Preliminary determination of the boundary surface of the geopolymer on the basis of the multiaxial compression tests

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Abstract

Regarding the ecological threats, building industry is searching for the new, environmental friendly solutions. One of the possibilities is geopolymer – material able to obtain concrete parameters without usage of cement. However, so far characteristics of geopolymer are not investigated sufficiently to use it as a universal building material. The paper presents early results of scientists from Silesian University of Technology in enlarging the knowledge about mechanical parameters of geopolymer by performing laboratory tests within the European research project REMINE. So far, there was tested bending and compression strength of cubic samples. The following set of research presented in the paper, includes among the others uniaxial and triaxial compressive strength tests of geopolymer cylindrical samples. Simultaneously to the compression strength, the stress-strain relation in examined samples was investigated. The main goal of this study is to determine the boundary surface of the geopolymer what enables establishment of its material model which could be introduced to software for computer numerical analyses. The expected effect states adaptation of existing numerical material concrete models for modelling geopolymer elements.

Keywords: building materials, geopolymer, uniaxial and triaxial compressive strength test, numerical analysis

1. Introduction

The main goal of initial tests performed on samples was to determine their compressive strength, Young Modulus and to obtain the first points on the boundary surface of the geopolymer based on waste aggregate from the tungsten mine.

During the multiaxial compressive strength tests, the geopolymer samples of cylindrical shape (60mm diameter and 120mm height) were tested. Specimens were made of ground waste aggregate from tungsten mine mixed with soda silicate, caustic soda and water-glass. The composition included only fine aggregate. The process of preparation and curing was proceeded at UBI (Portugal). Described laboratory tests were carried out at Silesian University of Technology. Works state the continuation of previously done tests [1]. All works were performed within European research project REMINE.

2. Tests results

2.1. Uniaxial compressive strength test

During the research, the five geopolymer samples were tested. Each sample was being loaded with vertical load until it was broken. Simultaneously, the horizontal and vertical strains in the samples were registered what enabled calculation of the Young Modulus of geopolymer. The results are presented in Table 1.

Table 1: Results of uniaxial compressive strength test.

Sample	Compressive strength [MPa]	Young Modulus [GPa]	Poisson’s ratio [-]
1	50.58	13.47	0.22
2	44.51	12.05	0.19
3	45.87	11.49	0.20
4	51.84	13.97	0.21
5	49.10	12.64	0.17
Mean value	48.38	12.73	0.20

2.2. Triaxial compressive strength tests

There were carried two tests for multiaxial compressive strength of geopolymer. In each test, the three cylindrical geopolymer samples were checked. Tests were performed in multiaxial compression apparatus ELE Hoek Cell-70-2100. In the first test each sample was firstly loaded simultaneously with the horizontal and vertical load. Horizontal stress subjected to the side surface of sample was increasing only to the value of 2MPa and then it was kept constant to the end of the test. Vertical stress increased until the sample was broken. The same procedure was repeated with the constant horizontal stress equal to 4MPa. Simultaneously, the horizontal and vertical strains in each sample were registered. The results are presented in Table 2 and Table 3.

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Table 2: Results of multiaxial compressive strength test with constant horizontal stress equal to 2MPa.

Sample	Compressive strength [MPa]	Young Modulus [GPa]
1	59.30	16.17
2	63.87	16.29
3	54.34	17.54
Mean value	59.17	16.67

Table 3: Results of multiaxial compressive strength test with constant horizontal stress equal to 4MPa.

Sample	Compressive strength [MPa]	Young Modulus [GPa]
1	60.11	15.19
2	62.11	15.42
3	67.34	15.74
Mean value	63.19	15.45

3. Samples loading paths in space of principal stresses

For determination of the boundary surface it was necessary to present loading paths in the space of principal stresses. The material model of the geopolymer created with use of the boundary surface will be presented in cylindrical coordinate system. It was assumed that stresses obtained in multiaxial compression apparatus are the main stresses. Since the stress subjected to the side surface has the same value on the entire area of the sample there are in fact two stresses: vertical stress σ_{ver} and horizontal stress σ_{hor}. These assumptions allow calculation of mean stress σ_m and stress intensity σ_i with formulas [2]:

$$\sigma_m = \frac{2\sigma_{hor} + \sigma_{ver}}{3} \tag{1}$$

$$\sigma_i = \frac{\sqrt{3}}{3}\left|\sigma_{hor} - \sigma_{ver}\right| \tag{2}$$

The results obtained from tests of uniaxial and multiaxial compressive strength of geopolymer were transferred to the values in space of principal stresses. In the Table 4 there are shown values of mean stress and stress intensity for each tested geopolymer sample. Samples subjected to the uniaxial compressive load were described as U-1:U-5. Samples M1:M-3 were subjected to the multiaxial compressive load with constant horizontal load equal to 2MPa. Samples M4:M-6 were subjected to the multiaxial compressive load with constant horizontal load equal to 4MPa.

Table 4: The extreme values of strains in space of principal stresses for constant horizontal stress.

The name of the sample	Mean stress σ_m [MPa]	Stress intensity σ_i [MPa]	Mean value of horizontal stress [MPa]
U-1	16.86	29.20	0
U-2	14.84	25.70	0
U-3	15.29	26.49	0
U-4	17.28	29.93	0
U-5	16.37	28.35	0
M-1	21.19	33.00	2.06
M-2	22.64	35.71	2.05
M-3	19.54	30.14	2.06
M-4	23.05	32.10	4.05
M-5	23.50	33.43	4.06
M-6	25.20	36.50	4.07

Results from the Table 4 are shown on the Figure 1.

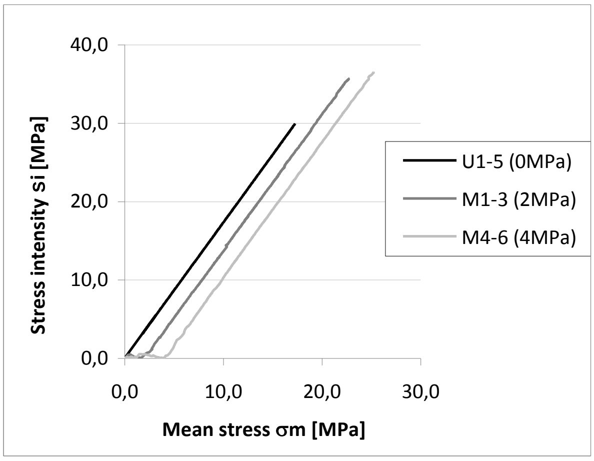

Figure 1: Geopolymer stress paths for the constant horizontal stress σ_{hor}=constant.

Tests performed on geopolymer samples allowed determination of the stress paths. In the further step the obtained results will be transformed to the octahedral coordinate system what will adapt input data to the calculation software. The boundary surface of the geopolymer will be also presented in octahedral coordinate system [2].

4. Summary

The paper presents advanced phase of the preliminary calculations of the geopolymer boundary surface. As the result of the presented three tests, the three points on the boundary surface were obtained. It allowed determination of one of the main meridians for geopolymer material in equivalent octahedral stress space. However, the further tests will allow obtaining grater accuracy and assurance of the correctness of determined meridian. The next problem is to find the multiaxial compressive strength of the geopolymer destroyed by the arising horizontal stress with constant vertical stress. That knowledge will allow to establish the second main meridian for geopolymer material in equivalent octahedral stress space [2]. Results obtained in all calculations will be sufficient for establishing material model of the geopolymer which can be introduced for the appropriate software and used for designing structural elements. One of the main future goals will be to construct structural elements made of described geopolymer. Tests performed on that elements will state the validation of the material model.

At the end, it is necessary to emphasise that the paper presents results for samples made of geopolymer with particular composition cured in a specified way. Consequently, the outcomes and obtained data are reliable only for elements prepared in the same way.

References

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