XI International Conference on Computational Plasticity. Fundamentals and Applications
COMPLAS XI
E. Oñate, D.R.J. Owen, D. Peric and B. Suárez (Eds)

COMPRESSION BEHAVIORS OF LOW-DENSITY POROUS MATERIALS UNDER MULTIAXIAL STRESS CONDITIONS

ATSUSHI SAKUMA[*] AND SHIGERU NAGAKI[†]

[*] Institute of Technology
Tokyo Univeristy of Agriculture and Technology
2-24-16 Nakacho, Koganei, Tokyo, Japan
e-mail: asakuma@cc.tuat.ac.jp

[†]Institute of Technology
Tokyo Univeristy of Agriculture and Technology
2-24-16 Nakacho, Koganei, Tokyo, Japan
e-mail: nagaki@cc.tuat.ac.jp

Key words: Stress-strain Measurement, Material Testing, Nonlinear Problem, Constitutive Equation, Inelasticity, Poromechanics, Low-density Porous Material, Phase Transformation, Compression Testing, Polystyrene foam

Abstract. In this study, uniaxial and multiaxial compression tests are conducted for studying the nonlinear deformation behaviors of a porous material during compression. In the results of uniaxial compression tests, the stress level in the plateau region is varied by the difference of direction but it is shown that this material has the character of transverse isotropicity. The multiaxial behavior of the material is also observed in this study. Equibiaxial pre-strained compression tests are adopted for the observation of the characteristics of the material. The results of these tests show that the pre-strain causes the porous material to harden, and the extent of the hardening depends on the difference of the amount of pre-strain.

1 INTRODUCTION

Low-density porous materials are useful to design the shock absorbing parts of various machines. The deformation analysis of the materials is needed in the design but it is difficult because of the nonlinearity caused by the crush of cellular structure in the materials.

Then, the multiaxial behavior of compression process of the porous materials is evaluated by using equibiaxial compression testing in addition to the fundamental uniaxial compression testing for the formulation of FEM. Polystyrene foam is adopted to study the behavior and it is revealed that there is complex relationship between the compression direction.

2 FUNDAMENTAT COMPRESSON

Uniaxtial compression test is adopted to reveal the fundamental characteristics of the porous materials. The specimens are made by using the polystyrene foam “STYROFOAM” of Dow Chemical, Co. Ltd. The dimensions of specimens are 30mm x 30mm x 10mm and talcum powder is sprinkled at their surfaces for lubrication in the testing. The three type of direction is defined as shown in Figure 1. Every type of the specimens are compressed in their direction of height, and observed response is indicated in Figure 2.

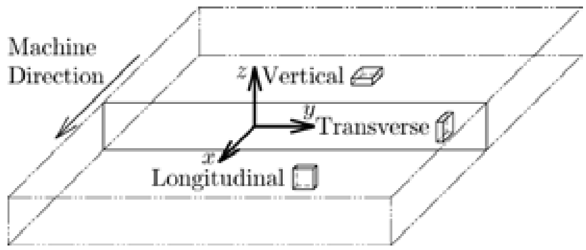

Figure 1: The three type of direction is defined by depending on machine direction of polystyrene form.

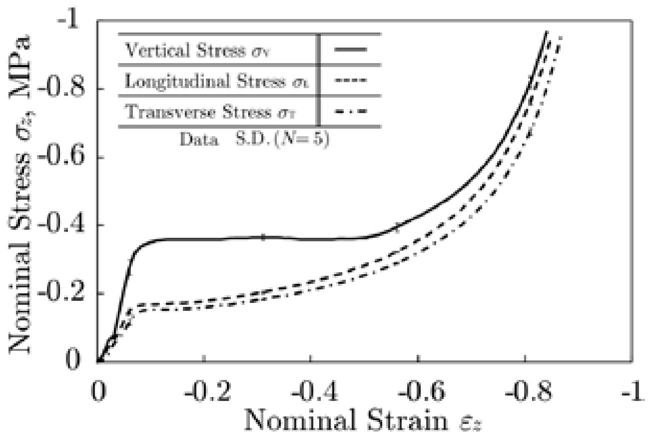

Figure 2: Transverse isotropicity is observed in uniaxial compression test. Here,

Uniaxtial compression test is adopted to reveal the fundamental characteristics of the porous materials. The specimens are made by using the polystyrene foam “STYROFOAM” of Dow Chemical, Co. Ltd. The dimensions of specimens are 30mm x 30mm x 10mm and talcum powder is sprinkled at their surfaces for lubrication in the testing. The three type of direction is defined as shown in Figure 1. Every type of the specimens is compressed in this test and transverse isotropicity is observed as shown in Figure 2. Here, highest level of plateau stress is observed in the vertical direction of the foam. The stress responses are similar between longitudinal and transverse directions.

3 MULTIAXIAL COMPRESSION

3.1 Procedure of compression

Multiaxial compression testing indicated in Figure 3 is proceeded to investigate the complicated behavior of the materials [1]. Here, the polystyrene form adopted in former section is also applied for the investigation.

The equibiaxial compression system indicated in Figure 3 can give pre-strain to the specimen. Here, Fig. (a)-(c) are the procedure of the multiaxial compression testing. In this Figure 3, settled specimen (a) is pre-strained at procedure (b), and compressed as shown at procedure (c).

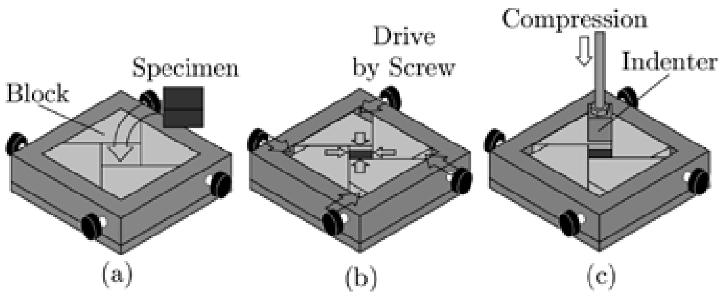

Figure 3: Multiaxial compression can be devied to three procedures (a)-(c).

3.2 Measurement of Stress Response

The stress response of the specimen is measured in the every direction of *x*, *y* and *z* of testing system by using load cell and pressure sensors as shown in Figure 4. The load cell is used to measure the stress response in the final compression procedure of Figure 3 (c). On the other hand, pressure sensors are settled at pre-straining surface of the block in equibiaxial compressor as shown in Figure 4, and used to measure the response in pre-straining and final compression procedures of Figure 3 (b)-(c).

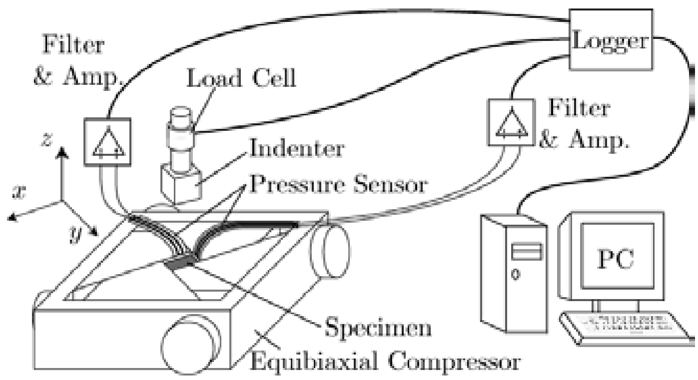

Figure 4: Measurement system of stress responce.

3.3 Muliaxial Response

3.3.1 Response in Pre-Straining

The result measured in pre-straining procedure is shown in Figure 5. This stress response is taken by using the pressure sensor on the block in equibiaxial compressor. The plateau stresses are observed in every direction of longitudinal and transverse even if little difference is also observed between them. This result indicates that the phenomena of plateau stress is occurred in the biaxial pre-straining process, and it is similar to the result of uniaxial compression which is shown in Figure 2.

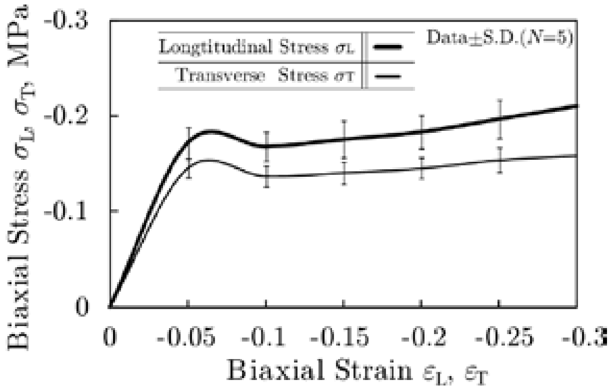

Figure 5: Stress response measured in pre-straining procedure.

3.3.2 Response in Final Compression

In the final compression procedure, the response of compression stress is measured with the response of equibiaxial stress.

Figure 6 shows the responses of compression stress observed in this procedure, and the variation caused by the difference of the amount of pre-strain can be observed here. Especially, the level of plateau stress is rise by pre-strain and the soften effect induced by the pre-strain is not observed in this direction.

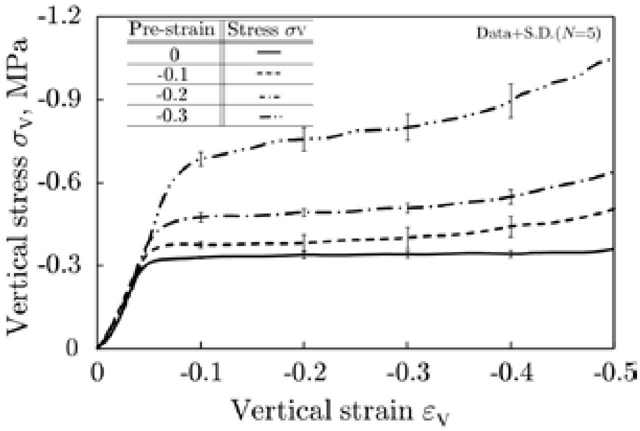

Figure 6: The stress responses of compression observed in final procedure.

The response of equibiaxial stress in final procedure is shown Figure 7. The variation induced by the difference of the amount of pre-strain is observed here, and it is shown that much pre-strain causes the stable level of plateau stress. On the other hand, the soften effects of this material are observed in the lower pre-strain conditions. This means that less pre-strain causes the instability of compression process of the porous materials even if the stable compression of the material can be observed in the condition of much pre-strain. Then, the maltiaxial condition of the low-density porous materials should be considered in the compression process with complex conditions of stresses.

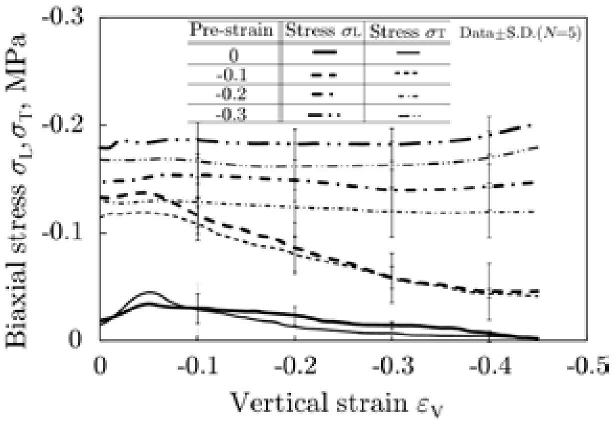

Figure 7: Equibiaxial stress response in final procedure of compression.

12 CONCLUSIONS

In order to study the behavior of multiaxial stress response of low-density porous materials, the compression test with multiaxial stress condition is conducted by developing the equibiaxial compressor [1]. Especially, the equibiaxial stress responses in the compression procedures are observed by the pressure sensor in the compressor. Then the instable phenomenon of the materials in multiaxial stress condition is observed by the conduction of the compression test of the materials.

By considering the results of this result, the constitutive equations of the porous materials will be formulated to simulate the compression of them for the machine design which uses the materials.

REFERENCES

[1] Sakuma, A., Azusawa, N., Shinomiya, M., Abe, K. and Nagaki, S., Multiaxial and Dynamic Compression Behavior of Low-Deisnty Porous Materials and their Constitutive Representation, *Proc. 10th Int. Conf. Comp. Plast. (COMPLAS X)*, (2009), CD-ROM.