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EVOLUTION AND COMPARATIVE ANALYSIS OF ASTM AND EN ISO STANDARDS FOR TRIAXIAL SOIL TESTING**

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Abstract

This paper presents the historical development of triaxial soil testing standardization and conducts a detailed comparative analysis between European/international norms (SRPS EN ISO 17892-8 and 9) and American standards (ASTM D2850 and ASTM D4767). Through a chronological review, the paper traces the evolution of this geotechnical test, from the establishment of the theoretical foundations of effective stresses to the modern digitization of instrumentation and global harmonization of laboratory protocols.

Within the comparative analysis, the key stages of conducting the triaxial test are evaluated in detail, including the control of the shearing rate, the sample saturation phase using Skempton's B-parameter, the correction for membrane elastic resistance, and the methodology for defining the point of failure. Although both groups of standards strive for the same ultimate goal, namely the reliable construction of the Mohr-Coulomb failure envelope and the determination of soil strength parameters, significant methodological differences are observed regarding sample geometry, flexibility during saturation, and the rigidity of the procedures themselves.

It is concluded that the ISO methodology, due to the application of analytical mathematical formulas and clearly defined constants, proves to be significantly more practical for the development of algorithms and software for the automatic processing of raw laboratory data. This ensures the efficient generation of complete stress-strain curves, which are essential as reliable input parameters for advanced constitutive models in modern numerical modeling software packages, such as the Slide, Phase2, and Plaxis tools.

Keywords: triaxial soil testing, SRPS EN ISO 17892, ASTM standards, shear strength, pore pressure, numerical modeling

1 INTRODUCTION

The development of standards for triaxial soil testing represents the evolution of the test, from simple strength determination to complex modeling of the interaction between solid particles, water, and air in the

pores. Today, these standards are not merely working instructions, but scientific protocols ensuring that data obtained in a laboratory in Bor or any geotechnical laboratory in Serbia are comparable to those from any part of the world.

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2 KEY PHASES AND ASPECTS OF THE DEVELOPMENT OF TRIAXIAL SOIL TESTING STANDARDS

2.1 Early Period and scientific foundations (1930s – 1950s)

Before the emergence of formal standards, development was tied to the pioneers of soil mechanics. Karl Terzaghi and Arthur Casagrande [1, 2] established the theoretical foundations of effective stresses, which was a prerequisite for the triaxial test.

- The first apparatuses were developed to overcome the limitations of direct shear (where the failure plane is predefined).
- The focus and goal were to understand the change in soil volume during shearing and the role of pore pressure, which later became the foundation of standards for CU (consolidated-undrained) tests.

2.2 Standardization through national institutes (1960s – 1980s)

During this period, the "bureaucratization" of science occurred to ensure the safety of major infrastructure projects (e.g., dams, mines, high-rise buildings).

- The American Society for Testing and Materials (ASTM) defined the D series of standards early on. The focus was on the practicality and robustness of tests for the needs of the US military and the Army Corps of Engineers [3, 4, 5].

- The British, through BS 1377, developed extremely detailed procedures that were the "gold standard" in Europe and the former Yugoslavia for decades [6].
- Our region followed the development through JUS standards (e.g., the U.B1 series), which heavily relied on European and Russian research of that time [7, 8].

2.3 Global harmonization and the ISO revolution (1990s to present)

With the globalization of the construction market, the need arose to bridge the differences between national standards.

- The ISO 17892 series (whose parts 8 and 9 we use) was created with the aim of replacing a multitude of different European national standards (DIN, BS, AFNOR) [9, 10].
- Modern standards, unlike older ones, take into account advanced instrumentation (Figure 1) - electronic pressure transducers, LVDT sensors for displacements, and automated systems for pressure control.

The development of standards introduced strict requirements for sample saturation, establishing Skempton's B-parameter as a mandatory verification criterion before the initiation of shearing.

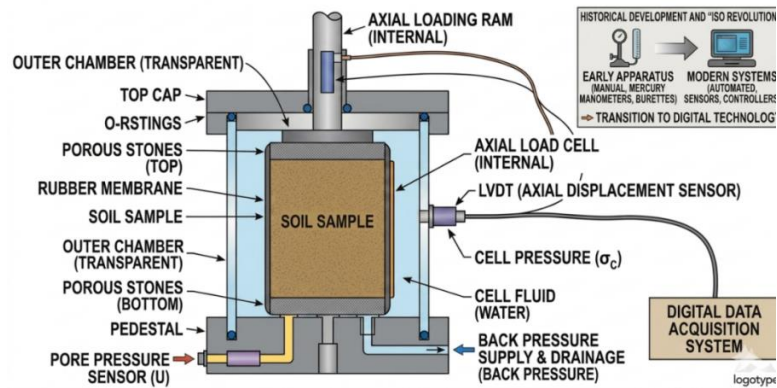


Figure 1 Schematic of a modern triaxial cell with a digital measuring system

2.4 The latest revision (ISO 17892:2018)

The SRPS EN ISO 17892 standard, parts 8 and 9 from 2018, brought several important changes compared to earlier versions:

- More strictly defined strain rates to ensure that pore pressure is evenly distributed (especially important for fine-grained materials from tailings ponds).
- Modern standards provide more detailed mathematical models for membrane resistance, as it has been shown

that in soft soils, rubber elasticity can significantly affect apparent strength.

- The new standards are written in a way that makes them easier to implement in data acquisition and processing software, reducing the room for human error during readings.

The presentation of the origin and evolution of the SRPS EN ISO 17892 standard parts 8 and 9 is shown in the following figure.

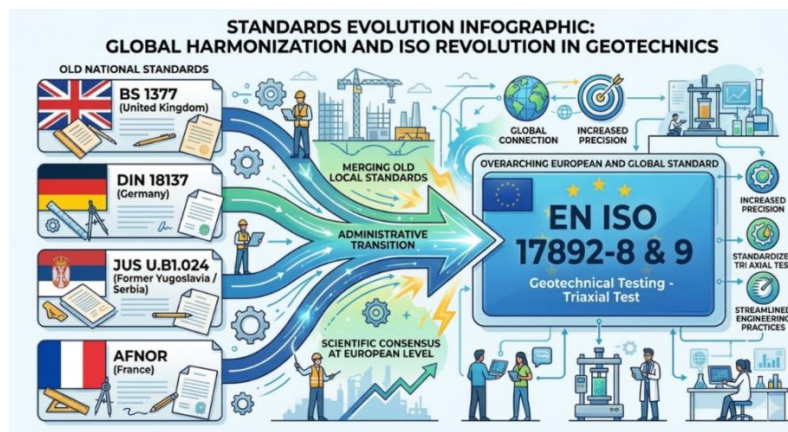


Figure 2 Infographic of the origin and global harmonization of the EN ISO 17892-8 and 9 standards

3 BASIC STRUCTURAL DIFFERENCE OF THE STANDARDS

Precise definition of geomechanical parameters is crucial for stability analysis and the development of advanced stress-strain state indicators. The choice between European (ISO) and American (ASTM) standards for triaxial testing directly dictates the reliability of input parameters for numerical models in software such as Slide, Phase2 [11], or Plaxis, which is especially important when modeling the specific beha-

vior of materials beneath planned infrastructure facilities.

Although both sets of standards strive for the same goal—reliably establishing the Mohr-Coulomb failure envelope ($c' \text{ i } \phi'$) and undrained strength parameters (c_u), there are subtle differences in methodology, scope, and result acceptance criteria. ISO standards pragmatically group the tests, whereas ASTM separates them into completely independent methods.

Table 1 Basic differences between ISO and ASTM standards

Characteristic	SRPS EN ISO 17892	ASTM Standards
Document scope	Consolidates all consolidated tests (CIU, CAU, CID, CAD) into a single document (Part 9). The unconsolidated undrained (UU) test is independent (Part 8).	Separates each type of test: D2850 for UU, D4767 for CU, and D7181 for CD tests.
Sample dimensions	Requires a diameter $\varnothing \geq 34$ mm and a height-to-diameter ratio (H/D) between 1.8 and 2.5.	Requires a diameter $\varnothing \geq 33$ mm (most commonly 38 mm or more is used), with a narrower H/D ratio that is strictly from 2.0 to 2.5.

4 COMPARATIVE ANALYSIS BY TEST PHASES

4.1 Shearing rate

Strain rate control is crucial to avoid generating false pore pressures that can artificially raise or lower the calculated slope stability.

UU tests: SRPS EN ISO 17892-8 prescribes an axial strain rate between 0.3% and 2% of the sample height per minute. For brittle materials, a lower value is explicitly advised. ASTM D2850 is more rigid: it prescribes a fixed 1%/min for plastic materials, while requiring a rate of 0.3%/min for brittle materials.

CU tests: ISO 17892-9 uses formulas to define the maximum rate based on the

consolidation time (t_{50} or t_{100}) applying empirical factors (F) from a table depending on drainage conditions. ASTM D4767 predominantly relies on the t_{50} time to calculate the time to failure, with the specific goal of ensuring pore pressure equalization of at least 95% within the sample at failure.

4.2 Saturation and Skempton's B-value

Both norms require high saturation prior to shearing so that the test faithfully simulates material behavior below the ground-water table. [12]

ISO 17892-9: Strictly defines that the saturation phase is considered complete only when the B-value reaches a minimum of 0.95. If this is not achieved, additional steps of increasing cell and back pressure are required.

ASTM D4767: Also requires $B \geq 0.95$, but is more flexible with overconsolidated or very stiff cohesive materials (where the volumetric compressibility of the skeleton is small), allowing saturation with B-values ≥ 0.90 .

4.3 Correction for membrane elasticity

Corrections are necessary because the rubber membrane provides a fictitious resistance that artificially increases stresses.

ISO Standards: Offer a fast and standardized mathematical approximation. The formula for deviator stress correction relies on an assumed or measured membrane modulus of elasticity (E_m). If a standard latex membrane is used, ISO allows adopting a constant of 1400 kPa.

ASTM Standards: Use a slightly different correction approach, which often relies on empirical curves developed earlier in practice, accounting for membrane extension in a more subtle manner, which complicates rapid automated processing without calibration tables.

4.4 Failure criteria

The interpretation of the point of failure changes the input data for stability index indicators.

ISO approach: Defines failure as the peak deviator stress, peak effective stress ratio, or a specific deformation criterion, such as 10% or 15% vertical strain, leaving room for engineer judgment.

ASTM approach: Most commonly sets an absolute limit for vertical strain at 15%

as the point of failure, unless the material exhibits a distinct peak in deviator stress or principal stress ratio prior to that limit.

5 CONCLUSION

The development of standards directly follows the development of numerical modeling. While early standards served merely to provide a "number" for c and ϕ , modern ISO standards enable the acquisition of complete stress-strain curves. This is crucial for advanced constitutive models during modeling, which are essential for simulating the complex behavior of soil, where static and dynamic stability depend on stress history and the degree of consolidation.

When developing an algorithm for the automatic processing of "raw" laboratory data, the ISO methodology often proves more practical due to clear formulas with defined constants, which significantly facilitates data normalization and the iterative formation of Mohr-Coulomb circles.

REFERENCES

- [1] Terzaghi, K. (1943). Theoretical Soil Mechanics. John Wiley and Sons, New York.
- [2] Casagrande, A. (1936). The Determination of the Pre-Consolidation Load and its Practical Significance. Proceedings of the International Conference on Soil Mechanics and Foundation Engineering, Cambridge.
- [3] ASTM D2850-15(2023) – Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils.
- [4] ASTM D4767-11(2020) – Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils.

- [5] ASTM D7181-20 – Standard Test Method for Method for Consolidated Drained Triaxial Compression Test for Soils.
- [6] BS 1377-8:1990 – Methods of test for soils for civil engineering purposes. Shear strength tests (triaxial shear).
- [7] JUS U.B1.024 – Methods of soil testing - Determination of soil shear strength using a triaxial apparatus with pore water pressure measurement (or the corresponding JUS standard from the U.B1 series used in our practice).
- [8] DIN 18137-2:2011 – Soil, investigation and testing - Determination of shear strength - Part 2: Triaxial test.
- [9] SRPS EN ISO 17892-8:2018 – Geotechnical investigation and testing – Laboratory testing of soil – Part 8: Unconsolidated undrained triaxial test.
- [10] SRPS EN ISO 17892-9:2018 – Geotechnical investigation and testing – Laboratory testing of soil – Part 9: Consolidated triaxial compression tests on water-saturated soils.
- [11] Rocscience (2024). Rocscience Soil Mechanics and Shear Strength Verification Manual. Toronto, Canada
- [12] Skempton, A. W. (1954). The Pore-Pressure Coefficients A and B. *Géotechnique*, 4(4), 143-147.