Marine Structures 49 (2016) 18–30

Contents lists available at ScienceDirect

Marine Structures

journal homepage: www.elsevier.com/locate/marstruc

Experimental assessment of tensile strength of corroded steel specimens subjected to sandblast and sandpaper cleaning

Y. Garbatov [a, 1], J. Parunov [b, 2], J. Kodvanj [b], S. Saad-Eldeen [a, 3, 4], C. Guedes Soares [a, *, 5]

[a] Centre for Marine Technology and Ocean Engineering (CENTEC), Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

[b] University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

ARTICLE INFO

Article history:
Received 10 October 2015
Received in revised form 17 May 2016
Accepted 24 May 2016

Keywords:
Corroded steel
Tensile tests
Mechanical properties
Degradation
Stress-strain relations

ABSTRACT

The effect of sandblasting and sand paper cleaning on the mechanical properties of corroded steel specimens is studied. An experimental assessment of tensile strength of small scale steel corroded specimens is performed. The specimens were cut from a box girder, initially corroded in sea water conditions and later the specimens were subjected to sandblast and sandpaper cleaning. Tension tests are performed to determine the mechanical properties of three groups of specimens, including non-maintained, sandblasted, and sandpaper cleaned, corroded specimen, allowing the estimation of the modulus of elasticity, yield stress, tensile strength, total uniform elongation and n and K strength parameters. Regression equations of the material properties are derived as a function of the degree of corrosion and maintenance actions. It is shown that these two methods of removing corrosion products from the surface of plate specimens have different effects on their mechanical properties and stress-strain relationships. Based on the achieved results a simplified stress-strain curve accounting for the corrosion degradation and maintenance actions is developed, which may be used for structural assessment of ageing marine structures.

1. Introduction

Corrosion degradation, crack growth and collisions are the most frequent damage scenarios in marine structures. Corrosion leads to surface roughness, reduction of the plate thickness and strength, and eventually plate perforation and leakage. Crack growth may provoke a sudden strength reduction and loss of structural integrity. Ship collision is a much rare scenario, but the consequence of it is always severe damage.

* Corresponding author.
E-mail address: c.guedes.soares@centec.tecnico.ulisboa.pt (C.G. Soares).

[1] Secretary ISSC2015; Chairman of the ISSC2018 Committee III3.2 Fatigue and Fracture.
[2] Member ISSC2015 Committee I.2 Loads; ISSC-ITTC2018 Joint Committee.
[3] On leave from the Naval Architecture and Marine Engineering Department, Faculty of Engineering, Port Said University, 42526, Port Fouad, Egypt.
[4] Member ISSC2018 Committee III.1 Ultimate Strength.
[5] Chairman ISSC2015; Chairman ISSC-ITTC2018 Joint Committee.

http://dx.doi.org/10.1016/j.marstruc.2016.05.009
0951-8339/

Under conditions of high temperature, inappropriate ventilation, high stress concentration, high stresses, very high rates of corrosion can be achieved in spaces such as ballast tanks and at specific structural locations. This has been of a great concern by ship operators and Classification Societies that have collected real measured data in the last decades. Different models have been developed to explain the growth of corrosion wastage, combining in general some considerations about the physics of corrosion growth with the fitting of service data [1–5].

Since the phenomena of corrosion deterioration is a consequence of extremely complex phenomena governed by many factors [6–9], it is necessary to establish corrosion margins and permissible corrosion levels by taking into account past records. An average annual corrosion rate obtained by dividing the thickness reduction of an aged member by a ship's age at a given time has conventionally been used as the basic criteria [10,11], due to easy of assessing and handling, but more rational criteria, assessing it with a probabilistic model are needed [12], so that reliability studies can be made [13].

Recently a very intensive experimental and numerical work is performed in identifying the effect of corrosion degradation on the strength of ageing marine structures. Corroded box girders have been tested for ultimate strength, showing an important reduction of strength [14]. The analysis of the results suggested that this might have been done by changes in mechanical properties of the corroded steel [15].

In the fatigue strength assessment performed in Ref. [16] it has been demonstrated that the severe corrosion degradation of a stiffened panel may reduce the fatigue strength from FAT 100 to 65 MPa as a result of the crack propagation starting from corrosion pits and due to the changes in mechanical properties of the corroded steel.

The study reported in Ref. [17] showed that the presence of corrosion pits produced by the method of constant temperature and humidity with prior immersion in saturated NaCl solution for about 2 min, significantly reduces the fatigue life of corroded steel. The relationship between fractal dimension of roughness surface and fatigue life of corroded steel plate, fractal dimension of roughness surface and corrosion ratio and corrosion ratio and fatigue life of corroded steel plate was also studied.

An interesting study has been reported in Ref. [18] evaluating the changes in the mechanical, micro structural and the corrosion properties of stainless steel 316 L under repeated repair welding. The specimen of the base metal and different conditions of shielded metal arc welding repairs were studied by looking in the micro structural changes, the chemical composition of the phases, the grain size (in the heat affected zone) and the effect on the mechanical and corrosion properties.

The work presented in Ref. [19] analysed small scale corroded specimens, which were firstly corroded and then tested under tensile load. Mechanical properties of specimens, namely modulus of elasticity, yield stress, tensile strength, resilience, fracture toughness and total uniform elongation were proven to be severely affected by the corrosion degradation.

A recent study [20] presented numerical and experimental analyses on the effect of the non-uniform corrosion degradation on the load carrying capacity of corroded stiffened plates. It has been confirmed that the corrosion degradation has a great influence on the ultimate strength reduction. The strength capacity is affected by the combination of several factors, including the degree of degradation, pit density, boundary conditions, initial imperfections, type of loading, failure buckling modes and material property changes due to corrosion.

The structural integrity of ageing structure is analysed based on the permissible stresses that are as a function of the yield stress of material in the case of tensile load and on buckling or ultimate strength in the case of compressive load. In both cases the stress-strain material properties relationship is fundamental. In fact, for the ultimate strength assessment in the non-linear finite element analysis an idealized stress-strain or load-displacement relation is used (see Fig. 1 left).

The limit state of ageing structures represents the collapse of the structure because of the loss of stiffness and strength. It is usually related to loss of equilibrium in part or to the entire structure from buckling and plastic collapse of plating, stiffened

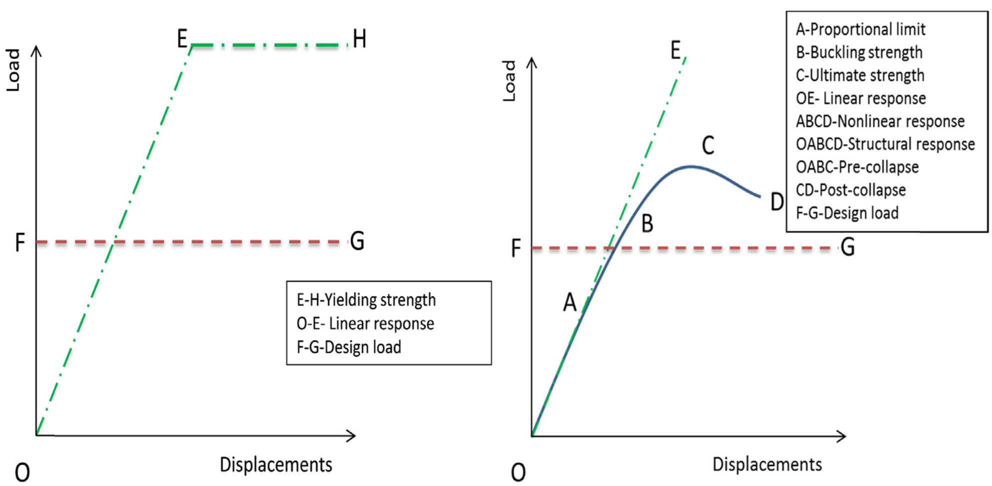

Fig. 1. Material load-displacement (left) and ultimate limit state (right).