</tr>
<tr>
<td>14:45</td>
<td>TOWARDS A PERFORMANCE BASED APPROACH, Dr Václav Vimmr, STU [CZ]</td>
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<tr>
<td>15:15</td>
<td>SOME EXPERIENCES OF REPAIR IN SPAIN, Sika [E]</td>
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<td>15:45</td>
<td>LESSONS FROM THE PAST, LOOKING TO THE FUTURE, Mr Jean-Philippe Fusier, Freyssinet International [F]</td>
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<tr>
<td>16:15</td>
<td>Discussion</td>
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<tr>
<td>16:45</td>
<td>CONCLUSION</td>
</tr>
<tr>
<td>17:00</td>
<td>CONCLUSION</td>
</tr>
</tbody>
</table>

- Garston / London in April 2006 at BRE for Members Workshop MW6
- St Malo, France in June 2006. It is proposed that this be held in conjunction with the international Concrete Solutions Conference (27 – 29 June 2006), at which CONREPNET is expecting to mount an one day parallel session (effectively our Public Workshop PW4). See www.concretesolutions.info/news.htm

Your contributions to this newsletter are most welcome!

If you have anything to communicate through this newsletter please don’t hesitate to contact us.

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More information about the CON REP NET Network, can be obtained from the website  http://projects.bre.co.uk/conrepnet

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