Reliability-based robustness analysis for a Croatian sports hall

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A B S T R A C T
This paper presents a probabilistic approach for structural robustness assessment for a timber structure built a few years ago. The robustness analysis is based on a structural reliability based framework for robustness and a simplified mechanical system modelling of a timber truss system. A complex timber structure with a large number of failure modes is modelled with only a few dominant failure modes. First, a component based robustness analysis is performed based on the reliability indices of the remaining elements after the removal of selected critical elements. The robustness is expressed and evaluated by a robustness index. Next, the robustness is assessed using system reliability indices where the probabilistic failure model is modelled by a series system of parallel systems.

1. Introduction

1.1. Robustness of structures in the codes

Robustness of structural systems has attracted renewed interest due to a much more frequent use of advanced types of structures with limited redundancy and serious consequences in case of failure. The interest has also been stimulated due to severe structural failures such as that at Ronan Point in 1968 [1] and at the World Trade Center towers in 2001. In order to minimise the risk of such disproportionate structural failures many modern building codes consider the need for robustness in structures and provide requirements, strategies and methods to obtain robustness, see e.g. [2,3]. The requirement for robustness is specified in most building codes in a way like the general requirements in the two Eurocodes, EN 1990 Eurocode 0: Basis of Structural Design [2] and EN 1991–1–7 Eurocode 1: Part 1–7 Accidental Actions [3]. The first provides the basic requirements, e.g. it is stated that a structure shall be “designed in such a way that it will not be damaged by events like fire, explosions, impact or consequences of human errors, to an extent disproportionate to the original cause”. The second provides strategies and methods to obtain robustness though actions, and design situations to consider.

1.1.1. Robustness measures

During the last few decades a variety of researchers have attempted to quantify aspects of robustness such as redundancy and to identify design principles that can improve robustness. All the proposed attempts for quantification of robustness can be divided into three main categories of measures: deterministic, probabilistic and risk based.

1.1.2. Deterministic robustness measures

A simple and ‘easy-to-use’ deterministic measure is given in [4]. In this robustness measure the ratio of the base shear capacity of the platform and the design load are compared. The base shear capacity is estimated using non-linear structural models with and without failed elements. In [5] a measure of robustness is proposed where the stiffness matrix of the intact structure and the stiffness matrix after removal of a structural element are compared and a robustness index is derived. The same authors also proposed energy and damage based definitions of robustness. Quite recently, a multi-level framework for the progressive collapse assessment of building structures subject to sudden column losses was presented by Izzuddin et al. [6]. The proposed assessment framework employs three stages: first determination of the nonlinear static response, then a simplified dynamic assessment and finally a ductility assessment. In [7] is presented an application of the proposed design-oriented method for progressive collapse assessment of multi-storey buildings.

1.1.3. Reliability-based robustness measures

In the late ‘80s [8] proposed reliability-based indices as measures of structural redundancy though the residual strength of a damaged system. The same authors also proposed a redundancy factor where the reliability indexes of the both intact and damaged systems are used to determine this factor. Lind [9] proposed a generic measure of system damage tolerance, where