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Estimation of initial elastic properties of 2D homogenised masonry model based on tensor scale indices ☆

Jiri Brozovsky*, Marketa Maluchova

VSB — Technical University of Ostrava, Faculty of Civil Engineering, Ludvika Podeste 1875, Ostrava, Poruba 708 33, Czech Republic

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Summary The paper discussed numerical approach for an estimation of initial elastic material properties for homogenised models of masonry. The tensor scale parameter is utilised. The paper discusses the principles of the use of the tensor scale for such task and it also discusses current limitations of the procedure. A numerical example is provided to illustrate the practical use of the proposed method.

Introduction

There are numerous masonry structures across the Europe. A lot of them have important cultural or historical value. A repair or a rehabilitation of such structure usually requires a very good knowledge about its structural function and bearing capacity (Cajka et al., 2012). This information can be usually obtained by a combination of in situ tests and numerical simulations. Numerical simulations are often very important because in situ tests on the historical masonry structures have to be limited as much as possible in order to protect original structures and materials (Witzany and Zigler, 2015).

Numerical simulations of structural behaviour can be conducted with use of numerical methods, in the most cases the finite element method is used (Zucchini and Lourenco, 2004). The computation can be both elastic (Witzany et al., 2014) or in-elastic (Portioli et al., 2012). One of the main problems is an acquirement of proper input data for the computations because masonry is a highly inhomogeneous material (Matysek and Witkowski, 2015). There have been numerous works that studied the masonry properties in certain regions and time periods, for example, see Matysek and Witkowski (2015). Many researches have been conducting different types of laboratory experiment to simulate behaviour of masonry structures in certain conditions in order to obtain data for numerical modelling (Cajka et al., 2012, 2014; Witzany et al., 2014; Witzany and Zigler, 2015). The results of above mentioned works have been resulted for

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* Corresponding author.
E-mail address: jiri.brozovsky@vsb.cz (J. Brozovsky).

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many types of models and approaches, the work of Sykora et al. (2013), can be mentioned as an example of numerical model for estimation of compressive strength of masonry.

The further problem is masonry anisotropy which is caused by its structure: it can be created from regular or irregular brick or stones which can have various shape and location. The structure of the masonry has an important influence on local masonry mechanical properties. It causes serious problems even for linear elastic analysis of masonry structures because precise modelling of all bricks (so-called micromodel approach) is usually very time-consuming or even impossible. For this reason numerical models with a homogenised material are used. It this case a micromodel with several materials is replaced by homogeneous model with one material which has to represent the material behaviour. An orthotropic material is often assumed (Cajka et al., 2014).

The homogenised material properties can be obtained from laboratory tests of numerical modelling of a relatively small piece of masonry (Brozovsky and Pankaj, 2007) but such approach assumes than structures of masonry does not differ too much within the structure. This assumption is correct for testing samples (which usually have regular shape) and for experimental structures but it can be incorrect for real buildings with arches, windows and with non-trivial shapes. An example of such structure is illustrated in Fig. 1. To simplify the process of numerical model preparation it is proposed to use available information of masonry structure (2D photos or X-ray pictures, for example) as a basis for automatic computation of orthotropic mechanical properties.

The proposed work is one of the first steps of an effort to create an automatic tool for computation of homogenised orthotropic properties which have to be based on a structure of the masonry. The current effort concentrates on 2D models but it is possible to extend it to the 3D later.

The approach consists of two main steps. The first one is an obtaining of 2D computer image of masonry structure. It may be a digital picture or X-ray scan. The second step is an analysis of the picture in order to describe the masonry structure in selected points. This step should result in a ready to use 2D finite element method (FEM) model with homogenised orthotropic material properties. The article deals with an approach required for the second step.

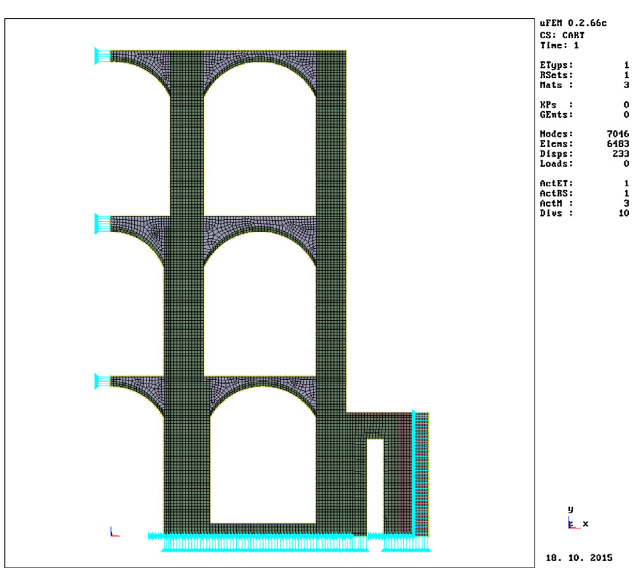

Figure 1 Example of masonry structure with complex geometry.

Measurement of material anisotropy

Brozovsky and Pankaj (2007) used the tensor scale indices (introduced by Saha and Wehrli, 2004, for analysis of human bone and then extended for other uses by Saha, 2005; Genau et al., 2009) for an estimation of material properties of material with complicated internal structure. The paper by Brozovsky and Pankaj (2007) compared the results of tensor scale analysis with finite element simulations of numerical with both original and homogenised material properties. It was shown that the tensor scale can be used for such tasks but some form of correlation between tensor scale indices and the mechanical properties has to be established for individual types of structures. The tensor scale can be directly used to find the orientations of material axes for homogenised orthotropic material, though.

The tensor scale in a material point is defined by sizes of axes of the largest possible ellipse that has centre in that point and that can be fitted in the material of the same type. An example of such ellipse is illustrated in Fig. 2. There are three main parameters of the ellipse: two axes sizes and the angle between **x** coordinate axis and the *a* axis of the ellipse.

There are several possible approaches to compute the tensor scale. The authors of this paper use the original approach proposed by Saha and Wehrli (2004). The computation is based on use of certain number of measurements of distances between the studied point and the nearest material point of different material type. The angle *α* between the all testing lines is usually the same. The procedure is illustrated in Fig. 3. A more detailed overview of the procedure is available in the paper by Brozovsky and Pankaj (2007).

The original approach was designed for measurement of homogeneous materials that include empty spaces. It is use for cases which involve more than one material requires certain modifications.

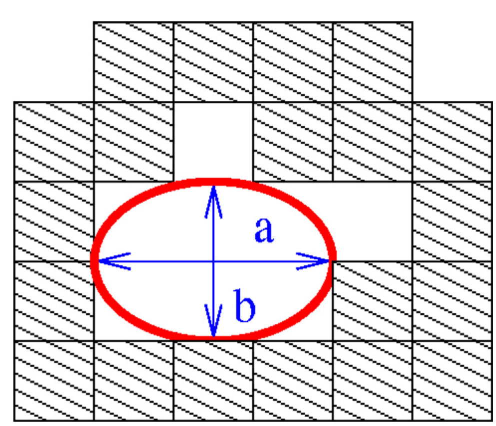

Figure 2 Tensor scale parameters (*a*, *b*) in a material point.