Advanced Materials Research Vols. 133-134 (2010) pp 519-524

doi:10.4028/www.scientific.net/AMR.133-134.519

Preliminary Studies for the Recovering of the Armstrong, Mitchell & Co. Hydraulic Crane of the Arsenal of Venice

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Abstract In this paper, the preliminary study of intervention on puddle iron and cast iron Hydraulic crane, situated in the “Arsenale” of Venice is described. The crane was built by Armstrong, Mitchell & Co. in 1885. It is one of the most important and the last remaining example of XIX century innovation of English engineering, after the disposal of other Armstrong Company cranes. Thanks to the interest of the Superintendency of Venice and The Venice in Peril Fund UNESCO Committee, the crane is now undergoing restoration works. To design and execute the restoring interventions of the crane, a preliminary study was necessary. The first fundamental step consisted on performing a detailed historical research, focused in particular of the past interventions and on identifying the most important causes of damage.

Keywords: Hydraulic crane, intervention, geometry (survey), materials (investigation), deterioration, behavior

Introduction

The most profound and radical transformation of the shipyards in the history of navigation, from its origins to the present time, took place during the 19th century. After the unification of Veneto to the Italian Reign, the “Arsenale” of Venice had to be transformed because the lagoon city had to be maintained a basic role (Martini 1877). At the same time due to technological evolution and shipbuildings, there was the development of lifting machines took place in which one of the main protagonists was the company founded by William George Armstrong. He started his research on applications of hydraulic lifting equipment on the late 30's and developed it in the subsequent years, with his partner George Rendel. Then, Armstrong Mitchell & Co. was founded by Sir William George Armstrong in 1847. In the eighties (same century) it incorporates the Charles Mitchell and C. company (Menichelli et al. 2006).

The cranes produced by Armstrong, Mitchell and Co. between 1877 and 1905 are the highpoint of 19th century technological achievement in the field of hoisting machinery. They were developed as product of vanguard of contemporary naval shipbuilding, in particular, the need to lift cannon weighing over 100 tons each, and armory for war-ships. The first of these cranes was installed in La Spezia in 1876, the others in Bombay, Liverpool, Malta, Taranto, Pozzuoli, and two in Japan (1892 and 1905) (Nascè 1994).

The need of a large-scale crane in the arsenal of Venice emerged in 1881 due to the decision of constructing the battleship Francesco Morosini, where 4 Armstrong breech-loading cannon from 106 tonnes had to be placed. In 1883, the crane was commissioned directly by the Italian Navy as part of a plan to enlarge and modernize the “Arsenale” of Venice. The crane started to operate in 1885 (Fig. 1) (Martini 1897, Menichelli 2003).

At the beginning of the 20th century the steam engine is substituted by an electric motor. The crane remained in operation for about 30 years, until the First World War, when it suffered some damage.

The lifting cylinder was put out of service in 1940. Later the crane continued to perform its function with the aid of a winch, damaged in 1946, but immediately repaired. Then, due of non-use of the arsenal of Venice for military purposes the crane stopped working during the fifties of the last century (Menichelli et al. 2006).

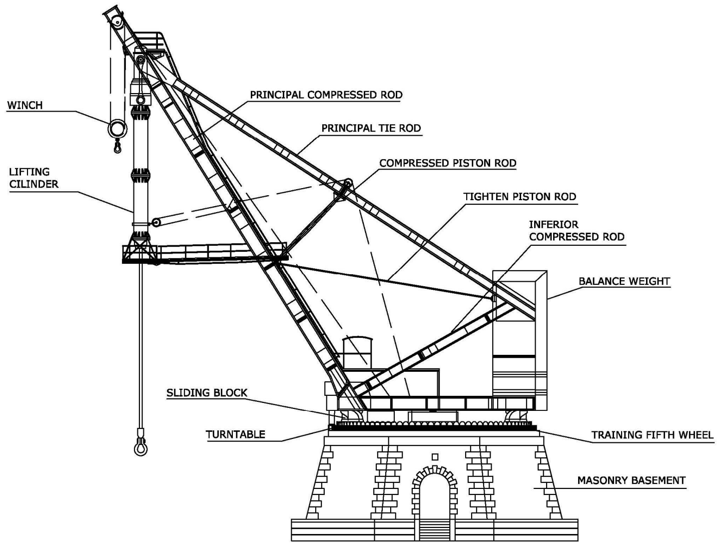

Figure 1: Armstrong, Mitchell & Co. Hydraulic crane in Venice (Bovolenta 2005)

Over the last century, the great cranes of the Armstrong Company were dismantled, one by one. The last to be dismantled, in 1992, was in La Spezia, leaving only this crane as witness of the engineering skill of our ancestors. For this reason, for its unique setting and for its particular constructional quality, the Venice hydraulic crane is an important part of the cities heritage.

Constructive Features

The crane is composed of two parts: fixed basement structure and mobile elevation structure. The first includes masonry basement and training fifth wheel. The second includes revolving platform, network structure of the arm and hydraulic lifting system.

The basement is built in masonry and Istria stone, upon concrete foundations placed on a dense piling. Its volume is a frustum of pyramid shaped octagonal base, and there is an internal room with a depressed vault. Here are located the machinery.

The mobile elevation structure includes training fifth wheel, turntable, sliding blocks, arm of the muzzle and balance weight. The training fifth wheel (Fig. 2) is built in cast iron and iron. It is composed by rolling ring and crown gear in cast iron, 96 rollers in cast iron, iron sheet ring with structure to caisson, iron structure composed by rods with a sunburst pattern.

The turntable (Fig. 2) is utterly built in puddle iron, it leans against and it slides on the rollers below by means of 4 cast iron sliding block. An horizontal frame with rectangular contour constitutes the structure of the platform. The arm of the muzzle is constituted by a reticular spatial structure composed by an inferior strut and a main one, a tight main rod, an intermediate compressed rod and a support tie rod. The balance weight is included in this static system.

Figure 2: mobile elevation structure, training fifth wheel and turntable

The materials that compose the crane are: regular bricks (6,5x13x26 cm) with different qualities of clay, header and stretcher alternate, mortar joint, two varieties of Istria stone, one more compact and white, worked by hack hammer and rod proof pointing, and a grey one worked with sand. Another material that makes up the crane is grey cast iron from foundry with approximately 3,5% temper, with presence in the structure of graphite flake and a percentage of silicium equal to 2,34%. It was product of the fusion of minerals in the blust fornace working with coke coal from the 18^{th} century onwards. The last one is puddled iron with silicium presence and superficial ferritic vitreous vein; carbon comprised between 0,005% and 0,2% (in general terms). It was produced since 1784 for decarburization of the fused cast iron obtained in puddling furnaces (Bovolenta 2005).

Deterioration Conditions

In 2004 the "Soprintendenza di Venezia" obtained a financing from the "Venice in Peril Fund" for assuring the safety of the crane and for the beginning of a recovery project.

In order to define the geometry of the crane it was carried out of observation campaigns, surveys and historical research, to identify all the elements and better define the recovery project.

The steps of the survey operation are: (1) finding of original drawings, (2) control survey, (3) photographic documentations and representation. Techniques used for the survey were topography, photogrammetry, laser scanning, measurement and photography.

This is done to provide the fundamental representations of the machine, its composing elements and building systems. It is used to estimate the consistence of materials of the crane with reference to the complex issues surrounding the conservation of metal structures and machines. Were also carried out investigations into materials for the definition of conservation status and performed structural assessment on the basis of the structural elements of knowledge available.

The measurement campaign is made in 1:1 scale. The scope of this work is to identify all the connection between elements of the crane. And also location of the rods, dimension of the sections, pitch and diameter of the rivets, characterization of the nodes in which rods and plates converge. All these measures have been reported in cards and then they were developed (Fig. 3).

Figure 3: Detailed survey of the crane

Degradation conditions of the structure was registered by detailed of the photographic survey (Fig. 4).

The different external preservation due to the speed of the wind on the south dock evidence strong erosion, differential degradation and superficial one. In particular, the north dock is affected by formation of black crusts, superficial drift, expulsions, disconnections and localized failings, but almost unchanged superficial consistency of materials was detected.

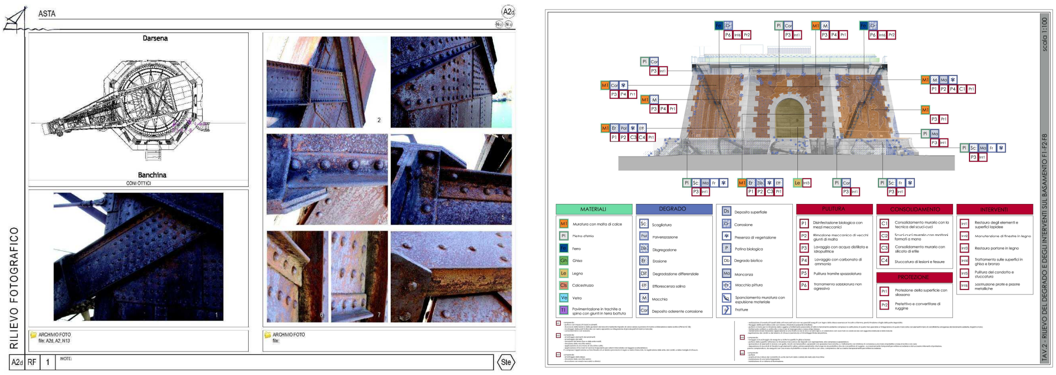

Figure 4: Photographic survey for characterization of the state of degradation

Superficial elements caused by scouring of the products of metallic structures oxidation was observed. The saline efflorescence is mainly in the lower parts and never on the corrosion drifts or the black crusts. The main cause is chemical agents due to the marine environment and presence of humidity. Inside the basement, the condensate humidity, the steams produced during the working and the external percolations have made easier the deposits of the corrosion products on the whole surface of the vault (Fig. 5).

In the crane there are diffusion and localized corrosion. The rollers localized corrosion is characterized by a particular exfoliation of the superficial veins due to the wear and to backwater. The rolling plane (Fig. 6) of the rollers is irregular because of differences in the load, the rods with a sunburst pattern are deformed and irregular. There is also a stratified drift of different materials that makes easier corrosion on the less ventilated areas.

The cast iron sliding blocks (Fig. 6) are interested by a strong localized corrosion, emphasized by a corrosion fatigue stress, mainly on the two sliding blocks behind, under the balance weight (400 t). On the back sliding blocks there are stiffening in sheet steel. The curtaining (Fig. 6) seem present only on the sheets steel of the balance weight, limited thanks to accurate steel structural work and for the low pith of the rivets. The diffuse corrosion in all the metallic parts didn’t have probably damaged the structural integrity of the crane thanks to the quality and the dimensions of the elements.

Figure 5: Actual degradation of the basement – outside and inside

Figure 6: Actual degradation of rolling plane, sliding blocks and curtaining

Intervention Plan

The interventions for the recovery of the crane could be articulated in 2 steps: interventions to provide safety conditions of the structure and materials and constructive technology recovery.

At this moment the first phase only (Fig. 7) was concluded. It was oriented towards reconfiguration a new equilibrium of the structure in the actual load patter (dead load, roll and purchase). For this study we made particular attention at the condition of the sliding blocks under the balance weight, that are interested by a strong localized corrosion.

In this first step the diagnostic phase of materials will be very important to estimate the actual safety of the structure and to choose the successive interventions.

The mechanical characterization of materials tests are pull tests, hardness tests (Brinell, Poldi, Vickers) and impact tests. The chemical characterization and microstructural tests for the qualification of superficial degradation are metallographic tests (microscopy and stereoscopy) and chemical analysis (spectrometrics and with prob for microanalysis).

The chemical analysis will be determining for the integrations or fusion of new elements and to choose the cleaning and protection interventions of the structures.

Operations that have been made for the recovery of the crane are reinforcement ring of the balance weight and the partial emptying of the balance structure maintains the equilibrium of the structure.

The wind pressure had been taking to account. The balance weight, which was approximately of 400 tons, has been reduced of 100 tons in order to maintain the balancing.

Figure 7: Intervention to provide safety conditions

Recovery Program

The second phase of the recovery program of the crane will consist in the interventions for the conservation. The studies made and the results of the investigations will be defined as the level reaches the intervention of conservation, with particular reference to the possibility of preservation the original material of the crane. The main intervention consists of removing all the content of the balance, recovering the balance and then put again the material.

To perform the recovery interventions it will be necessary to develop a detailed FEM model of the crane. The aim of this model is the estimation of the global behavior of the structure. It will be an essential tool for the evaluation of the most suitable intervention for the structure without changing

the existing situation and the equilibrium of the crane. It will also allow the identification of critical points and access the need for intervention and what is the most appropriate solution.

Following the evaluation of structural joint efficiency respect to the new load conditions, the recovery of the rivet joints to reserve not only the static behavior but also their symbolic and esthetic role will be consider. After that, materials will be recovered with particular techniques for cast iron elements (electrodes and resin infiltrations), elimination of the drifts and infiltrations, restoration of the collection and of disposal system of water. Protection of the elements from the corrosion due to aggressive marine environment by means of cleaning with appropriate techniques and products will be also considered. Finally, strengthening, cleaning and preservation of the basement will be performed, followed by the arrangement of a program of planned maintenance and one of run planning for the check.

The purpose of work will be valorization and fruition to deliver the crane to the visitors. It consists in the conservation of the machines located into the basement with the restoration of standing finishes and the check of the interior humidity. Creation of an illustration room that can show also the dynamical aspect of the crane. Evaluation of the degree of fruition of the crane parts with regard to the necessary measures of safety for the visitors. The crane will be inserted into a route through the story of the technological “Arsenale” of Venice progress.

Conclusions

The preliminary approach for the successive preservation intervention of the Armstrong hydraulic crane, located at the Arsenale of Venice, was presented. The objective was to provide the fundamental representation (plans, elevation and sections) of the machine, its constitutive elements and building systems, to estimate the consistence of materials of the crane with reference to the complex issues of the conservation of metal structures and machines.

The preliminary study consisted in the acquisition of a detailed knowledge of the structure by means of a research of all the relevant historical information of the Armstrong’s cranes (in particular for that present at the Arsenale of Venice), the definition of the constructive features, the execution of geometrical and photographic survey, the identification of the actual degraded conditions and the investigation of the mechanical and chemical characteristic of the materials.

At the present only the mechanical tests are missing for completing the acquisition of detailed knowledge of the Armstrong’s crane. The detailed knowledge, aided by a finite element model of the crane, will allow the drafting of a targeted preservation project and program of the crane.

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