duratiNet

ACESSIBILITY & TRANSPORTS

Project nr 2008-1/049

Durable Transport Infrastructures in the Atlantic Area Network

2009- 2011

REFER EPE Hugo Patrício

European Union
European Regional Development Fund
Investing in our common future
ATLANTIC AREA Transnational Programme

WG4
STEEL MAINTENANCE AND REPAIR

ACTIVIDADES DO PROJECTO

Objectivo 1

Objectivo 2

Objectivo 3

Objectivo 4

Objectivo 5

Actividade 2
Optimização da Manutenção e Ferramentas de Decisão

Actividade 9
Comunicação e disseminação

Actividade 8
DURATINET SITE & DB-DURATI Manual Web

Actividade 5
Requisitos de Controlo de qualidade na Reparação

Actividade 6
Materiais de Reparação Estrutural "Inteligentes & Verdes"

Actividade 3
Reparação de Estruturas de Betão Armado e Pré-Esforçado

Actividade 7
Avaliação da Eficiência Estrutural e dos Produtos de Reparação

Actividade 4
Reparação de Estruturas Metálicas

Actividade 10
GESTÃO DO PROJECTO DURATINET

Actividade 1
Preparação do Projecto

Working Group 4

> Maintenance and repair of steel structures

- Part 01– Durability Factors
- Part 02 - Degradation
- Part 03 – NDT Techniques
- Part 04 – Repair methods
- Part 05 – Protection methods

Parceiros activos: LNEC, U.Nantes, REFER, LCPC, EP, BEL

MECANISMOS DE DEGRADAÇÃO

> Defeitos

- Podem ser usados 3 critérios para a classificação dos defeitos:
  - *Causa*
  - *Causa-efeito*
  - *Efeito*

Defeitos Básicos

Contaminação

Deformação

Defeitos Básicos

Deslocamento

Descontinuidade

Defeitos Básicos

Deterioração

Perda de Material

Mecanismos de degradação

- The mass transport of the oxidant or of the reaction products;
- The anodic or cathodic charge transfer;
- The properties of the passive film.

When this limiting step is accelerated, the term "depolarization" is sometimes used, we then speak of cathodic or anodic depolarization according to the partial reaction considered (Crolet, 1998).

The products of reactions (4.4.1) and (4.4.3) are ions dissolved in water and can respond by giving a precipitate given by the reaction:

$$M^{n+} + nOH^- \rightarrow M(OH)_n \quad (4.1.4)$$

The corrosion process is of the electrochemical type, because it is both a chemical reaction (precipitation, etc.,), but also an electron transfer. The precipitate is a hydroxide which covers the metal surface. In the case of products containing iron, it is rust. This reaction is called "recovery" or the old terminology "passivation". If this layer is completely sealed from the time of the smallest thickness, less than 10-9.m, passivation is called perfect (Raharinaivo, 1998).

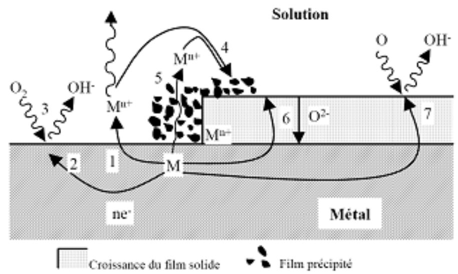

Fig. 4.1.2 Widespread corrosion process involving phenomena of charge transfer, film formation and transport processes, from ASM Handbook (1987)).

Figure 4.1.2 illustrates the different sites (numbered 1 to 7) on the surface of a metal M immersed in an aerated electrolyte solution in which the reactions occur, influenced by the formation of a precipitate on the one hand, and solid corrosion products on the other.

When corrosion products are soluble enough not to precipitate at the metal surface, allowing free access of the liquid at any point on the metal surface, then the reaction of anodic dissolution of metal (site 1) or the cathodic reduction of oxygen (site 2) generally controls the overall reaction. If these reactions are rapid and the oxygen concentration is low, then its rate of diffusion to the cathodic site (site 3) will be the limiting factor of corrosion.

In a liquid, convection represents an infinite capacity of transport in relation to flows involved in corrosion reactions. However, between the convective fluid and metal, there is a laminar boundary layer which can only be penetrated by diffusion. But the spread, even in the liquid phase, is a relatively slow transport process. The laminar boundary layer will have two effects:

- For the removal of corrosion products, this may lead to local enrichment leading to precipitation;

- Mecanismos de Degradação
  - Quimico
    - Corrosão
  - Físico
    - Fadiga
    - Altas temperaturas
    - Fendilhação
    - Penetração de água
    - Cargas Excessivas
  - Biológico
    - Sujidade
    - Organismos vivos

INSPECÇÃO
> NDT “IN SITU”

INSPECTION TECHNIQUES

MAGNETIC PARTICLES TECHNIQUE

Objective /Application field	Detection of surface and subsurface discontinuities, defects in metallic elements		
Principle	The technique consists in applying to a ferromagnetic material a magnetic field with simultaneous pulverization of revealing made up of very fine iron oxide particles. The surface defects cause at their place a magnetic flux leakage on which the particles of the revealing accumulate. Detection of the indications of defects is done in visible light with coloured particles or in U.V. light with fluorescent particles. Before the test, metal parts are cleaned (oil, corrosion product, paint...) Applicable mainly to welds with internal defects at the surface or subsurface (2 to 3 mm)		
Equipment and availability	Several commercial systems available.		
Destructive feature	NDT ☒	DT ☐	SD ☐
Cost of inspection	Low ☒	Medium ☐	High ☐
Access to element	1 Face ☒	2 Faces ☐	
Qualification & interpretation	Inspector ☒	Inspector+Specialist ☒	Specialised lab ☐
Condition of application in situ	**Traffic restriction : NO** **Preliminary works:** Surface cleaning **Environmental restrictions:** electromagnetic perturbations **Time consumption :** medium		
Advantages	Detection of surface or subsurface defects Several magnetisation methods Estimation of the length of cracks		
Limits	Applicable only to ferromagnetic materials Surface must be cleaned till metal before inspection (time consuming in presence of corrosion)		
Maturity	> 10 years ☒	< 5 years ☐	Under development ☐
Accuracy			
Standards	ISO 3059, Non-destructive testing – Penetrant testing and magnetic particle testing – Viewing conditions ISO 9934-1, Non-destructive testing – Magnetic particle testing – Part 1: General principles ISO 9934-2, Non-destructive testing – Magnetic particle testing – Part 2: Detection media ISO 9934-3, Non-destructive testing – Magnetic particle testing – Part 3: Equipment ISO 17638, Non-destructive testing of welds – Magnetic particle testing ISO 23278, Non-destructive testing of welds – Magnetic particle testing of welds – Acceptance levels		
Example	 Detection of cracking in welded element **Typical application**	 Magnetisation of the element **Typical result**	
Application under development			
References	EN 1330-7, Non-destructive testing – Terminology – Part 7: Terms used in magnetic particle testing E1444-05 Standard Practice for Magnetic Particle Testing E709-01 Standard Guide for Magnetic Particle Examination E2297-04 Standard Guide for Use of UV-A and Visible Light Sources and Meters used in the Liquid Penetrant and Magnetic Particle Methods		
Contribution: laurent	Version and date: 15-01-10		

REPARAÇÃO E PROTECÇÃO DE ESTRUTURA METÁLICA

ATLANTIC AREA
Transnational Programme
European Union
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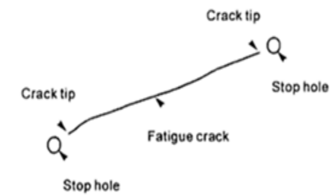
STEEL STRUCTURES

REPAIR METHODS

STOP HOLE



Description		Stop hole consists in drilling a hole at or close to the crack tip to reduce the local stress concentration and prevent crack propagation.		
Applicability	Defect(s)	Small through-thickness cracks subjected to low stress ranges in plates or plate components of structural elements, and to arrest the crack tip of large cracks provided that the remaining length of the crack is repaired by either welding or bolted splice plates.		
Applicability	Generic	Fatigue life extension technique of cracked structural elements, in both welded and bolted/riveted structures.		
Applicability	Advantages| Disadvantages	Simple, economic and used as a temporary or emergency repair method.		
Applicability	Effectiveness	In welded structures, stop hole is good for fatigue cracking due to lack of fusion, cold cracks, restraint and web breathing and may also be applied for causes such as: vibration, web gaps and geometrical changes. In bolted and riveted structures, this method is excellent for out-of-plane bending, good for problems such as secondary stresses, and fair for local stress concentration.		
Applicability	Limits	Should be used together with other repair methods but it can be considered permanent if specific conditions are fulfilled. It very dependent on the operator skill and experience. Special care is also required when crack fronts are not uniform through the thickness.*		
Applicability	Control	Visual inspection and NDT such as liquid penetrant testing, according to EN 571-1 [49] and EN ISO 23277 [50]. If the crack tip was not intercepted, the hole should be slightly enlarged.		
Specific equipment		Drilling machines, such as a portable magnetic drill machine. Protective clothing and equipment.		
Sustainability – Social	Service disruption	Yes ☐	No ☒	
Sustainability – Environmental and health	Health	Yes ☐	No ☒	
Sustainability – Environmental and health	Ecology	Yes ☒	No ☐	The waste caused by drilling should be collected.
Sustainability – Economical	Preliminary works	Yes ☐	No ☒	
Sustainability – Economical	Specialized labour	Yes ☒	No ☐	
Sustainability – Economical	Time consumption	Low ☒	Medium ☒	High ☐
Sustainability – Economical	Posterior works	Yes ☒	No ☐	Restoration of protective system depending on the material.
Sustainability – Economical	Cost	Low ☒	Medium ☐	High ☐
Standards		No available European standards. Literature referred in the manual text.		

	many types of paints.	detect, but it may be prevented by adopting suitable quality control procedures.
	Good resistance to acidic conditions, unlike metal coatings, and different materials available for different requirements.	
	No limits on size and type of structure.	The expected life is difficult to predict, even with standards and specifications, unlike metal coatings.
	Generally, application is straightforward.	

4.3 Protective coating systems

4.3.1 Paint coatings

General

The most applied protective system to metallic structures is paint coating. This type of protective system provides several advantages such as [122]: easy applicability, no limitation on the size of protected steelwork and decorative finishing.

Paint and paint coating are 2 different terms where paint is the liquid material and paint coating is the protective film formed after drying. Paint is normally constituted by binder, pigment and solvent. The protective film is formed by solvent evaporation and binder conversion into a solid paint film. The paint may also have other constituents, e.g. diluents, depending on the required properties which are best preserved when selecting an appropriate application technique. Both liquid paint and paint coating require different properties [122].

The properties of paint should include [122]: capability of application and drying under specified conditions; capacity to provide good adhesion and required decoration; and ability to provide a dry film with suitable properties, e.g. hardness, gloss, etc.

Standard EN ISO 12944-5 [107] describes several types of paint used in the protection of steel structures against corrosion. Annex A from the same standard contains numerous tables where some of the most common paint systems are characterized and divided according to their corrosivity category.

Paint properties are determined mainly by the type of binder used. Table 16 from Annex C, in Standard EN ISO 12944-5 [107], provides the main physical and mechanical properties of different generic types of paint.

Table 16. General properties of different generic types of paint [107]

Suitability ■ Good ▲ Limited • Poor □ Not relevant	Poly(vinyl chloride) (PVC)	Chlorinated rubber (CR)	Acrylic (AY)	Alkyd (AK)	Polyurethane, aromatic (PUR, aromatic)	Polyurethane, aliphatic (PUR, aliphatic)	Ethyl zinc silicate (ESI)	Epoxy (EP)	Epoxy combination (EPC)
Gloss retention	▲	▲	▲	▲	•	■	□	•	•
Colour retention	▲	▲	■	▲	•	■	□	•	•
Resistance to chemicals:									
Water immersion	▲	■	▲	•	▲	•	▲	■	■
Rain/condensation	■	■	■	▲	■	▲	■	■	■
Solvents	•	•	•	▲	■	▲	■	■	▲
Solvents (splash)	•	•	•	■	■	■	■	■	■
Acids	▲	■	▲	▲	■	▲	•	▲	■
Acids (splash)	■	■	▲	▲	■	■	•	■	■
Alkalis	▲	▲	▲	▲	▲	▲	•	■	■
Alkalis (splash)	■	■	▲	▲	■	■	•	■	■
Resistance to dry heat:									
up to 70ºC	•	•	▲	■	■	■	■	■	■
70ºC to 120ºC	□	□	▲	■	■	■	■	■	▲
120ºC to 150ºC	□	□	▲	•	▲	•	■	▲	▲
150ºC to 400ºC	□	□	□	□	□	□	■	□	□
Physical properties:									
Abrasion resistance	•	•	•	▲	■	▲	■	■	▲
Impact resistance	▲	▲	▲	▲	■	▲	▲	■	▲
Flexibility	■	■	■	▲	▲	■	•	▲	▲
Hardness	▲	▲	▲	■	■	▲	■	■	■

Note: This information has been drawn from a wide cross-section of sources and is intended to provide a general indication of the properties of the different generic types of paint available. Variations will occur within resin groups, and some products are specifically formulated to provide exceptional resistance to certain chemicals or conditions. Always consult the paint manufacturer when any given paint is chosen for a particular application.

The main requirement for protective paint coatings is to provide protection against the type of environment to which it will be exposed. Other general requirements for paint coatings are [122]: possibility to be repainted; easy application; reasonable storage life and price; durability in the specified environment; formation of a coherent film with good adhesion; resistance to impact and mechanical damage; etc. In order to meet these requirements, suitable binders, pigments, and other additional constituents should be provided.

Protection of steelwork by painting is usually assured by several coatings, forming a protective paint system. The different types of coating are [122]: the priming coat or primer, the undercoat, and the finishing coat.

The primer is applied to the substrate and there is no significant difference compared to other coatings. The main function of the primer is to "wet" the steel surface and to provide good adhesion with the steel substrate. Standard EN ISO 12944-5 [107] defines 2 main categories of primer: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