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Analysis of brick-wall structural behavior under compression in its plane

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Abstract

The paper presents the attempt of description an orthotropic material model, which takes into account the changes of the material parameters, depending on the load direction. The analyzes are carried out for masonry structures in numerical models consisting of uniformly material with the averaged properties. The use of material is only possible if the material model describes the sensitivity of material strength which depends on principal stress direction. This model sensitivity will be presented in stress-space by boundary surface changes. This paper shows the changes path of the boundary surface due to direction loads on the layered structures.

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Keywords: brick-wall masonry; FEM; orthotropic material; boundary surface

1. Introduction

Structural engineers use specified civil engineering standards during a design process of any object. These standards comprise the majority of building cases, however, for complex and unusual buildings the structural engineers can use a numerical analysis of the structure. For sufficient analysis of the structure and approved material

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it is necessary to apply a proper material model in the numerical analysis. Masonry structures are challenges for engineers during a design process of complex objects due to the visible layered structure of the material. The use of an adequate model in this case is crucial. An attempt to create such a material model is presented in this paper.

The material models for masonry structures are being still developed by different researchers specially in last decades. The main part of that material model is focused on determination of the yield as well as the boundary surface. The attempt of such a theoretical description was made by the Ganz and Thürlimann team [1, 2], which presented the space of possible material work in the space created from the part of cylinder. The cylinder is limited by two conical surfaces, and a plane one. The development of this solution was presented by Mojsilović and Marty team and subsequent researchers involved in this problem [3, 4, 5]. The main part of the surface in this case forms a roll which is additionally bounded by planes reducing shear stresses in the material model. The surface based on the respectively together connected cones in the space of stresses was developed by Dhanasekar, Page, Kleeman team [6]. Another solution was proposed by Lorenço, who combined the criteria of Rankin and Hill, forming one boundary surface [7, 8]. An interesting proposal has also been given by the team Syrmakezis and Asteris [9, 10, 11], where surface was created by an ellipsoid.

All above-mentioned spaces are set in the spatial Cartesian coordinate system formed by the axes created by the two normal stresses (parallel and perpendicular to the bed joint) and shear stress perpendicular to them. The surfaces, except the last one, also have edges that occur at the place of permeation of individual surface parts. The descriptions of the various surface shapes are difficult to incorporate into computational software due to a different recording stress space and the occurrence of discontinuity at the place of sharp edge surfaces which create problems for the numerical solutions.

Nomenclature

α	angle between direction of principal compression stress and bed layer
σ_x, σ_y, σ_z	normal stresses in Cartesian coordinate system;
σ_3	principal compression stress;
τ_{xy}, τ_{yz}, τ_{zx}	shear stresses in Cartesian coordinate system;
σ_{oct}	normal stresses in octahedral stress space;
τ_{oct}	shear stresses in octahedral stress space;
Θ	Lode angle in octahedral stress space;
J_2, J_3	second and third invariant of stress state deviator;
f_c, f_t, f_{cc}	uniaxial compression strength, uniaxial tensile strength, biaxial compression strength;
f_{tf}	unreal value of uniaxial tensile strength;
m_t, m_{tf}	real and unreal value of uniaxial tensile strength in dimensionless coordinate system;
j_m, h_b	mortar and brick layer thickness;
η_b, η_m	participation rate of brick and mortar in the brick-wall;
E_b, E_m, E_x, E_z,	Young's modulus for brick, mortar and appropriate directions;
ν_b, ν_m, ν	Poisson's ratio for brick, mortar and uniform brick-wall;

2. Boundary surface of the brick-wall components

It is worth to create such a material model that would allow easy interpretation of the state of stress in the material finite element in a numerical analysis. This state of stress could be described by cylindrical coordinate system, which are determined by normal σ_{oct} and shear τ_{oct} octahedral stresses and Lode angle Θ. The transformation of traditional Cartesian coordinate system to cylindrical octahedral one is given by one following equations (1) to (5).

$$\sigma_{oct} = \sigma_m = \frac{\sigma_x + \sigma_y + \sigma_z}{3} \tag{1}$$