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5th Transnational Workshop
UV, VIGO, 21st January 2011

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Reinforced concrete structures affected by rebar corrosion

Experiences of assessing and repairing

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Presentation

Enmacosa is a Quality Control consultancy linked to the construction sector

Among others our activities include:

- Geotechnical reporting and surveying
- Laboratory and on site material Testing
- Final test of installations and building components
- Technical support prior to and during the construction process

Construction pathology assessment

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Fundamentals needed to achieve an efficient and effective repair job

Our experiences has taught us to focus on the following aspects:

- A detailed and correct initial assessment
- The design of an appropriate repair solution
 - The solution has to work
 - Can be carried out from a technical and practical perspective
 - The solution must be cost effective
- The repair works should be carried out by specialised personnel, and should employ integrated systems without mixing products from different manufactures to avoid incompatibilities

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Initial assessment

Preliminary visual inspection

- Identification of the main deterioration mechanism
 - Chlorides – Carbonation - Stress Corrosion Cracking
 - And whether other processes which may also be taking place
- Mapping of damages
- Preliminary selection of sites for subsequent testing

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Initial assessment

Desk work

- Collection of Background data on the structure
 - Calculations and structural models
 - Design drawings
- Exposure classification
- Grouping in lots (according to three different criteria)
 - Type of structural element
 - Environmental aggressivity
 - Level of damage

This classification is essential in order to establish lots of homogeneous elements, assuming that final decisions adopted can be different for different lots and will affect all the elements of the group.

Initial assessment

In situ testing

Depth of aggressive front: carbonation and chloride advance

Mechanical strength

Resistivity

Geometry and dimension of element

Cover thickness

Section loss

Rebar detailing

Loads on structure

In situ testing



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In situ testing



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Designing an appropriate solution. Cases studies.

Designs are tailor-made to each case.

The cases that we typically find can be categorized as follows:

- **A first classification can be made according to the damage mechanism**
In this way the most common cases are:

Advance of de carbonation front

Presence of chlorides

Present in the mix

Added externally (deicing salts, marine environments, industrial plants)

Those damage mechanisms will be affected (among others) by two relevant factors:

Low cover thickness
Dry-wet conditions



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Designing an appropriate solution. Subclasses.

A subsequent subdivision can be made according to the level of damage

- Rebars without corrosion or low corrosion and the aggressive has reached the rebars or is next to it.
- Rebars with moderate or high corrosion but the structure still has enough safety margin.
- Rebars with high corrosion and the structure already has a relevant reduction of the load bearing capacity.



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Repair Solutions for each case.

Next we expose different solutions for usually cases of damage mechanism and level of damage

Case 1

Damage mechanism: Advance of de carbonation front, chlorides, or both simultaneously.

Level of damage: Rebars **without corrosion or low corrosion** and the aggressive has reached the rebars or is next to it.

Repair process

1. The cover thickness and the concrete in contact with the steel must be passived. In order to achieve this effect we prescribe a surface applied corrosion inhibitor, for use as an impregnation of steel reinforced concrete.

FerroGard-903.
Protectosil Cit

2. Both products can be used as part of an overall repair strategy using concrete Repair Systems to increase the cover thickness and provide additional corrosion protection.

MonoTop-620
EMACO NANOCRETE R4

There are several commercial products but to carry on a guaranteed repair we always recommend integrated systems and contrasted manufactures.



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Repair Solutions: Realistic case using a surface applied corrosion inhibitor



Photographs courtesy of T.V.M.A.C.,S.L. and BASF Chemical Company



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Repair Solutions for each case.

Case 2

Damage mechanism: Advance of de carbonation front, chlorides, or both simultaneously.

Level of damage: Rebars with **moderate or high corrosion** and the structure still has enough safety margin .

Repair process

1. Delaminated, weak, damaged and deteriorated concrete and, where necessary, sound concrete shall be removed by suitable mechanical or very high pressure waterblasting.
2. Surfaces should be prepared using abrasive blast cleaning techniques or high pressure waterblasting techniques.
3. Rust, scale, mortar, concrete, dust and other loose and deleterious material which reduces bond or contributes to corrosion shall be removed from the rebars.
4. Apply a corrosion inhibitor
5. Apply a primer concrete repair for reinforcement protection and also a bonding bridge.
6. Apply a second concrete repair and reprofiling mortar.
7. Optionally it can be complemented with an final protective coat and Impregnations.

There are several commercial products but to carry on a guaranteed repair we always recommend integrated systems and contrasted manufactures.



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Repair Solutions for each case.

Case 2

Damage mechanism: Advance of de carbonation front, chlorides, or both simultaneously.

Level of damage: Rebars with **moderate or high corrosion** and the structure still has enough safety margin .

Integrated commercial systems.

To carry out a guaranteed repair we always recommend to apply contrasted and integrated systems.

Option 1:

Emaco NanoCrete AP

Functions: rust inhibiting properties as it reinstates a high pH environment

Emaco NanoCrete R4

Functions: structural concrete repair and reprofiling

Masterseal 325E

Functions: final protective coat , water repellent, used for control of moisture and Chloride ion ingress, CO2 and SO2.



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Repair Solutions: Realistic case applying option 1



Photographs courtesy of T.V.M.A.C., S.L. and BASF Chemical Company



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Repair Solutions for each case.

Case 2

Damage mechanism: Advance of de carbonation front, chlorides, or both simultaneously.

Level of damage: Rebars with **moderate or high corrosion** and the structure still has enough safety margin .

Integrated commercial systems.

To carry out a guaranteed repair we always recommend applying contrasted and integrated systems.

Option 2:

FerroGard-903

Functions: Corrosion inhibitor

MonoTop-610:

Functions: Bonding primer and reinforcement coating

MonoTop-612:

Functions: Hand and wet spray applied repair mortar with a layer thickness between 5.0 mm min. / 30 mm max.

MonoTop-620:

Functions: concrete pore sealer/levelling mortar/smoothing coat



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Repair Solutions for each case.

Case 3

Damage mechanism: Advance of de carbonation front, chlorides, or both simultaneously.
Level of damage: with **high corrosion and the structure already has a relevant reduction of the load bearing capacity** .

Repair process

- In this case structural reinforcement must be designed using the most appropriate solution and material to each case, from a technical, practical and cost perspective.
- If its available, we generally design the reinforcement to carry full design loads.
- In either case, the damaged and deteriorated concrete and the highly corrode rebars shall be removed and usable structures will be protected as per case 2 (previous slide).
- Finally remember that every managment strategy must establish an urgency of intervention according to the safety margin, the present attack penetration and the prediction of advance of the agresive.

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Thank you

Experiences of assessing and repairing