Reinforcement of corroded overhead contact line masts

Alexandre Machet, Jean-Paul Mentel, Paris (FR); Stanislas Boulet d'Auria, Monaco (MC)

Significant corrosion was detected on French Railway Network's contact line supports. In order to restore and maintain the performance of those masts, SNCF and the 3X Engineering Company developed a method aiming at restoring the supports. This method combines metallic materials and composite reinforced resin. The contact line mast repair applying composite materials allows to regain their initial performance and to diminish the logistical efforts for reconstruction as well as the costs involved.

SANIERUNG KORRODIERTER FAHRLEITUNGSMASTEN
An Oberleitungstragwerken im französischen Eisenbahnnetz wurde bedeutende Korrosion entdeckt. Um die Korrosion auszugleichen und die Leistungsfähigkeit der betroffenen Masten wieder herzustellen, entwickelten SNCF und der Partner 3X Engineering Company eine Methode zur Wiederherstellung der Tragfähigkeit der Tragwerke. Diese Methode verwendet metallische Komponenten zusammen mit faserverstärkten Harzen. Mit dieser Methode wurde die ursprüngliche Tragfähigkeit der Masten wieder herstellt. Dabei sind die Aufwendungen für die Logistik im Zusammenhang mit der Wiederherstellung und die daraus resultierenden Kosten gegenüber früheren Methoden erheblich gemindert.

RENFORCEMENT DE SUPPORTS CATÉNAIRE CORRODÉS
Certains cas de corrosion importante ont été detectés sur des pieds de supports caténaire sur le Réseau Ferré National Français. Afin de garantir le maintien en performance de ces supports une méthode a été développée en partenariat entre la SNCF et l'entreprise 3X Engineering afin de renforcer les pieds de support. Cette méthode s'appuie sur une combinaison de matériaux métalliques et composites et de résines. La réparation des supports caténaire permet de retrouver les performances initiales et diminue les moyens et contraintes logistiques ainsi que les coûts associés.

1 Introduction

For many years, the SNCF has been facing a significant level of corrosion on their contact line masts in specific geographical areas. This corrosion may be caused by saline sprays. Without the intervention of strength maintenance crew, the corrosion would deteriorate the masts due to a diminution of its strength (Figure 1 and 2).

In order to restore or maintain the mast's mechanical performance, SNCF utilizes different technical solutions:
- raising of the mast's concrete foundation block
- mechanical reinforcement of the mast by a welded mechanical assembly

Although these solutions have proved efficient over the years, they continued to be inconvenient since they require works on the tracks affecting the train operation. These solutions have already been tested on the network. However, the Engineering Department management was not completely satisfied and wanted to develop a new reinforcement method concerning other materials and less effect on operation. Studies resulted in using of hybrid composite and metallic materials for the reinforcement.

2 State of the art and developments

The corroded masts are presently repaired by conventional methods applying welded mechanical assemblies or raising of the mast's concrete foundation block. The effective implementation of these repairs is accompanied by severe inconveniences. The contact line masts are embedded in concrete and the effective load transfer needs a close mast/foundation unit. This type of close contact can only be achieved in the absence of rail traffic and requires significant logistics in order to supply the materials and tools onto the site. Sometimes, it is, therefore, preferable to replace the corroded mast in total because this procedure is economically favourable. After implementation, these reinforcement solutions need special treatment, monitoring and maintenance.

Figure 1:
Typical example of corroded mast in French network (photos 1, 2, 3, 5 and Figure 6: SNCF).

Figure 2:
Typical example of corroded mast in French network.

This situation caused SNCF to look for an innovative solution that achieves the objectives of mechanical repair and restricts the logistical constraints. Commonly with an industrial partner a solution was achieved which relies on repairs by use of composite materials adopted so far to strengthen or repair structures such as concrete piers, bridges and steel pipelines. Such repairs are carried out also in very critical atmospheres and underwater, for example. These solutions use bandages by tissues usually made of Kevlar®, impregnation by resin and added localised reinforcement which can be plastic fibers, glass or metallic fibers.

Thanks to its expertise in engineering and implementation of composite materials SNCF's partner 3X Engineering company offered a basic design for the restoration of the corrosion damaged contact line supports. The final reinforcement method was based on calculations by finite element programs taking into account ageing, fatigue of materials and vibrations and results of tests carried out in the SNCF testing centre.

3X Engineering's proposal which was developed further and patented by SNCF combines materials and technologies to an optimum solution concerning quality and costs (Figure 3).

The result of the development is a method to carry out reinforcements by portable equipment without any interruption of railway traffic and by working during the railway traffic.

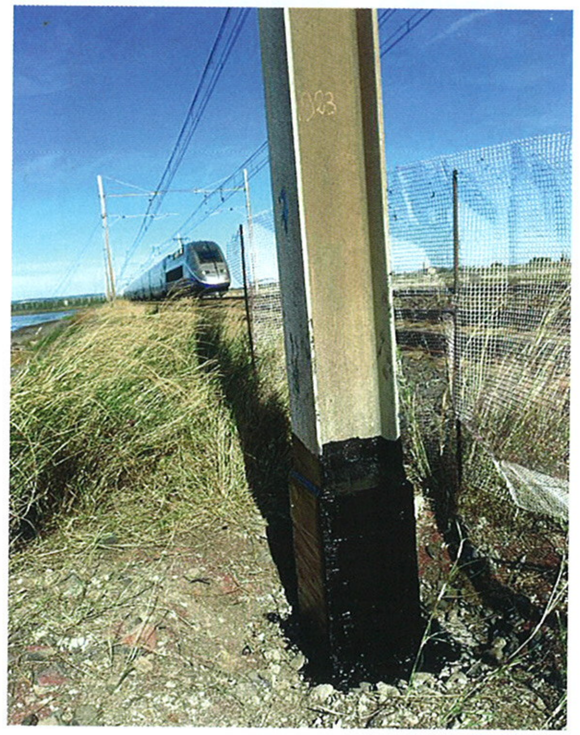

Figure 3:
Conventional mast reinforcement.

The main components of the restoration method are
- metallic inserts to get back the rigidity,
- specials mastics to block corrosion and absorb the vibrations and

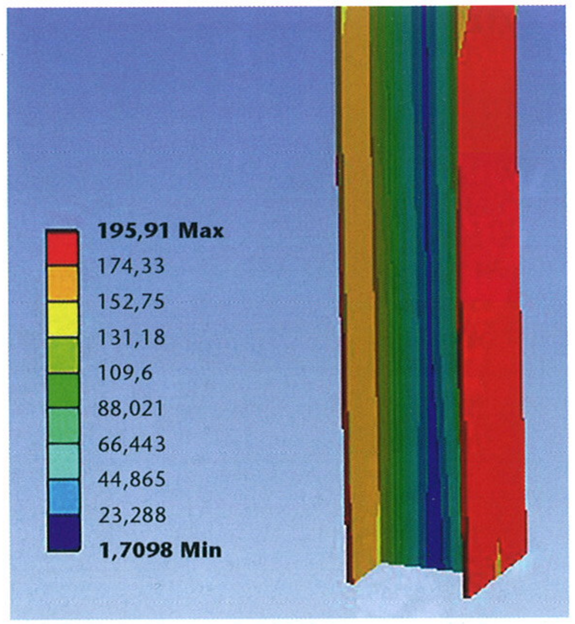

Figure 4a:
Numerical stress analysis of a new H-type mast (photos 4, 7, 8, 9: 3XEngineering).

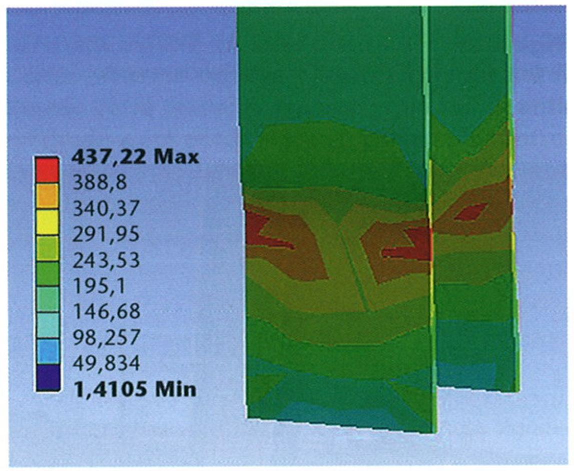

Figure 4b:
Numerical stress analysis of a corroded H-type mast.

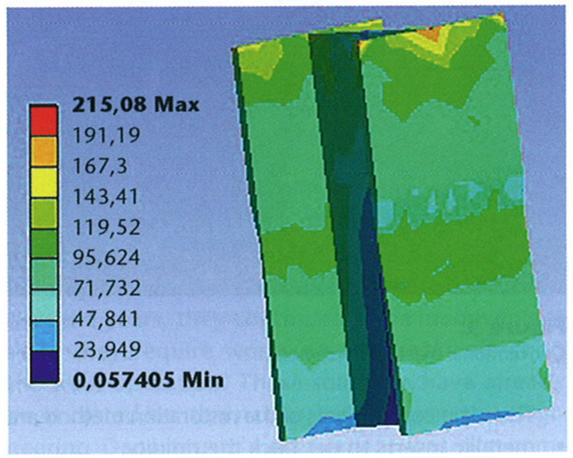

Figure 4c:
Numerical stress analysis of a reinforced H-type mast.

- a composite material bandage which fixes the inserts, produces the bending strength of the contact line mast and homogenises the reinforcing unit. Most of the stress on the base of the contact line mast is thus retrieved by the inserts. In addition, a Neoprene coating protects the unit against UV and possible impacts by the ballasts.

3 Numerical simulations

The reinforcement method was analysed by simulation with finite elements. For the simulation a worst-case scenario was assumed characterized by a gust wind of 150 km/h and the dead weight of the mast. Corrosion with a loss of 70 % of the initial material thickness was also simulated in the study. In anticipation of the ageing of the repairs, a partial factor of 2 was applied with 150 km/h wind speed and a factor of 2,7 with a 112 km/h wind speed. These assumptions are in total compliance with French standards in force. The stresses were calculated at 0,20 m above the foundation top.

Simulations with these conditions were applied for several cases:

- The initial state of the mast was simulated on an HEA mast with 70 % loss of thickness due to corrosion at the base.
- The same HEA mast reinforced by the composite ReinforceKiT HEA.

The obtained results (Figure 3) permit to obtain the maximal stress at the mast under this load in different cases. The simulated stresses of masts at 200 mm above the top of foundation are given in Table 1.

This study demonstrated the importance of the repairs, both for the dimensions of the metal inserts, but also for the number of composite coats. It was found that a mast reinforced by the so-called HEA ReinforceKiT also exceeds the original strength of the mast.

The minimal yield strength of new HEA masts is 235 MPa and the reliability coefficient is 1,2 at 150 km/h wind speed and increases to 1,7 with a 112 km/h wind. In case of the corroded HEA, there is a huge risk of a support failure under the assumed wind speeds.

In the case of the reinforced HEA, the reliability coefficient will be 2 with a 150 km/h wind and 2,7 with a 112 km/h wind. The maximum stress of 215 MPa is due to an abrupt section variation. These stresses are reduced by progressively varying section during the implementation of the reinforcement.

TABLE 1

Numerically estimated maximum stress in MPA of various H-type masts in site foot.

	New mast	Used mast	Reinforced mast
Stress	174 to 195	389 to 437	96 to 120

From the Table 1 and the comparative simulations presented in Figure 4a) to c), it is clear that the reinforcement will consolidate the basis of HEA masts significantly beyond its initial mechanical values in respect of maximum corrosion at 200 mm above the top of foundation.

The ageing of this reinforcement was also studied and led to the following conclusions:

Since the 1960's, the experiments on composite materials proved the reliability and durability of these materials. The expansion of using these materials in many fields of civil engineering confirms this fact. Today, after 20 years of experiment, after several installations in critical environments such as North Sea, deserts, submerged or buried in damp ground on different types of supports, 3X Engineering never has got any negative return of the ReinforceKIT®. The assumed degradations of the components by environmental impacts are detailed in Table 2.

The technical assessment allows being optimistic about the longevity of repaired masts, especially as the composite part of the ReinforceKiT 4D-HEA is the least attacked. This reinforcement method guarantees the durability of the installations while avoiding the efforts for huge and tedious construction sites. The biggest part of the mechanical loading is absorbed by the metallic inserts. A preventive application of the product anti-UV and anti-impact components is planned.

TABLE 2

Frequency of environmental attack possibility on the components of the ReinforceKIT®.

	Attack type				
	UV	Humidity	Stress	Chemical	Impact
Insert	No	No	More than 50 years	No	No
Composite	No, because protected	No, because protected	More than 20 years	No	Verified in situ
Coating	5 years	5 years	No	No	5 years

4 In situ mechanical tests

Some tests were carried out as a part of the validation of the reinforcement process mast sections. Thus, masts were errected on SNCF testing station. The tests involved estimating the mast reaction under mechanical loads applied at the mast head (Figure 5a)). The tested masts were:

- one new mast
- two weakened and reinforced masts
- one weakened but non-reinforced mast.

Figure 5a:
Testing of a reinforced H-type mast.

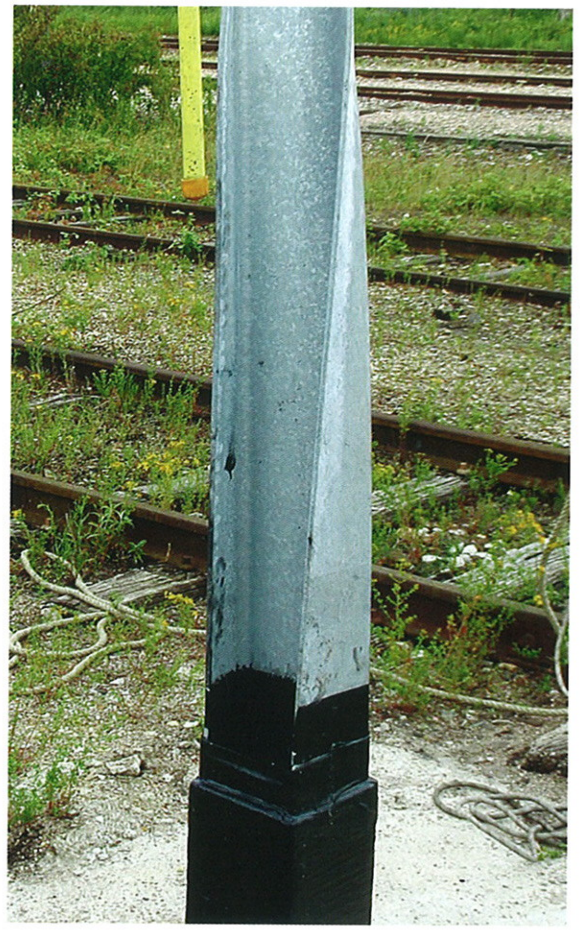

Figure 5b:
Performance of the reinforced part of H-type mast after testing.

The supports were artificially weakened by grinding.

These results (Figure 6) clearly state reproducibly that the reinforced masts' performance is clearly better than that of the weakened mast. Moreover, it is better than the performance of new masts.

The mechanical tests demonstrated that the mast mechanical reinforcement by composite materials comply with the requirements on new supports. The performance of the reinforced mast is simply explained by the fact that the mast reinforcement appears as a displacement of the embedment area, and thus reduces the effective length of the HEA beam.

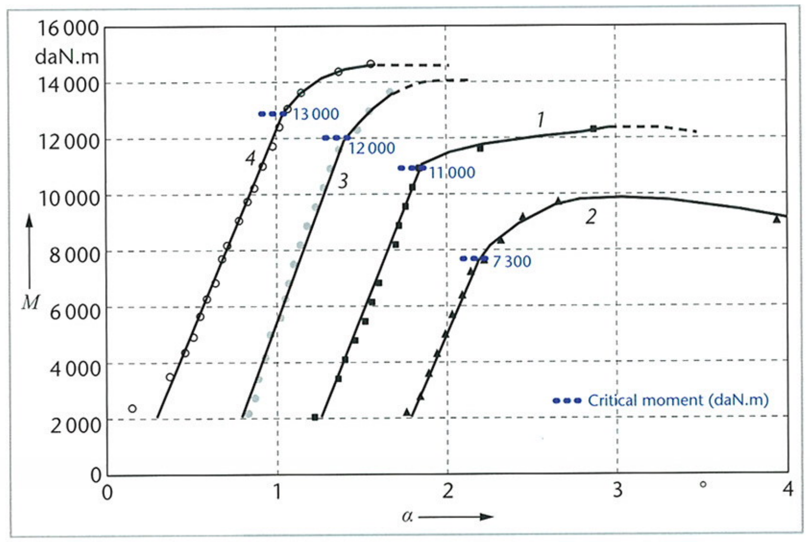

Figure 6:
Bending moment M depending on angle α.
1 new mast
2 used and corroded mast
3 reinforced mast type 1
4 reinforced mast type 2

5 Implementation on the National Railway Network

The implementing process on the National Railway Network will be carried out in several steps:

- Step 1: Preparation of the mast's surface by shot-blasting with a minimum roughness profile of 60 µm in order to ensure the adhesion of the reinforcement on the mast and the emerging part of the concrete. It is realised by sandblasting or grit blasting tool (Figure 7a)).
- Step 2: Re-aggregation of the cankers due to corrosion by application of an epoxide mastic. This mastic ensures the transmission of contact line mast's stresses to the inserts constituting the reinforcement (Figure 7b) and c)). The mastic's role is also to ensure the cold welding of the four inserts.
- Step 3: Implementation of the four inserts. Size and nature of the chosen materials are related to their mechanical and physical characteristics (Figure 7d)).
  - The unit of blocks and slabs is maintained thanks to straps during the time of polymerization of the mastic in order to avoid any risk of gap or detachment of the inserts (Figure 7e)).
  - The resin is applied on the emerging part of the mast with a particular attention given to the mast embedment part (Figure 7f)).

Figure 7a:
Preparaton of mast surface (step 1).

Figure 7b:
Mast pepared for repair (step 2).

Figure 7c:
Preparation of inserts (step 2).

Figure 7d:
Reparation of inserts (step 3).

Figure 7e:
Polymerization of the mastic (step 3).

Figure 7f:
Application of resin (step 3).

Figure 7g:
Wrapping the Kevlar® strip on the repaired mast (step 4).

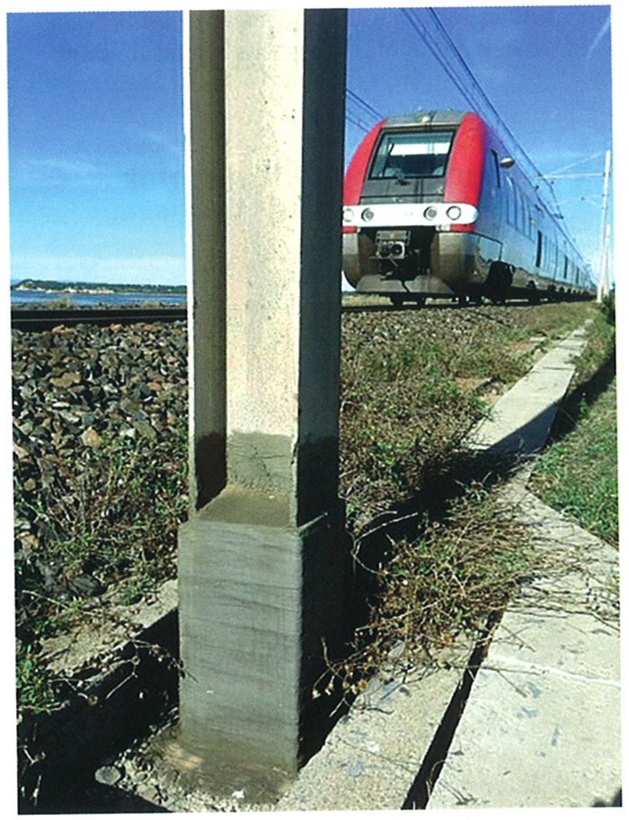

Figure 7h:
Repaired mast (step 5).

Figure 8:
Restored mast on the Narbonne to Port Leucate railway line in the Aude.

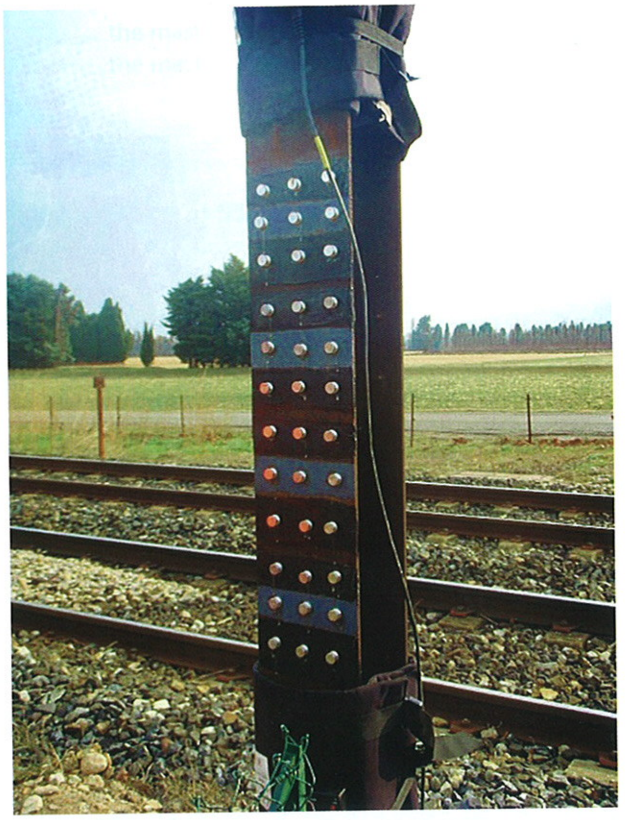

Figure 9:
Preliminary study on restoration of a corroded mast made of CORTEN steel to select the most appropriated resin.

- Step 4: Wrapping of the whole repair with a Kevlar® strip soaked in an epoxide resin.
  - Several coats are made; the wrapping is carried out from the base to the top with a constant covering of about 50 % (Figure 7g)).
  - The top zone of inserts is machined with a slope in order to present an angled top face to avoid any risk of stagnant water.
- Step 5: Application of an elastomeric resin which guarantees a protection against UV and other impacts (Figure 7h)).

This new mast rehabilitation procedure has notable economic advantages:

- It avoids the cessation of railway traffic.
- It avoids dismantling the existing masts.
- It avoids purchasing of a new mast.
- It avoids the implementation of an extended construction site
- It limits the logistical efforts.
- It can be quickly carried out if urgent.

Today, this reparation method is approved by the SNCF for H-type masts. It is envisaged to extend this repair method to other types of supports.

The 3X Engineering company already started several campaigns on this type of reinforcements on the French National Railway Network. The Narbonne to Port Leucate railway line in the Aude was the subject of two campaigns in 2011 and 2013 in order to treat several hundreds of masts on two tracks (Figure 8).

A new campaign is being prepared and will concern the contact line masts of the line Miramas to Avignon. The 54 masts concerned by this campaign were realised in CORTEN type steel.

A preliminary analysis of the supports (Figure 9) allowed to prepare the masts and to select the most appropriated resin. The implementation is scheduled for September 2014.

AUTHORS

Alexandre Machet (39), Materials and metallurgy PhD, Pierre et Marie Curie University of Paris (Paris VI). R&D Engineer in charge of technical developments in Overhead Contact Line components and systems. Since 2014, manager of OCL Simulations, R&D, Measurements and Expertises unit within SNCF Fixed Installation for Electrical Traction Department.

Address: SNCF Infrastructure Engineering Division, Fixed Installations for Electrical Traction – Power Supply and Overhead Contact Systems Units, 6 Avenue François Mitterrand, 93574 La Plaine Saint Denis, France;
phone:+33 1 41620578;
e-mail: alexandre.machet@sncf.fr

Jean-Paul Mentel (57), Mecanical and Electrotechnical Engineer. Expert SNCF in Overhead Contact System. Design manager of OCS, maintenance infrastructure manager (OCS, power supply, track, signaling...). Since 2010, deputy of the SNCF Fixed Installations for Electric Traction Department and in charge of FIET research and development.

Address: see above;
phone: +33 1 416206.59;
e-mail :jean-paul.mentel@sncf.fr

Stanislas Boulet d'Auria (57), Engineer ESTACA (1980). R&D Engineer in charge of technical developments in INNOGE (Electrofusion sleeve for PE Pipe), Commercial manager in MIP (mold maker), CEO Empreinte (Specialist design, conception, mold and injection for plastics parts. Since 1990 CEO 3X Engineering.

Address: 3X Engineering, 9 Avenue Albert II, 98000 Monaco, Monaco;
phone: +377 92 057981;
e-mail: sbda@3xeng.com