NUMERICAL INVESTIGATION OF PORES STATISTIC DISTRIBUTION INFLUENCE ON POROUS MATERIAL MECHANICAL BEHAVIOUR

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1. Introduction

Many materials, especially natural ones, are characterized by so called dual porosity. In example shale rocks have in their structures two levels of porosity [1]:

- 1-st porosity level – micro and meso pores,
- 2-nd porosity level – macro pores and natural fractures.

This structure influences gas flow phenomena in shale rocks and also can influence their mechanical properties. Such structure appears also in such rocks as sandstone, limestone or granite [2].

Dual porosity can be also find in human-made materials such as single-walled carbon nanotubes [3], polytetrafluoroethylene [4], etc.

In the paper the numerical research on statistically generated numerical models of dual porosity material structures was shown. The mechanical behavior of such structures was studied and influence of the materials structure on the material strength was investigated.

2. Model development

Numerical model of dual porosity material structure was developed on the base of quasi-fractal porous media model proposed in [5].

The model generation method is presented in Figure 1. A threedimensional cube composed of cubical cells of two types: "material" (labeled 1) and "void" (labeled 0) is considered. In the porous medium of the first generation ("medium 1"), there are the material cells and voids. In the second generation medium ("medium 2"), the material cells are cubes of the first generation; similarly, the material cells of the third generation ("medium 3") are cubes of the second generation. A multitude of pore sizes is created.

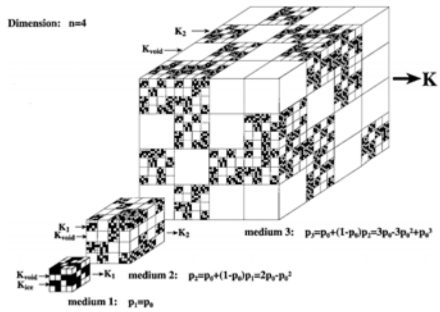

Figure 1. Schematic representation of the hierarchical (fractal) model of a porous medium. The dimension is n = 4. The basic porosity is p_0 = 0.5 [5].

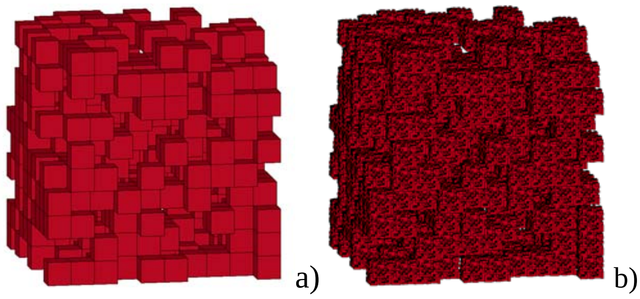

Figure 2. Example of the numerical model used in research – model was developed with the use of linear randomization, $p0$=0.6: a) first porosity level, b) second porosity level.

For the purpose of the presented research a series of FEM models were developed. The basic porosity p_0 was 0.3, 0.4, 0.5 and 0.6% (Figure 2). The total porosity of the models was 0.51, 0.64, 0.75 and 0.85 respectively.

Three methods of random selection of pores localization were assumed: based on linear, normal (μ=0, σ^2=0)and Weibull distribution (λ=1, k=2). The use of linear distribution resulted with homogenous pores distribution, when the use of normal one – the increase in pore spaces in the middle part of the sample and Weibull one – pores number increase in the bottom part of the sample. For the statistic calculation ten models of each kind were developed.

3. Results and discussion

The material model for the analyzed samples was assumed as elastic – plastic with Young modulus of 71 GPa, Poisson's ratio of 0.33, yield stress – 0.318 GPa, strength – 0.488 GPa. The model was compressed with the use of rigid plates with the friction coefficient of 0.2. The surface to surface contact with penalty function was applied. The load speed was 0.1 m/s. Each model dimension was 10x10x10 mm.

The results were achieved as force-displacement relations for each model, which were averaged for each type of sample and compared. All models showed typical behavior for porous material. The comparison of resulted first "peak" force was shown in Table 2.

p_0	Peak force for linear distribution models [kN]	Peak force for normal distribution models [kN]	Peak force for normal distribution models [kN]
30	80.2	80.4	80.3
40	40.0	30.1	36.2
50	10.2	7.5	8.6
60	0.51	0.33	0.42

The results of numerical calculation showed the significant influence of pores distribution on the strength behavior of the porous material. The smallest difference is for models of porosity p_0=30% - probably the number of pores is too low to influence the mechanical properties of material.

For models of p_0=40, 50 and 60% the biggest "peak" force appears when the model was based on linear randomization, lower force values appear for Weibull distribution and the lowest ones are for normal distribution.

Those interesting results are the initialization of the research on models with the so called dependent distribution of pores randomization development - in those models after the initial selection of the pores the probability of the appearance of the pores in the neighborhood of the selected pores will increase.

6. References

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7. Acknowledgements

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