

The Vienna Terzaghi Archive

Dietmar Adam, Roman Markiewicz, Andreas Hausenberger
 Institute of Geotechnics, TU Wien, Austria, dietmar.adam@tuwien.ac.at

Paulus Ebner
 TU Wien Archives, TU Wien, Austria

ABSTRACT: The paper outlines the history, development, and scientific importance of the Vienna Terzaghi Archive at TU Wien. Located in the original Soil Mechanics Laboratory founded by Karl Terzaghi, the archive commemorates the origins of modern soil mechanics, particularly his groundbreaking 1925 publication, and highlights Vienna's key role in the rise of geotechnical engineering. The archive was realized through restoring the laboratory rooms and refurbishing historical equipment. It also presents the life and work of Karl Terzaghi, considered the founder of modern soil mechanics. He revolutionized the understanding of soil behavior by introducing physically based theories, especially the principle of effective stress and consolidation theory. A central feature of the archive is its collection of restored experimental devices, including the oedometer, various shear apparatuses, and early triaxial testing equipment. These devices illustrate the experimental foundations of the discipline. Overall, the archive preserves an important scientific heritage, demonstrates the early development of soil mechanics, and emphasizes Vienna's role as its birthplace.

KEYWORDS: Karl von Terzaghi, Vienna Terzaghi Archive, soil mechanics laboratory, history of soil mechanics.

1 INTRODUCTION

The 21st International Conference on Soil Mechanics and Geotechnical Engineering (21 ICSMGE 2026) in Vienna, Austria, in June 2026 is dedicated to the 100th anniversary of the birth of modern soil mechanics. The publication of Karl Terzaghi's groundbreaking book „Erdbaumechanik auf bodenmechanischer Grundlage“ ('Soil mechanics based on soil physics') (Figure 1) in Vienna in 1925 heralded a new era in the handling of the oldest building material, yet one whose fundamental mechanisms had been largely misunderstood until then – soil. Vienna was obviously 'fertile ground', as the world's first institute dedicated to this field, founded in 1928 at the 'Technische Hochschule Wien' (now TU Wien) (Figure 2), had a reputation as the 'Mecca of Soil Mechanics' in the 1930s.

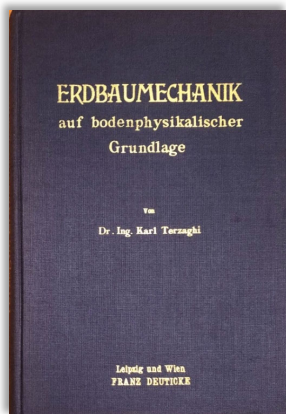


Figure 1. Terzaghi's book "Erdbaumechanik auf bodenphysikalischer Grundlage" marks the beginning of modern soil mechanics (Terzaghi, 1925).

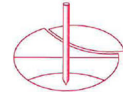


Figure 2. TU Wien, main building in the center of Vienna, home of the Institute of Geotechnics, the former Soil Mechanics Institute and Laboratory and now the Vienna Terzaghi Archive (© TU Wien).

The Soil Mechanics Laboratory (also: Earthworks Laboratory) was established with the founding of the new institute by Karl Terzaghi and his close colleague Arthur Casagrande. It was set up on the ground floor and in the basement of the main building, where it remained until it moved to the new Science Center of TU Wien in 2019.

In the early 2000s, Heinz Brandl, then head of the Institute for Ground Engineering and Soil Mechanics at TU Wien, took the initiative to establish a museum dedicated to the work and life of K. Terzaghi. William F. Van Impe, the then Immediate Past President of ISSMGE, was delighted about this idea and expressed this in a letter to H. Brandl (Figure 3).

International Society for Soil Mechanics and Geotechnical Engineering
Société Internationale de Mécanique des Sols et de la Géotechnique



Prof. H. BRANDL
 Technische Universität Wien
 Inst. für Grundbau, Geologie und Felsbau
 Karlsplatz 13/221
 1040 WIEN
 Austria

Immediate Past President
 Professor William Van Impe
 Faculty of Engineering
 Laboratory of Geotechnics
 Technologiepark 905
 9052 Zwijnaarde BELGIUM
 Tel: +32 9 264 57 17
 Fax: +32 9 264 58 48
 E-mail: william.vanimpe@ugent.be

15 February 2007

Dear Prof. Brandl,

It was a delightful message to me learning from you about the initiative proposed recently in the civil engineering faculty of the T.U. Vienna, to establish a museum dedicated to the work and life of K. v. Terzaghi.

As you may know, this idea of a Geotechnical Heritage Museum was born with me in the ISSMGE as early as in 1996. As far, there is not yet any real outcome linked to this idea; very unfortunately excellent opportunities offered more than 10 years ago in the city of Istanbul could not be materialised.

All the more reasons indeed to warmly applaud the initiative of the T.U. Vienna to come up with the most important part of such a Heritage Museum, being the honouring of Prof. K. v. Terzaghi.

If by all means this could for example be realised in 2008, this would be an excellent opportunity to remember K.v. Terzaghi's 125th birthday.

Congratulations to the faculty and to yourself.

Sincerely yours,

Prof. Dr ir W.F. Van Impe
 Immediate Past President

ISSMGE Secretariat, City University, Northampton Square, London EC1V 9HB UK. Tel: +44 20 7040 8154. Fax: +44 20 7040 8832. E-mail: secretariat@issmge.org

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Figure 3. Letter of W.F. Van Impe, then Immediate Past President of ISSMGE, to H. Brandl (2007).

However, the implementation of the museum was delayed. After H. Brandl retired in 2008, his successor, Dietmar Adam, took over the initiative. After initial hesitation on the part of the rectorate of the TU Wien, it was agreed to set up an archive instead of a museum in the basement rooms of the original laboratory, in which primarily the still existing early devices would be exhibited. The rooms were restored as faithfully as possible to their original state and the existing equipment was subsequently repaired. Some devices were still in use, while others had been stored improperly, requiring extensive repair work. Finally, it was decided that the equipment would be renovated as faithfully as possible to its original state by the institute's own staff. This was the only way to ensure that the function of the equipment could be understood and made operational. Roman Markiewicz, head of the laboratory, and Andreas Hausenberger, laboratory engineer, invested some hundreds of hours in renovating the equipment. In addition to the old equipment and the description of its development, selected exhibits, certificates, planning documents, dissertations, etc. were included in the documentation rooms now known as the 'Vienna Terzaghi Archive'.

2 A TRIBUTE TO KARL TERZAGHI

The Vienna Terzaghi Archive provides an overview of Karl Terzaghi's life and professional career. The following section briefly presents the most important stages of his life and some of his companions along the way. (Brandl, 1983/1984; Brandl, 1996)



Figure 4. Karl Terzaghi during his period in Vienna from 1929 to 1938. Note: since the 1919 law abolishing the nobility, his name was no longer Karl von Terzaghi according to the law (Brandl, 1983/1984).

2.1 Childhood, teenage years, and education

Karl von Terzaghi was born on October 2, 1883 in Prague (then Austrian-Hungarian Monarchy). He came from an old Austrian noble family with a long military tradition; his father, Anton von Terzaghi, Edler von Pontenuovo, was a lieutenant colonel in the Imperial Army. The family moved from Prague to Graz (Austria) and when Terzaghi's father died, his grandfather became his guardian. His grandfather had studied engineering and was a role model for the young Terzaghi.

In 1893 from the age of 10, he attended various military-oriented secondary schools in Hungary, Moravia, Vienna, and Graz. In 1900 his high school graduation took place in Graz, followed by mechanical engineering studies at the 'Technische Hochschule Graz' (now TU Graz), which he completed in 1904. During this time, he also turned his attention to civil engineering and geology, attending seminars with hydraulic engineer professor P. Forchheimer, among others.

In 1905 during his one-year military service, he translated Sir A. Geiki's work 'Outlines of Field-Geology', which was published in 1906 as „Anleitung zu Geologischen Aufnahmen” ('Guide to Geological Surveys'). This was Terzaghi's first publication.

2.2 Professional career

From 1906 to 1912 Terzaghi initially worked as a mechanical engineer in Graz, but realized that he would “find no satisfaction” in this field. He then went on to work as a project engineer at the concrete construction company Adolf Baron Pittel in Vienna (now PITTEL+BRAUSEWETTER). After three years, he took up positions in Croatia and Russia. During projects at home and abroad, unexpected ground settlement or difficulties with foundation work sometimes arose, leading Terzaghi to decide to focus his efforts on researching the border area between geology and civil engineering. In retrospect, this was the beginning of developing modern soil mechanics.

In 1912 Terzaghi received his doctorate from the 'Technische Hochschule Graz' (now TU Graz) for his dissertation entitled „Beitrag zur statischen Untersuchung cylindrischer Wasserbehälter” ('Contribution to the static investigation of cylindrical water tanks').

From 1914 to 1916, during World War I, Terzaghi led a pioneer company in Serbia as a first lieutenant. He later worked on the expansion of the Aspern military airfield in Austria.

From 1916 to 1918 he was professor in Turkey at the Royal Ottoman University in Constantinople (now TU Istanbul). Terzaghi conducted his first soil mechanics research there; a paper on earth pressure on retaining walls was translated into English in 1919. After the war ended, he continued his work at Robert College (an American high school founded in Constantinople in 1863) from 1918 to 1925 and conducted laboratory experiments with the most basic equipment: “The inventory of my laboratory consisted solely of empty cigar boxes, the college's kitchen scales, an old apothecary's scales that I had bought in the bazaar in Istanbul, and a few steel bands.” (Terzaghi, 1932)

In 1925 Terzaghi published his groundbreaking findings in Vienna – including the consolidation of cohesive soils with his theory of effective stresses – in his fundamental book „Erdbaumechanik auf bodenphysikalischer Grundlage” ('Soil mechanics based on soil physics'). (Terzaghi, 1925; Figure 1)

From 1925 to 1929 he was professor in the USA (at M.I.T. Massachusetts Institute of Technology). Terzaghi summed up this period as follows: “Interest in the problems of soil mechanics has been aroused throughout the American professional world through word of mouth and in writing. Laboratories have been set up in Washington D.C., Cambridge, Massachusetts, Boston, San Francisco, and the Sandwich Islands, where research continues even after my departure from the United States.” (Terzaghi, 1932)

From 1929 to 1938 he was professor in Austria at the 'Technische Hochschule Wien' (now TU Wien). Terzaghi began setting up a soil mechanics laboratory in the basement of the university. Due to his mechanical engineering studies, he was able to build the necessary equipment himself, together with his colleagues who came from Austria and abroad to work with him (Figure 5, Figure 6). A. Casagrande (Figure 7), already a close colleague of Terzaghi, considered these years in Vienna to be the most important: “There is no question that during the nine years from 1929 to 1938, Vienna rapidly developed into the world's leading center for soil mechanics.” (Hofmann, 2024)

Terzaghi's new theses and theories led to a scientific dispute with his Viennese colleague Paul Fillunger (Professor of elasticity and strength of materials at the 'Technische Hochschule Wien' (now TU Wien)), which was played out in public in a series of sometimes polemical publications. Fillunger criticized Terzaghi's consolidation theory and attacked him personally. A commission of inquiry set up by the rectorate ultimately ruled in Terzaghi's favor in 1937; however, Fillunger took this so much to heart that he and his wife subsequently committed suicide.



Figure 5. K. Terzaghi with assistants in Vienna in 1933. From the left: L. Rendulić, Mrs. Rendulić, W. Steinbrenner, K. Terzaghi, Mrs. Terzaghi, P. Siedek, K. Kienzl (Brandl, 1983/1984).



Figure 6. Assistants of K. Terzaghi in front of the Soil Mechanics Laboratory in Vienna in 1935. From the left: K. Kienzl, O. Schwarz, J. Hvorslev, O.K. Fröhlich, H. Borowicka, W. Steinbrenner (Brandl, 1983/1984).

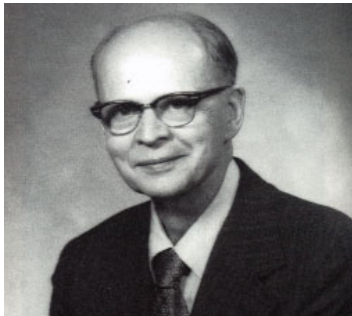


Figure 7. Arthur Casagrande in 1974; he was born in Heidenschaft (then Austrian-Hungarian Monarchy, now Slovenia) on August 28, 1902 and died in the USA on September 6, 1981 (Brandl, 1983/1984).

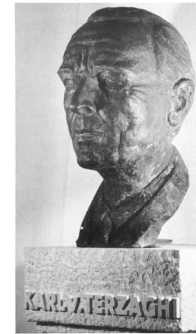


Figure 8. Bust of Karl Terzaghi donated by A. Casagrande for lecture hall XVI at the 'Technische Hochschule Wien' (now TU Wien) in 1967 (Borowicka, 1967).



Figure 9. Participants at the 1st International Conference on Soil Mechanics and Foundation Engineering at Harvard University (USA) in 1936, organized by A. Casagrande. Participants with relation to Austria were: No. 46: K. Terzaghi, No. 63: R. Tillmann, No. 76: A. Casagrande, No. 98: C. Veder, No. 117: L. Casagrande.

In 1938 Terzaghi left Vienna and became a professor in the USA at Harvard University in Massachusetts, where he taught soil mechanics and supervised numerous construction projects both nationally and internationally. Terzaghi retired in 1953, but continued to give guest lectures and also continued to work as a consulting engineer.

On October 25, 1963, Terzaghi died in Winchester, Massachusetts, shortly after his 80th birthday. Until his death, he was married to the American geologist Ruth D. Terzaghi.

2.3 Achievements

Terzaghi is considered the 'father of modern soil mechanics'. He was the first to study soils not only empirically, but also on the basis of physical principles. He laid the foundations of geotechnical engineering, thereby changing civil engineering forever. His ideas and methods are taught and applied worldwide – he remains a key figure in the history of engineering. He received the Norman Medal from the ASCE (American Society of Civil Engineers) four times, nine honorary doctorates, and authored over 200 publications.

Thanks to the efforts of L. Bjerrum, a large part of his estate is now housed in the 'Terzaghi Library' in Oslo at the Norwegian Geotechnical Institute.

Terzaghi received many honors after his death, only one is mentioned here, as it is now part of the Terzaghi Archive. A. Casagrande donated a bust in honor of the founder of the Chair of Ground Engineering and Soil Mechanics on the occasion of the opening of the newly adapted lecture hall XVI at the 'Technische Hochschule Wien' (now TU Wien) on March 31, 1967 (Figure 8). The lecture hall was dedicated to Terzaghi and named after him. In the course of a general refurbishment, this lecture hall was disbanded and no longer exists.

Together with A. Casagrande, Terzaghi also played a key role in the founding of the International Society for Soil Mechanics and Foundation Engineering (ISSMFE) in 1936, which had its origins in the First International Conference on Soil Mechanics and Foundation Engineering held in Harvard in 1936. A total of 206 delegates attended from 20 countries (Figure 9). An Executive Committee was set up with Terzaghi as President and A. Casagrande as Secretary to ensure continuation of this very successful initiative.

After 90 years, the ICSMGE returns to Vienna, the birthplace of modern soil mechanics, to host the 21st International Conference on Soil Mechanics and Geotechnical Engineering, under the motto “join us ... where it all began”.

3 THE VIENNA TERZAGHI ARCHIVE AND A PRESENTATION OF SELECTED EXHIBITS

The Vienna Terzaghi Archive was established in one of the basement rooms where the Soil Mechanics Laboratory first began. Many of the devices developed at that time and built in the laboratory’s own workshop have thus returned to their original home. Figure 10 shows the floor plan and the layout of the exhibited historical equipment. The original devices and further developments are exhibited, and original documents from that period are presented in display cases. Space has also been set aside for the Physical Time Capsule, an initiative launched by Marc Ballouz, the current President of the ISSMGE.

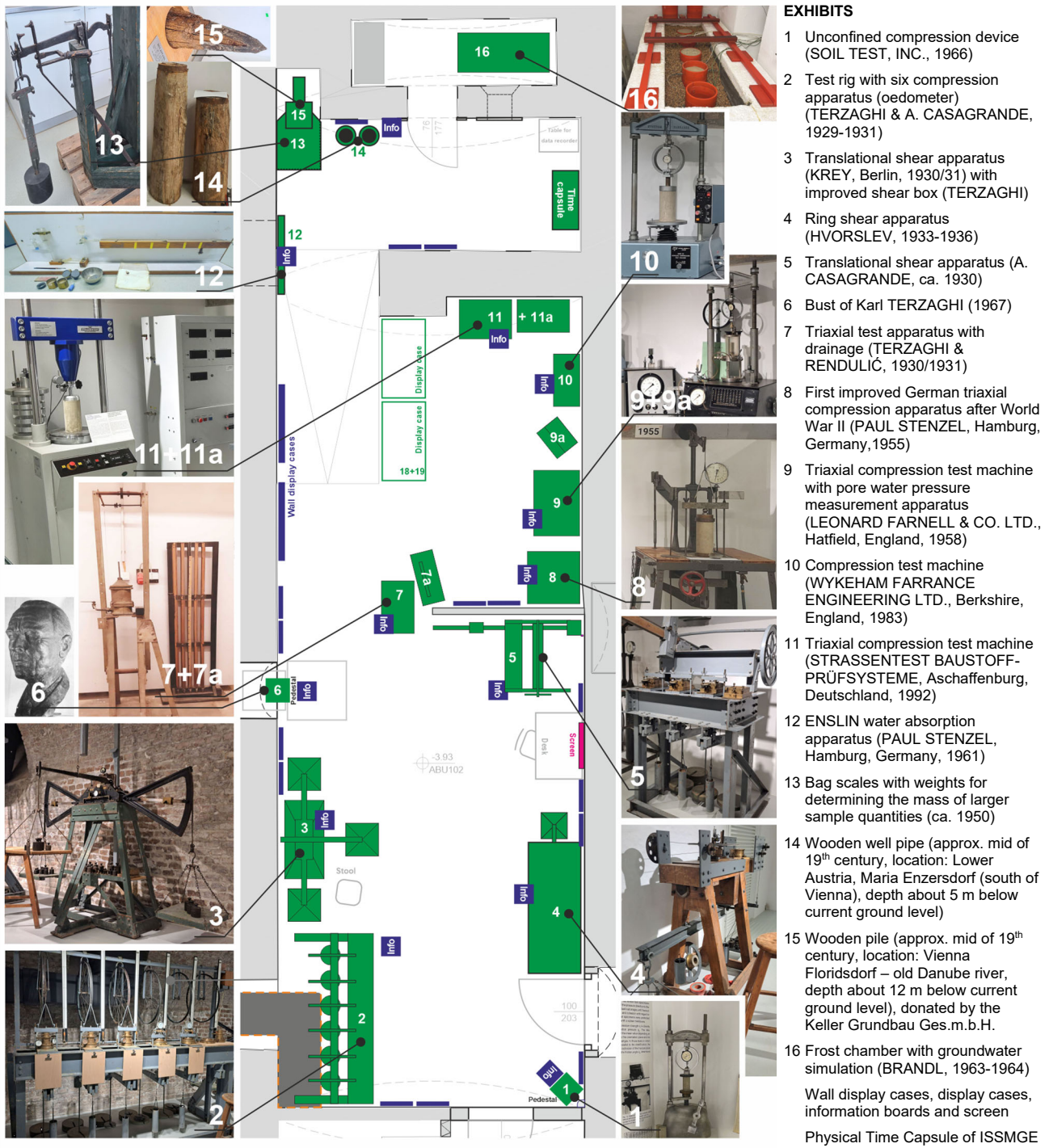


Figure 10. The Vienna Terzaghi Archive at TU Wien. Floor plan and the layout of the historical equipment including photo images of the refurbished original devices (© Markiewicz, Hausenberger, 2026).

A complete description of all the exhibits in the Vienna Terzaghi Archive would go far beyond the scope of this paper. Therefore, only a selection of the exhibited devices is presented in the following and their development described.

3.1 Compression apparatus (oedometer) (Karl Terzaghi, 1929–1931)

The influence of clayey soils on settlement behavior has been investigated since the beginning of the 19th century by means of settlement measurements. However, the theoretical relationships for describing such settlement processes were first described by Terzaghi in 1923 in „Die Berechnung der Durchlässigkeitsziffer des Tones aus dem Verlauf der hydrodynamischen Spannungserscheinungen” (‘Calculation of the permeability coefficient of clay from hydrodynamic stress data’) and in 1925 in his work „Erdbaumechanik auf bodenphysikalischer Grundlage” (‘Soil mechanics based on soil physics’). The solution of the one-dimensional consolidation theory and the description of the compression test/oedometer test still form the basis for settlement calculations and the determination of the time-settlement behavior of soils.

In 1936, K. Terzaghi and O.K. Fröhlich published further mathematical solutions of the consolidation theory for some important standard cases.

3.1.1 The principle of effective stresses

The principle of effective stresses was introduced by Terzaghi and explained as early as 1933 using the well-known spring model. In „Die Ödometer-Beobachtung als Hilfsmittel zur Erforschung der Gelstruktur” (‘Oedometer observation as a tool for researching gel structure’), Terzaghi describes as follows using Figure 11:

“This figure represents a cylindrical vessel with a ground-in, perforated flask. The piston rests on spiral springs and its position is clearly determined by the tension of the springs. If the springs are shortened by loading the piston, the corresponding downward movement of the piston occurs without delay when the vessel is empty. If, on the other hand, the vessel is filled with water, the downward movement of the piston is delayed due to the resistance to the water escaping through the openings. The smaller the openings, the longer the delay. During the downward movement, there is a hydrostatic excess pressure in the water below the piston, which absorbs the difference between the load and the spring tension.”

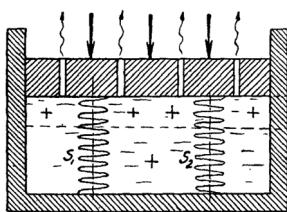


Figure 11. Spring model by Terzaghi to describe the principle of effective stresses (Terzaghi, 1933).

The mathematical description of the mechanical behavior of the soil was a major challenge.

3.1.2 Development of the compression apparatus (oedometer)

Between 1929 and 1933, Terzaghi and Casagrande developed the first compression devices in Vienna that differed in design but functioned in the same way. Figure 12 shows the cross-section of the Terzaghi-oedometer (original drawing).

Figure 13 shows originals of the first devices designed by Terzaghi and Casagrande. Further developments made it

possible to carry out compression and permeability tests simultaneously (Terzaghi, 1931).

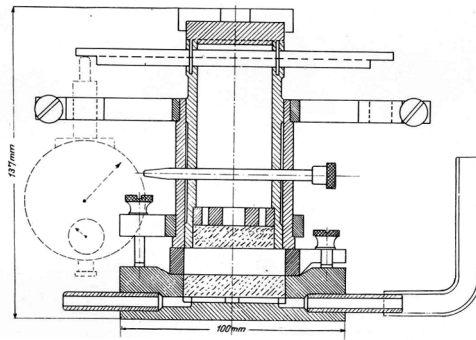


Figure 12. Cross-section of the Terzaghi-oedometer (original drawing) (Brandl, 1983/1984).

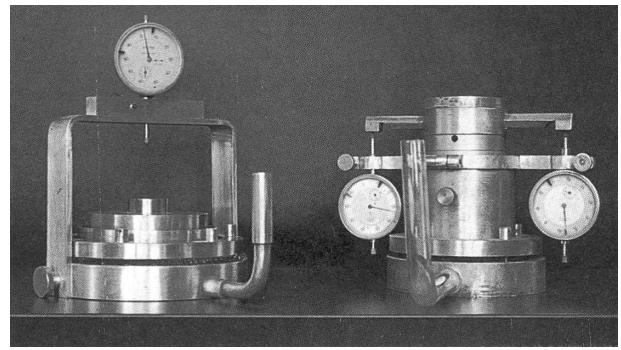


Figure 13. Compression apparatus (oedometers) designed by Terzaghi (on right) and Casagrande (on left); originals of the first fabricates between 1929 and 1933 (Brandl, 1983/1984).

3.1.3 Preparation of test specimens

As already mentioned, the investigation of the compression of clay soils was first described by Terzaghi in 1923 and then in detail in 1925. The apparatus shown in Figure 14a was used to prepare a soil sample. The clay slurry is placed in the glass cylinder G. A filter paper disk rests on the base plate B and on this a bronze ring I, which contains the soil sample for the later tests. A layer of quartz sand is applied to the clay slurry, the vessel G is filled with water and the load is successively increased using lead scrap and then a lever.

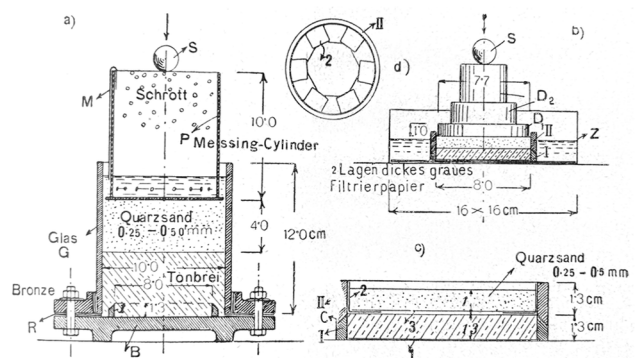


Fig. 13.

Figure 14. Terzaghi test apparatus for producing the test specimens (a) and for investigation the compression (b, c) (Terzaghi, 1925).

After a few days of preloading, the bronze ring I with the 1.3 cm thick clay layer in it is carefully removed and installed in the compression apparatus in Figure 14b. The apparatus consists of a square zinc sheet basin Z, in which the bronze rings I and II are located. Ring II is ground onto ring I after a conical surface C (Figure 14c). The surface of the clay layer is covered with

filter paper and ring II is filled with a 1 cm thick layer of fine, wet quartz sand. The double ring I-II and its contents are placed in the zinc basin Z, which is then placed under the pressure piston of a firming machine. After applying the set of disks D1, D2 and the steel ball s, the load on the clay layer is successively increased and the zinc basin Z is filled with water.

3.1.4 Conducting experiments

The load to the soil sample is applied via a lever with a transmission ratio of 1:5 to carry out tests with high pressures. The load applied using weights acts as a dead load, so that no load fluctuations occur even during prolonged tests. The dead weight of the construction is balanced by the cable deflection guided over the wheels. Oedometers of different sizes can be used for the tests. Water is supplied via the water tank located at the top right, so that the permeability can also be determined during the compression test with a falling pressure head (Figure 15, background).

An identical test rig is still in use in the Soil Mechanics Laboratory now at the Science Center of TU Wien.

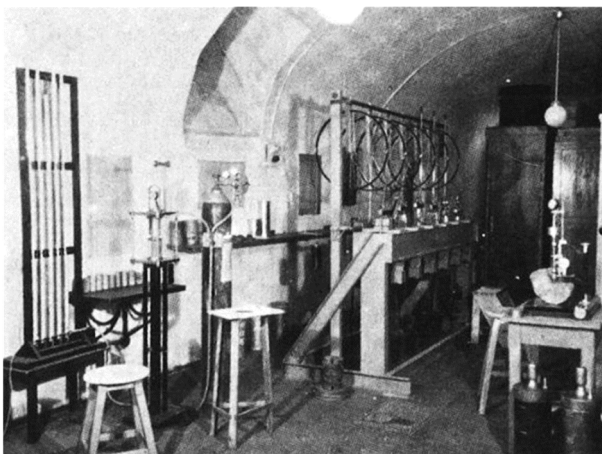


Figure 15. One of the laboratory rooms in the basement of the Soil Mechanics Laboratory, 1935. Left: triaxial apparatus. Right: Swedish cone penetrometer. Background: test rig with six compression apparatus (consolidation devices and instrumentation for permeability), now location of the Vienna Terzaghi Archive (Terzaghi, 1935).

3.1.5 Terzaghi's personal remarks

On the occasion of his admission to the Austrian Academy of Sciences in Vienna, Terzaghi commented in his autobiography „Mein Lebensweg und meine Ziele“ (My life and my targets) on his research into soil compression in 1932, describing how challenging this period was for him:

“In 1923, my work came to a standstill again. This time it was about the mathematical recording of the process of gradual compression that the clay undergoes under the influence of constant pressure. I had become so engrossed in the task that I neglected all my duties for a month and worked late into the night every day to solve the problem. The attempt failed and I decided to publish the results of my previous investigations, with the intention of leaving the solution of this core theoretical problem of soil mechanics to a successor with a luckier hand.

Six months later, while I was still busy writing the planned paper, I managed to solve the problem effortlessly after half an hour's thought. It consisted of the differential equation of the compaction process, which today forms the basis for all investigations concerning the gradual settlement of buildings on clay soils. Only after this equation had been established could the attempt to determine the strength properties of soils be considered a success. The invitation to deliver a lecture at the 1st International Congress for Applied Mathematics and Mechanics in Delft in 1924 gave me a welcome opportunity to

bring the newly discovered differential equation of the compaction process to the attention of my colleagues.

All my investigations were initiated by the formulation of working hypotheses which expressed my sometimes purely emotional ideas of the relationship between cause and effect. The next step was to plan experiments whose results clearly confirmed or refuted the working hypothesis. The conclusion was formed either by correcting the initial theory or by developing a new one, which then had to be tested again for its truth by means of experiments. The simpler and cheaper the apparatus, the better it suited such a purpose, because it could be adapted to the growing insight into the nature of the process to be investigated without any loss of time or money, or it could be deactivated and replaced by a new one. Expensive and sensitive instruments are only appropriate when the essence of the phenomenon has already been clearly grasped and the raw figures are to be replaced by precise values. If one begins with an expensive apparatus, one is a slave to one's instruments and an experiment that does not serve to verify the truth of a high-quality concept merely helps us to recognize a fact, but never to recognize a law.”

3.2 Translational shear apparatus (Hans-Detlef Krey, 1930/1931) with improved shear box (Karl Terzaghi)

H.-D. Krey developed a shear test apparatus for the Research Institute for Hydraulic and Ship Engineering in Berlin in the 1920s that almost neutralized the influence of skin friction in the shear box (Figure 16, Figure 17). The equipment was initially designed for the determination of the wall friction of plates with different surface roughness against soil. Krey did not use the term 'shear box', but named the lower movable part of the apparatus, on which the soil to be tested lay, 'test plate'.

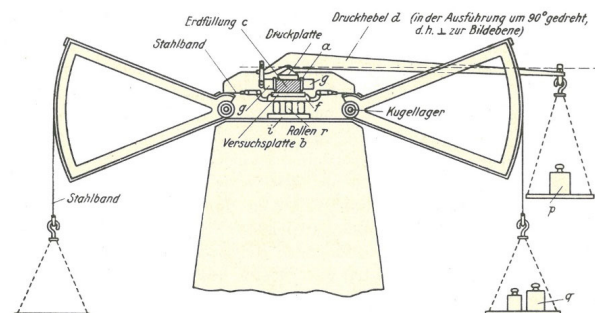


Figure 16. Krey shear test apparatus, Research Institute for Hydraulic and Ship Engineering Berlin (Krey & Ehrenberg, 1935).



Figure 17. Krey shear test apparatus; original of the first fabricate at TU Berlin (© Adam, 2025).

Terzaghi improved Krey's shear box. He realized that toppling of the shear box had to be avoided to impede distortion caused by imprecise application of the normal force. Furthermore, A. Casagrande and M.J. Hvorslev performed extensive testing on the coarseness and type of serrated pervious plates in the shear box. At that time, the formation of a properly even shear plane and the fundamental applicability of direct shear tests were discussed.

Shear testing was the subject of major research activity under the lead of H. Borowicka in the 1960s at the 'Technische Hochschule Wien' (now TU Wien). The excess pore water pressure caused by volumetric displacement was impeded by maintaining a constant void ratio during the test. As an alternative to the ring shear apparatus for large shear displacements, an option for determining the residual shear strength was found also for square shear boxes by shearing to and fro a few times. From this principle the so called 'Vienna routine shear test' was derived.

3.2.1 Composition of the Krey shear apparatus with the shear box improved by Terzaghi

Figure 18, Figure 19 and Figure 20 show Krey's shear apparatus with the shear box improved by Terzaghi (10 cm x 10 cm). The test specimen E is located between two serrated pervious plates D. During shearing, the slide Q and the lower part A of the shear box are moved in a horizontal direction, while the frame B is held in place by the guide jaws P so that it can only move in a vertical direction.

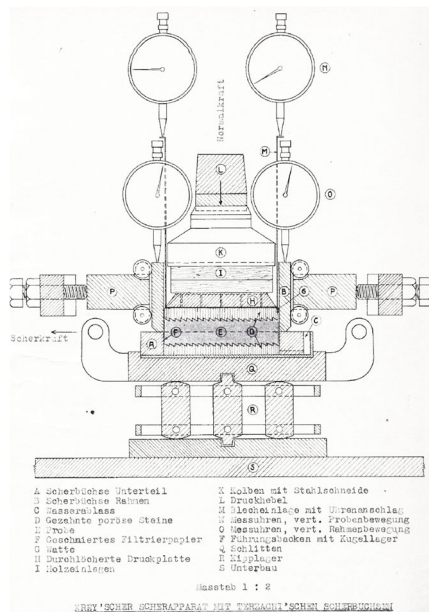


Figure 18. Krey shear test apparatus, with Terzaghi's shear box (Hvorslev, 1936).

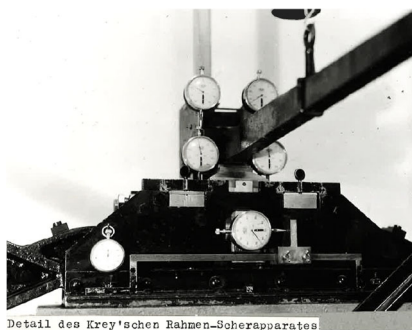


Figure 19. Detail of Krey shear test apparatus, with Terzaghi's shear box (© TU Wien).

The change in specimen height during the shearing is determined by the two-dial gauge N, the lifting of frame B by the dial gauge O. The horizontal movements of the box Q are measured by another dial gauge (not shown) and also automatically recorded on a writing drum (Figure 19) at ten times magnification.

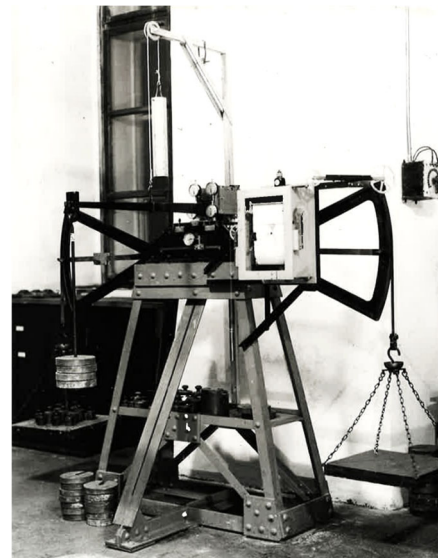


Figure 20. Krey's shear apparatus around 1934 with automatic writing drum to show the shear path (© TU Wien).

Figure 21 shows a later design in which only one dial gauge is used to observe the sample height. Such devices are still in use in the Soil Mechanics Laboratory at TU Wien.

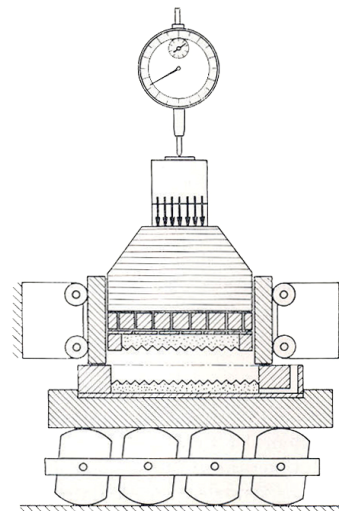


Figure 21. Cross-section through the shear box in Krey's shear apparatus (Brandl, 1990).

3.2.2 Changes in shape of the sample during shearing and influence of serration and granularity of the serrated pervious plates

From 1933 to 1936 Hvorslev used this apparatus to investigate, among other aspects, the internal changes in the shape of the sample during shearing and the influence of the serration and granularity of the serrated pervious plates before the standard version of Terzaghi's shear box (Figure 22) was developed. For this purpose, Hvorslev colored thin, vertical zones in the sample and examined the internal displacements and failure surfaces. Figure 23 shows the internal changes in shape of a sample 2 cm high (Wiener Tegel / Vienna Clay) with a shear deformation of 13 mm.



Figure 22. Terzaghi's shear box (Hvorslev, 1936).

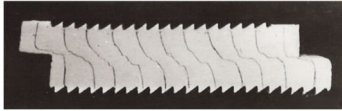


Figure 23. Internal deformations of shear sample: Vienna Clay in Terzaghi shear box (Hvorslev, 1936).

The influence of the serration of the serrated pervious plates on the shear resistance was also investigated. Hvorslev found that a fairly uniform pressure distribution was already present at a height of approximately half the spacing of serration above the serration tips. Figure 24 shows the internal changes in shape of a sample when displaced in and against the direction of serration. The tests showed that the direction of serration had no influence on the shear resistance.

Rough pervious plates were also used instead of serrated pervious plates (Figure 25). When using coarse-grained pervious plates, the same test results were obtained as with the serrated pervious plates; with fine-grained plates, the shear resistance was lower and a failure surface formed along the surface of the pervious plate, so that the permissible lower limit of the grain size could be found.



Figure 24. Influence of direction of serration (serration height 2.6 mm and spacing of serration 4.6 mm) with shear off just above the serration (Hvorslev, 1936).



Figure 25. Influence of grain size with shear off just above the serration (Hvorslev, 1936).

3.3 Ring shear apparatus (Mikael Juul Hvorslev, 1933-1936)

Hvorslev used the standard shear boxes for further developments and designed the first ring shear apparatus from December 1933 to May 1936 (Figure 26, Figure 27, Figure 28). Mainly he conducted comprehensive testing series on plastic deformation before failure, but investigated also the shear resistance after failure. The ring shear apparatus made it possible for the first time to examine long shear paths.

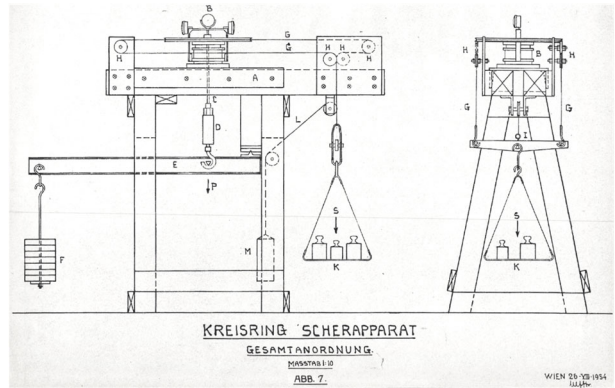


Figure 26. Ring shear apparatus, overall arrangement with load frame (Hvorslev, 1936).

In his doctoral thesis published in 1936, Hvorslev describes the motivation for the studies as follows:

“Although a lot of test results on shear strength and unconfined compression strength of remolded soil samples already exist, they cannot be explained completely by the failure conditions established so far. To date only a few results about the slow plastic deformation before failure and the change of the shear resistance after the failure have been published (Terzaghi, 1931; Grüner & Haefeli, 1934). This mainly results from the fact, that the shear testing equipment recently used is not suitable for the type of tests mentioned above, since the effective shear plane, and with it the state of stress, changes during the test. The gap in knowledge referred to above gave rise to the present thesis.”

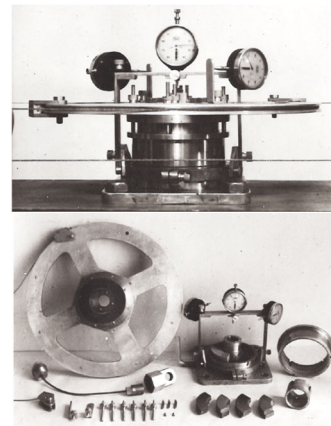


Figure 27. Ring shear apparatus, original of the first fabricate (Hvorslev, 1936).

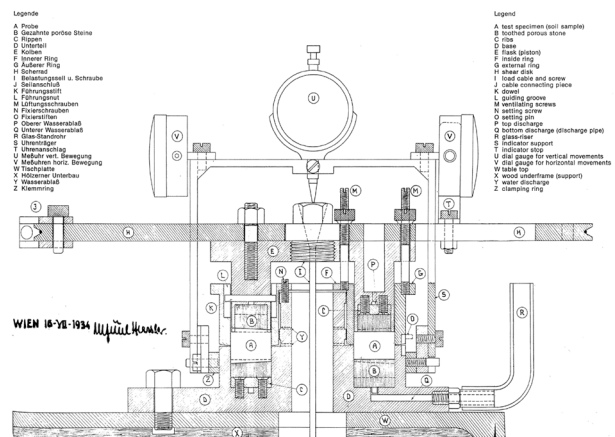


Figure 28. Ring shear apparatus - overview section (original drawing, 1934) (Hvorslev, 1936).

In addition, Hvorslev developed, based on existing failure conditions as Coulomb and Krey-Tiedemann, an extended failure criterion, that describes the shear resistance of cohesive soils (independently of former stress states) as a function of the effective normal stress and the void ratio at failure.

3.3.1 Advantages and disadvantages of the circular ring shear apparatus

Compared to the shear apparatus, in which the fracture is caused by horizontal parallel displacement, an apparatus with torsional loading offers the advantage that this type of loading is better suited for a theoretical treatment of the stress distribution and the shear surface does not change during the test. This makes it possible to continue the test for any length of time even after the shear strength has been overcome and to investigate the behavior after fracture.

Shearing apparatuses with a full circle as the shearing surface were already being used in America and Europe at that time. However, these had the disadvantage that the shear stresses and deformation decrease to zero towards the center and are therefore distributed non-uniformly. Hvorslev therefore replaced the full circular cross-section with a circular ring cross-section, which resulted in the following advantages:

- More uniform distribution of the normal stress on the shear plane, resulting in better agreement with the theoretical assumptions.
- Reduced difference between the maximum and minimum shear stresses, allowing better investigation of premature plastic flow phenomena and volume changes.
- The uniform stress distribution makes it possible to investigate the dependence of the shear resistance after fracture on the flow rate.

A disadvantage, however, is that the influence of friction on the side walls is greater and undisturbed soil samples are difficult to install.

3.3.2 Shear tests with the circular ring shear apparatus

Hvorslev determined the internal changes in shape by coloring thin, perpendicular layers (Figure 29) and thus investigated the differences between the two test variants (fixed / floating rings) as well as the validity of the theoretical formulas on which they were based.

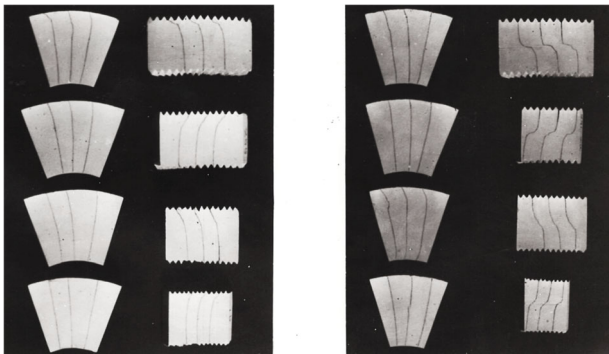


Figure 29. Internal deformations of soil sample in ring shear test: left: with fixed rings; right: with floating rings (Hvorslev, 1936).

The deformation curve for shear obeys approximately the following equation (1) up to the vicinity of the breaking point:

$$\tau = \beta \cdot \gamma^m \quad (1)$$

Hvorslev has shown that the ratio τ_2/τ_a is constant and is determined by the following equation (τ_1 and τ_2 are the shear stresses at the inner and outer edges respectively and τ_a is the mean shear stress):

$$\frac{\tau_2}{\tau_a} = \left(1 + \frac{r}{3}\right) \frac{1 - n^3}{1 - n^3 + m} = k \quad (2)$$

Figure 30 shows test results for the Vienna Clay. Before the failure occurs, the relationship between the two curves τ_2 and τ_a is exactly given by equation (2); after the failure, the two curves differ by a larger amount until the equalization of the stresses becomes effective. The maximum values of τ_2 and τ_a are almost the same, although they do not correspond to the same torsion.

If the shear force is reduced after the failure until it comes to a standstill and the test is repeated after a rest period, a recovery of the shear resistance can be observed. The original maximum is quickly exceeded, while the minimum value of the shear resistance remains at the same value after each failure.

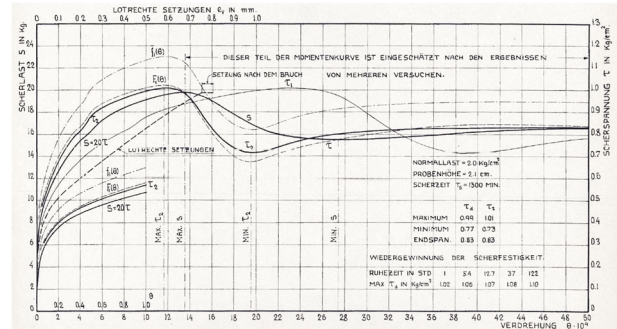


Figure 30. Shear resistance of the Vienna Clay, determined with the circular ring shear apparatus with fixed rings (Hvorslev, 1936).

3.4 Translational shear apparatus (Arthur Casagrande, ca. 1930)

A. Casagrande developed a shear apparatus in which the compaction/consolidation and the subsequent shearing process could be carried out in the same apparatus, and in addition several soil samples could be tested one after the other using the movable shearing device (Figure 31, Figure 32). This was a decisive advantage over the Krey shear apparatus, in which the shear boxes were installed into the shear apparatus after the sample had been fully compacted/consolidated in a separate pre-pressure apparatus. This had the disadvantage that the sample had to be completely unloaded for reinstallation.

The normal forces are applied via a lever with a vertical weight rod (lead weights of different mass are suspended on the rod by hand), whereby the dead weight is compensated by a counterweight. The shearing force is applied by a weight running on a second lever. In contrast to the shear apparatus according to Krey, in the shear apparatus according to A. Casagrande the lower frame is held in place and the upper frame is moved via a belly-like extension. The soil sample has side lengths of 10 cm x 10 cm and a height of about 2 cm when compressed. As with the Terzaghi shear box, permeable and serrated pervious plates are used at the top and bottom (Figure 33, Figure 34).

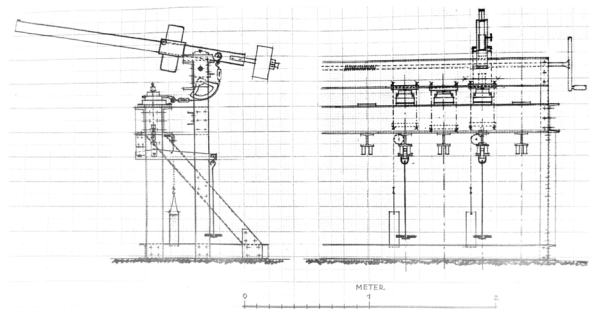


Figure 31. Design drawing for the A. Casagrande shear apparatus (Tettinek, 1953).

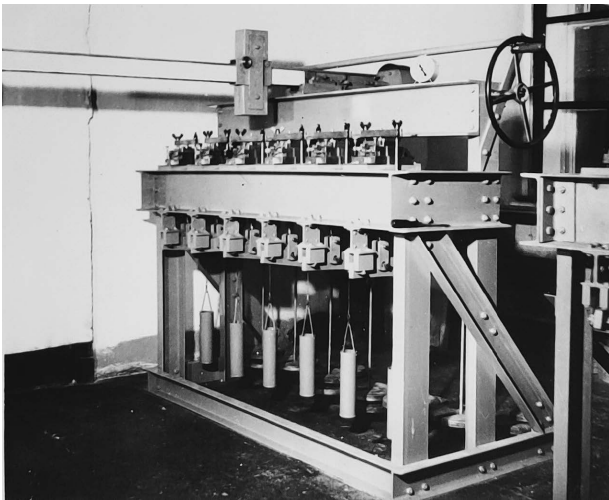


Figure 32. Shear apparatus according to A. Casagrande for six soil samples in the original Soil Mechanics Laboratory (Tettinek, 1953).

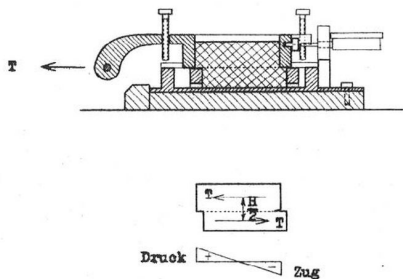


Figure 33. Cross-section, A. Casagrande shear box (Tettinek, 1953).

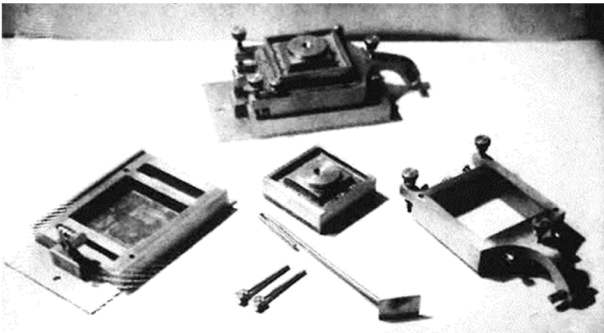


Figure 34. Shear box disassembled and assembled (Tettinek, 1953).

3.5 Triaxial test apparatus with drainage (Karl Terzaghi and Leo Rendulić, 1930/1931)

Five years after developing the triaxial test apparatus, L. Rendulić published the principle of a simple apparatus for maintaining hydrostatic pressure on soil samples. By means of this system he was able to verify the “basic law of clay mechanics” for the first time by experimental studies. Following this theory, the “total stress state is the sum of the effective stress state and the pore water pressure” (Rendulić, 1935, 1936, 1937). In the year 1937 he developed some – what he called – 'auxiliary devices', which provide a two-axial total state of stress on cylindrical specimen and allow the measurement of excess pore water pressure.

3.5.1 Oil pressure apparatus

As early as 1928, J. Ehrenberg (a colleague of Krey in Berlin) designed the first triaxial device for soil testing. However, further developments were required, which were implemented by Terzaghi and Rendulić, to be able to experimentally substantiate the theory of effective stresses in the soil developed by Terzaghi.

With the test device, also known as the ‘oil pressure apparatus’ (Figure 35, Figure 36), a constant lateral pressure and an additional axial pressure could be applied to the sample. The apparatus provided a central drainage core. Following one of Terzaghi’s ideas, a sand-mica-mixture was used for dissipating the pore water. This method was considered necessary to avoid any influence of the drainage core on the forced deformation of the specimen.

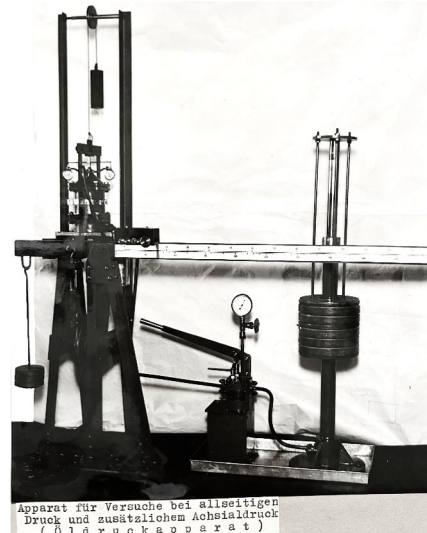


Figure 35. Photo of the so-called 'oil pressure apparatus' (© TU Wien).

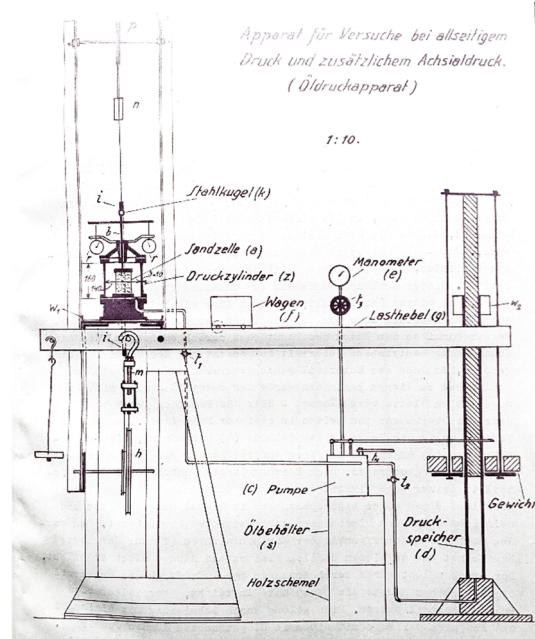


Figure 36. Schematic drawing of the so-called 'oil pressure apparatus' (© TU Wien).

In this manner, an anisotropic consolidation of the specimen was possible. Rendulić derived the monitoring time of each load step from Hvorslev’s knowledge about the plastic behavior of cohesive soils before failure.

3.5.2 Setup of the first triaxial test apparatus with measurement of pore water pressure

The 'additional device' (Figure 15, left, and Figure 37) made it possible to measure the excess pore water pressure using a mercury manometer and to measure the cell pressure. With his test apparatus, Rendulić was able to prove that the effective stresses alone are relevant for the displacement of the specimen.

Furthermore, he could confirm the significant influence of excess pore water pressure on the strength:

“All those, who have already performed shear tests on clayey soils know that, if total stresses are assumed, one can obtain practically any angle of internal friction, according to the interval between the individual load steps.”

Figure 37 shows the schematic plan of the test setup for the first triaxial compression apparatus ('oil pressure device') by Terzaghi and Rendulić. On the right, the special fivefold pressure gauge to measure cell pressure is drawn. Originally a rigid carborundum pin was used instead of the sand/mica cone to drain water off. Both carborundum and pure sand were abandoned, the latter tending to behave like a rigid body when under pressure from all sides. However, mixtures of sand and mica stay plastic also under confining pressure, so they resist deformations imposed from outside to roughly the same extent as clay.

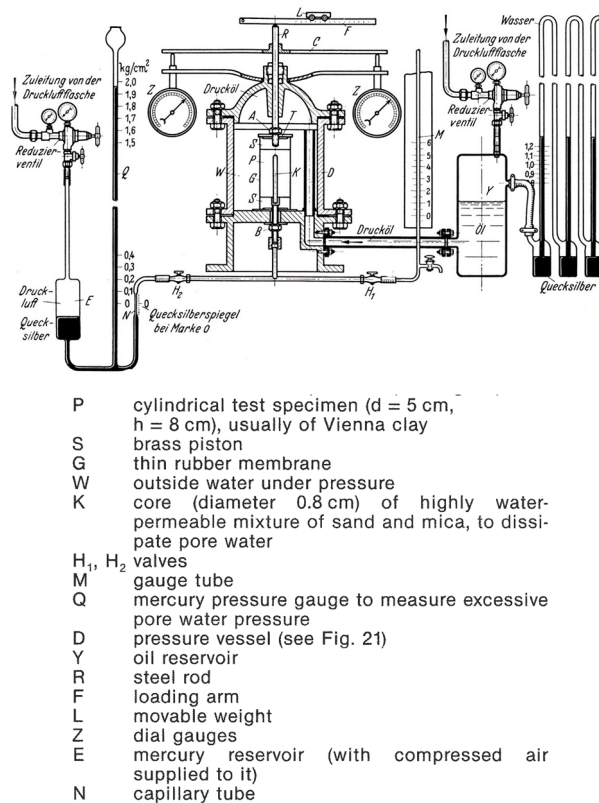


Figure 37. Schematic plan of the test setup for the first triaxial compression apparatus ('oil pressure device') with additional devices to measure pore water pressure and cell pressure (Rendulić, 1937).

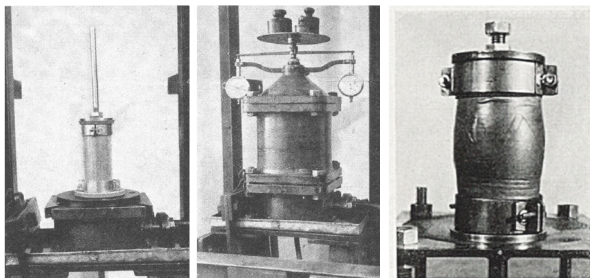


Figure 38. Left: Sample before the test. Middle: Pressure cell during a test. Right: Sample after the test (Rendulić, 1937).

Figure 38 gives an idea of how the samples were carefully prepared and placed into the triaxial apparatus and how the test was conducted. At that time, the load cell was made of solid metal to withstand lateral pressure. As a result, it was not possible to visually observe the deformation of the soil sample

and the process up to of failure. Consequently, the researcher had to rely on the measurement data.

4 SUMMARY

This paper presents the history, development, and scientific significance of the Vienna Terzaghi Archive at TU Wien, established in the original premises of the Soil Mechanics Laboratory founded by Karl Terzaghi. The archive commemorates the origins of modern soil mechanics, marked by Terzaghi's seminal 1925 publication "Erdbaumechanik auf bodenphysikalischer Grundlage" ('Soil mechanics based on soil physics'), and highlights Vienna's central role in the emergence of geotechnical engineering. The initiative to preserve historical laboratory equipment and documents evolved from an earlier proposal to create a museum and was realized through the restoration of the former laboratory rooms and the careful refurbishment of original experimental devices.

In addition to presenting the archive, the paper outlines the life and career of Karl Terzaghi, widely regarded as the father of modern soil mechanics. From his education in Graz and early professional work to his academic appointments in Istanbul, the United States, and Vienna, Terzaghi's research fundamentally transformed the understanding of soil behavior by introducing physically based theories, particularly the principle of effective stresses and consolidation theory. His work laid the foundation for modern geotechnical engineering and influenced laboratories and research worldwide.

The core of the archive consists of restored experimental apparatus developed in the early decades of soil mechanics. Selected exhibits include the compression apparatus (oedometer) developed by Terzaghi and Casagrande, various shear testing devices such as the Krey shear apparatus and its improvements, the Casagrande translational shear apparatus, Hvorslev's ring shear apparatus for investigating long shear paths and post-failure behavior, and early triaxial testing equipment developed by Terzaghi and Rendulić for studying effective stress and pore water pressure. These instruments illustrate the experimental approaches that supported the theoretical advances of the discipline.

By documenting both the historical context and the original testing equipment, the Vienna Terzaghi Archive preserves an important scientific heritage and provides insight into the experimental foundations of soil mechanics, emphasizing Vienna as the birthplace of the field and connecting its origins with the 21st International Conference on Soil Mechanics and Geotechnical Engineering in 2026.



Figure 39. Logo of the 21 ICSMGE 2026 and of the ISSMGE.

5 VISITS TO THE VIENNA TERZAGHI ARCHIVE

Following the official inauguration of the Vienna Terzaghi Archive during the opening ceremony of the 21st International Conference on Soil Mechanics and Geotechnical Engineering (21 ICSMGE 2026) in Vienna on June 15, 2026, the archive is open to the public by appointment. Anyone interested in the history of soil mechanics and geotechnical engineering is cordially invited to visit the birthplace of modern soil mechanics at TU Wien, the workplace of Karl Terzaghi, Arthur Casagrande, and many other renowned researchers in the field. Please contact us in advance by email:

dietmar.adam@tuwien.ac.at

6 ACKNOWLEDGEMENTS

The authors recognize all those who supported the realization of the Vienna Terzaghi Archive from concept to completion. H. Brandl was the one who came up with the idea of preserving these historical artifacts for posterity in a small museum. The ISSMGE leadership welcomed this initiative, first of all W. Van Impe, then Immediate Past President of the ISSMGE, and M. Ballouz, the current President of the ISSMGE.

Despite initial skepticism from the then-administration of TU Wien, approval was granted for the project's implementation. One of the basement rooms, which was part of the original Laboratory of Soil Mechanics, was restored by the Technical Service Department of the TU Wien (TU-GUT) to its original condition and renovated so that the space is suitable for the long-term display of the exhibits now.

The first author expresses his sincere gratitude to his co-authors in particular. The head of the laboratory, R. Markiewicz, was the mastermind behind the realization of the archive. Not only did he take decisive initiatives regarding the restoration of the equipment through his own efforts, but he also drafted the texts and designed and curated the exhibition with the utmost professionalism. In all of this, he was supported by laboratory engineer A. Hausenberger, who contributed significantly to the success of this project with his creativity and original ideas. Both accomplished all of this alongside their regular duties with incredible enthusiasm over several years. Without them, the implementation of the Terzaghi Archive at this high level would not have been possible, for which I owe them a debt of gratitude.

Co-author P. Ebner, head of the TU Wien Archives, supported the project from the very beginning, meticulously searching for documents from the time the institute and laboratory was founded and thus providing us with a fascinating insight into the mindset of Terzaghi and his colleagues in challenging times between the world wars. Thus, an authentic picture of the early days of modern soil mechanics could be formed. I am very grateful to him and his staff.

Finally, it should be noted that all of the work and purchases was carried out without any external funding.

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