Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 77 (1998)

Artikel: Reliability analysis in structural masonry engineering

Autor: Schueremans, Luc / Van Gemert, Dionys

DOI: https://doi.org/10.5169/seals-58190

Reliability Analysis in Structural Masonry Engineering

Luc SCHUEREMANS
Civil Engineer
K.U. Leuven
Leuven, Belgium

Luc Schueremans, born 1970, graduated as a civil engineer at KU Leuven in 1995. Since 1995, he is a researcher at the Building Materials Division of the Civil Engineering Department of KU Leuven. His research focuses on the development of a reliability method for the structural evaluation of ancient masonry structures.

Dionys VAN GEMERT
Civil Engineer
K.U. Leuven
Leuven, Belgium

Dionys van Gemert, born 1948, graduated as a civil engineer at KU Leuven in 1971. He obtained PhD at KU Leuven in 1976. Since 1978 he is member of the academic staff of the Civil Engineering Department of KU Leuven. He is president of WTA-International for Restoration. He is head of the Reyntjens Laboratory for Materials Testing. His research concerns repair and strengthening of constructions and concrete polymer composite.

Summary

This paper presents a probabilistic method to evaluate the reliability of structural masonry elements. This methodology is meant as a decision tool in the restoration process to determine whether of not structural strengthening by grouting or other methods is needed. The proposed reliability analysis method will be illustrated on three structural masonry problems. The first illustration focusses on the theoretical aspects and calculates the local probability of failure of a masonry shear wall. Two case-studies deal with the practical goals in masonry engineering problems: the reliability analysis of a masonry sewer system and the reliability of the façade of the St.-Amandus chapel. This research is part of a complete program on structural strengthening of ancient masonry and grout design, in which risk analysis, grouting and non-destructive tests are considered.

1. Introduction

Research in the Reyntjens Laboratory on ancient masonry deals with different aspects of restoration and renovation of masonry structures : diagnosis, (non)-destructive testing methods, strengthening and repair. As consolidation and strengthening of ancient masonry are always expensive procedures, it is of utmost importance to decide whether or not these interventions are required. For this purpose, a reliability analysis using a FORM-algorithm is performed. This is illustrated on tested shear walls, reported in literature. A simplified analysis is presented to calculate the probability of failure of a masonry sewer system. In the third example, the global probability of failure of an out of plumb standing façade is calculated.

2. Local probability of failure of masonry shear panels

A reliability analysis is performed to calculate the reliability index β or the local probability of failure p_f of masonry shear panels. Attention is paid to the applied methodology, the algorithm (FORM : First Order Reliability Method), the different failure modes and corresponding limit state functions, figure 1, and the probability distributions for the basic variables in these limit state functions : the masonry material properties and stresses in the masonry due to external loads. The probability of failure p_f or the reliability index β, is calculated in different points of the masonry shear panels. The obtained results are plotted in contour graphs. These provide a visual interpretation of the local probability of failure or of the reliability index.

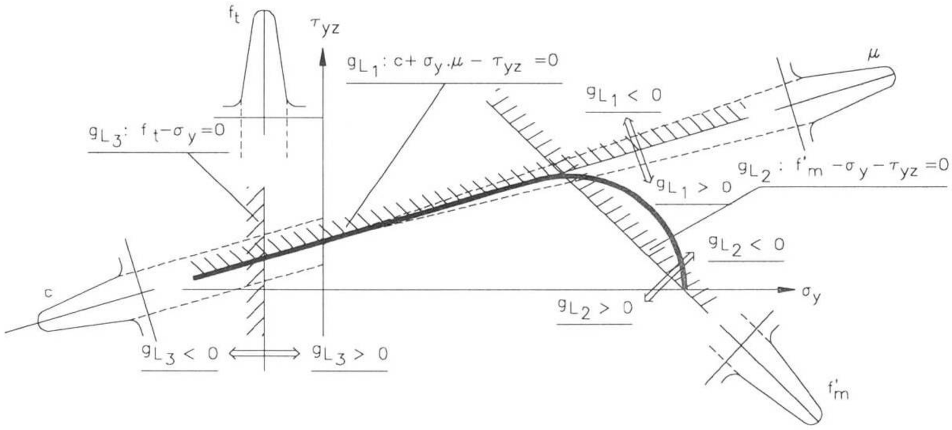

Fig. 1: Linearised "Cap-model" for unreinforced masonry shear walls

3. Sewer System

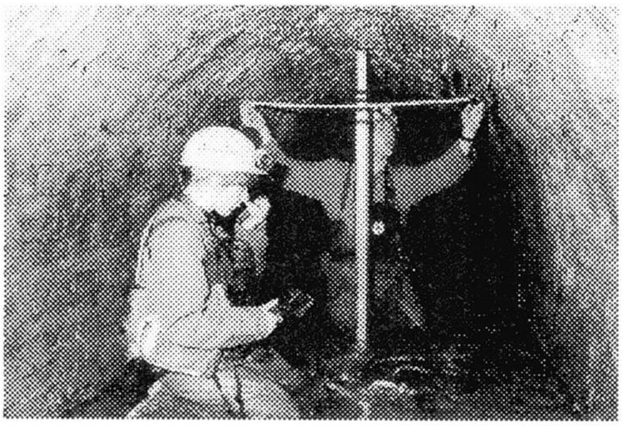

Fig.2: Sewer system Schiffweiler - Neuland

The method was applied in a restoration project to calculate a first value for the safety level of a masonry sewer system, figure 2. In this application, reaching the compressive strength of the masonry was the only ultimate limit state considered: $g(x_1,x_2) = x_1-x_2$. The calculated probability of failure amounts: $p_f=\Phi(-\beta)\cong 10^{-3}$.
Whether such a safety level is acceptable or not is a socio-economical problem. The probabilistic analysis provides a quantitative measure of the safety that can be used to compare different alternatives.

4. The façade of the St.-Amandus chapel

In the case study of the Saint-Amandus chapel at Erembodegem, the global probability of failure of an out of plumb standing wall is calculated. To save the authenticity of the chapel it was decided to minimize the (semi)-destructive test program. Because of the leaning forward of the façade, it was decided to monitor the evolution of the cracks, deformations and eccentricities. Supplementary, a reliability analysis of this structural element was performed, to assess the remaining safety. Therefor, it is required to be able to evaluate the reliability based on limited data: the geometry and the measured eccentricities.
The results are outlined in a graph: the measured eccentricities are plotted on the x-axis, the reliability index β is plotted on the y-axis. That enables to judge the remaining safety, using the eccentricities as a single input parameter.