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Failure analysis of the highway sign structure and the design improvement

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ABSTRACT

In this paper failure analysis of the highway sign supporting structure due to wind loading is presented. It is explained why the commonly practiced static strength validation of such structures, under the extreme monotonic wind load, is not sufficient for the design of wind-loaded stationary structures. A reliable procedure, necessary to validate the structural strength under wind loads, must include the structural strength validation under extreme monotonic load as well as the evaluation of fatigue under the stress spectra of the variable service loads. It is described in what manner the service stress spectra can be derived on the basis of the finite element method (FEM) results and the data about wind activity and intensity (duration and frequency, direction, speed). Taking into account the estimated service stress spectra and the data about allowable stresses for welded joints, given in corresponding design codes, the fatigue evaluation and fatigue life prediction for the fractured structure was carried out. Based on the data of the fatigue evaluation, different design variants of the sign supporting structure were analysed and the best option to fulfil the requirements was selected.

1. Introduction

The sign support structure, designed as shown in Fig. 1, has been used in various sizes throughout Croatia for a number of years in order to support different types of traffic signs and signals. They are designed according to the commonly used design procedures (rules and recommendations). The column on which the sign panels are welded is a seamless tube with dimensions 457 × 12.5 mm, Fig. 1, manufactured from steel material with ultimate static strength R_m = 430 MPa and yield point $R_{p,0.2}$ = 275 MPa; the material of the braces is a mild steel with ultimate static strength R_m = 360 MPa and yield point $R_{p,0.2}$ = 235 MPa. However, an increased use of this type of structure at specific locations in the Croatian coastal region, particularly in Dalmatia, has recently resulted in a series of premature failures. Failure analysis of these fractures including service strength evaluation, treated in Sections 2 and 3, has shown that these fractures were generated by fatigue due to the variable wind loads.

According to EN 1991-1-4:2005 [1], the basic parameter for the calculation of wind actions on structures is the fundamental value of the basic wind velocity, defined as the characteristic 10 min mean wind velocity, irrespective of wind direction and time of the year at 10 m above ground level on a terrain category II. To determine all the values needed for the design, it is necessary to use statistical methods for a reliable estimation of extreme values (e.g. maximum wind speed per year) and the spectra of wind loads being representative for the operational usage [1–4]. Dalmatia, according to [5], is covered with expected fundamental value of wind speed exceeding 30 m/s, while the maximum recorded speed reaches

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