SOI: 1.1/TAS DOI: 10.15863/TAS

International Scientific Journal

Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2025 **Issue:** 11 **Volume:** 151

Received: 21.11.2025
Accepted/Published: 30.11.2025

https://T-Science.org

Issue Article

Denis Chemezov
Vladimir Polytechnic College
MEng, Honorary Worker of the Education Field of the Russian Federation, Academician of International Academy of Theoretical and Applied Sciences, Lecturer, Russian Federation
https://orcid.org/0000-0002-2747-552X
vpk-science@yandex.ru

Anzhelika Bayakina
Vladimir Polytechnic College
Lecturer, Russian Federation

Daniil Bubnov
Vladimir Polytechnic College
Student, Russian Federation

Dmitriy Voronich
Vladimir Polytechnic College
Student, Russian Federation

Darya Mishakova
Vladimir Polytechnic College
Student, Russian Federation

Aleksandr Klyauzov
Vladimir Polytechnic College
Student, Russian Federation

Vladislav Markin
Vladimir Polytechnic College
Student, Russian Federation

Matvey Alekseev
Vladimir Polytechnic College
Student, Russian Federation

Aleksandr Kosarenko
Vladimir Polytechnic College
Student, Russian Federation

INTERPRETATION OF THE STRESS STATE OF A PLASTIC MATERIAL UNDER COMBINED LOADING

***Abstract**: The analysis of stress intensity and the maximum permissible values of mechanical properties of plastic materials is based on the measurement results obtained during mechanical testing. Since the soil is subject to a combined load in different coordinate planes under real conditions, instead of a uniaxial load, it is important to analyze the stress and strain state of the material under these conditions to assess the strength characteristics of a* *three-dimensional object. This article proposes an assessment of the stress state of a plastic material based on the calculated values of the Lode angle under the conditions of a combined variable load applied to a cylindrical sample.*

Key words*: stress, Lode angle, load, sample, triaxial test.*

Language*: English*

Citation: Chemezov, D., et al. (2025). Interpretation of the stress state of a plastic material under combined loading. *ISJ Theoretical & Applied Science, 11 (151)*, 42-44.

Soi: https://s-o-i.org/1.1/TAS-11-151-8 ***Doi***: crossref https://dx.doi.org/10.15863/TAS.2025.11.151.8

Scopus ASCC*: 2206.*

1. Introduction

During construction, the soil is subjected to various loads. For example, the use of heavy machinery and foundations leads to significant loads on the soil, which change its structure and strength. Excessive pressure can cause the soil to compact, settle, and damage. Determining the type and intensity of stress is a key aspect of ensuring the safe operation of materials in construction projects.

The Lode angle is an important parameter for understanding the stress state of a material [1]. This parameter helps to identify different types of stress, such as tension, compression, and shear. The Lode angle is determined based on the stresses and reflects the relative values of these stresses. In applied sciences, the analysis of the Lode angle allows us to determine whether a material is under axial tension, pure shear, or axial compression [2-5]. This analysis is important because the type of stress affects how materials deform and eventually damage. The Lode angle is used to predict possible cracks or malleability in plastic materials.

This article analyzes the transient states of soil loaded with a variable combined load by estimating the calculated values of the Lode angle.

2. Materials and methods

The behavior of plastic materials under combined loads can be evaluated by simulating the mechanical testing process. A triaxial test is performed to determine the stress and strain state of complex structural materials, such as soil [6]. The resulting shear stress, caused by increasing longitudinal and transverse loads, leads to bending and subsequent failure of the sample. Based on the test results, such as the maximum loads at which the sample breaks, the properties of soil are determined [7-10].

Modern software packages for engineering analysis allow you to simulate mechanical testing processes, including setting the properties of sample models, applying variable loads to the sample in various coordinate planes, and analyzing test results using special options. The advantages of modeling include high accuracy of calculated data compared to experimental data, reduced procedure time, and detailed analysis of soil sample stress and strain over the entire time range of the computer experiment.

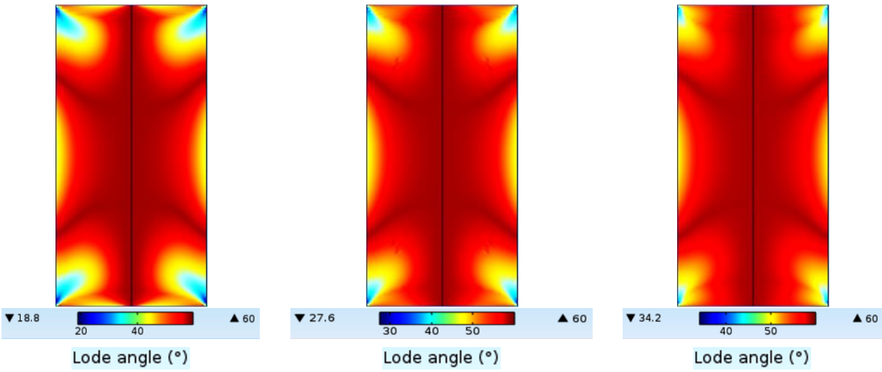
According to the official regulations for conducting a triaxial test on soil samples with a diameter of 100 mm and a height of 200 mm, the longitudinal and transverse loads vary between 5 and 35 kN. To detail the change in the stress state of the soil sample, the load increment step is proposed to be 15 kN. Setting properties such as Young's modulus (2.5 MPa), Poisson's ratio (0.3), cohesion (12 kPa), and internal friction angle (30 degrees) for the sample model ensures the validity of computer testing. The transition of soil to a plastic state, depending on the stresses that occur, is described by the Drucker-Prager criterion, which is isotropic due to the same conditional yield strength in the direction of all coordinate axes. The soil sample model domain should be finalized by generating a finite element mesh with a maximum element size of 2 mm. The solution time was reduced by calculating the stationary process of the triaxial test using the MUMPS solver.

3. Results and discussion

The change in the behavior of a plastic material under combined variable load can be observed in the Figure 1.

The graphical part of the experiment results is presented by a three-dimensional model of the stress and strain state of the sample in the longitudinal section. The scale below the model shows the range of the Lode angle in degrees.

In the longitudinal section of the sample, the following transient stress states of the material can be observed. As the load increases, a constant stress in the form of uniaxial compression is observed in the middle part of the sample, which is confirmed by the value of the Lode angle, which is 55-60 degrees. At the same time, a decrease in the Lode angle in the range of 40-45 degrees was observed in the surface layers of the forming model, which indicates a transition process from uniaxial compression to pure shear (taking into account hydrostatic pressure). In the upper and lower parts of the sample, the stress intensity gradient vector is directed at an angle of 40-45 degrees to the radius of the sample. The Lode angle in the specified area varies between 18.8 and 50 degrees, which implies a transition from pure uniaxial tension to uniaxial compression. When the load on the material increases, both pure shear and uniaxial compression occur simultaneously in these areas.



A **B** **C**

Figure 1. The Lode angle is used to determine the deformed state of the sample during the triaxial test: A – sample load of 5 kN; B – sample load of 20 kN; C – sample load of 35 kN.

4. Conclusion

The simultaneous action of increasing longitudinal and transverse loads causes a transient stress state in plastic materials, in this case, soils: pure uniaxial tension, pure shear plus hydrostatic pressure, and uniaxial compression plus hydrostatic pressure.

At the same time, the predominant stress is uniaxial compression, which changes in certain volumes of the studied material when combined loads are applied to them in the range from 5 to 35 kN.

A detailed representation of the change in the Lode angle allows for a qualitative analysis of the soil's state under normal conditions to determine the strength characteristics of the material, which is widely used in construction and road projects.

References:

1. Bruhns, O. T. (2024). Some remarks on Lode angle and Lode parameter. *PAMM, Vol. 24,* No. 2.
2. Dunand, M., & Mohr, D. (2014). Effect of Lode parameter on plastic flow localization after proportional loading at low stress triaxialities. *Journal of the Mechanics and Physics of Solids, Volume 66*, 133-153.
3. Algarni, M., Ghazali, S., & Zwawi, M. (2021). The Emerging of Stress Triaxiality and Lode Angle in Both Solid and Damage Mechanics: A Review. *Mech. Solids, 56*, 787-806.
4. Mattiello, A., & Desmorat, R. (2021). Lode angle dependency due to anisotropic damage. *International Journal of Damage Mechanics, 30 (2)*, 214-259.
5. Zhu, Y. Z., Engelhardt, M. D., & Kiran, R. (2018). Combined effects of triaxiality, Lode parameter and shear stress on void growth and coalescence. *Eng. Fract. Mech., 199*, 410-437.
6. Jogur, V. (no date). *Introduction to triaxial testing, Part 1*.
7. Skuodis, Š., Karaman, A. H., & Dirgėlienė, N. (2017). Comparison of one step and step wise compression tests. *Geologija. Geografija, 3(1)*, 1-10.
8. Omar, T., & Sadrekarimi, A. (2015). Effect of triaxial specimen size on engineering design and analysis. *International Journal of Geo-Engineering, 6(5)*, 1-17.
9. Lekstutyte, I. (2019). Change of soil mechanical properties due to triaxial sample size. *Modern Building Materials, Structures and Techniques*.
10. Amšiejus, J., Dirgėlienė, N., Norkus, A., & Žilionienė, D. (2009). Evaluation of soil shear strength parameters via triaxial testing by height versus diameter ratio of sample. *The Baltic Journal of Road and Bridge Engineering, 4(2)*, 54-60.