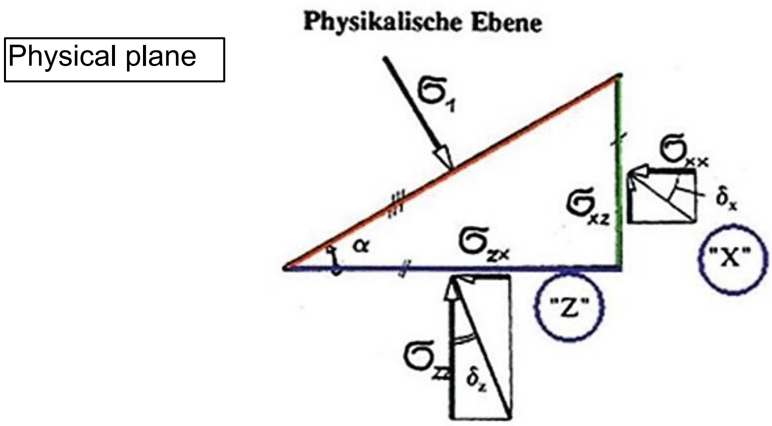
# Soil angle

The writings on current and new earth pressure teachings contain widely differing representations of earth pressure, particularly in regard to its location and intensity. Some of these differences are due to the use of different soil angles and effective deviations from the pure basics of physics when determining earth pressure. These controversies will be examined with reference to the tutorial of the Center for Geotechnology at the Technical University Munich TUM, and to those of the New Earth Pressure Teachings, which are presented on this website.

The angle measurement methods are described in the TUM tutorial under "Scherfestigkeit I" (shear strength I) in I.4, page I.11. The relationship between angle measurement and earth pressure calculation is shown on page 1.5 with Fig. I01.70: Physical plane and Mohr's stress circle.

To be noted is that the devices used to measure shear strength and shear angle always exert a force on the sample, although such a load on the terrain surface is rarely found in free nature. Moreover, it is presumably known in expert circles that undisturbed soil samples for clamping in the test devices can only be taken from max. five soil types. Similarly, what is not taken into account during these measurements is the influence of diverse soil states such as dry, moist, wet, and under water. Consequently, shear angle measurement results obtained with such devices cannot be relevant for all the other soil types.




Further explanations are given in the paper below:
**Soil angle – measurement and evaluation**

*Paper:*

## Soil angle – measurement and evaluation

It will be proven that it is not possible to determine equally valid soil angles and shear properties for all soil types by means of the few measurements carried out in accordance with current teachings using soil samples clamped in devices. For this purpose, visual material and explanations will be presented.

The collective term ”soil” is used in the new earth pressure teachings to describe all soil types, regardless of their origin, e.g. igneous, metamorphic or sedimentary source material, and also for the previous classification according to cohesive and non-cohesive soils. For earth pressure calculation, soils with extreme grain structure, directional fabric, and distribution structure become less important with increasing calculation amounts. Therefore, the term ”soil” covers all bedrocks and their decomposition products down to dust. When soils are loosened or compacted or absorb water, their properties and volumes are changed, thereby creating new soil types. As an extension of the multi-phase system of soil mechanics, and using the volume and weight portions of soils, the new earth pressure teachings show a method to calculate all properties of soils in the dry, moist, and wet states as well as soils under water. Book: 3 Calculation of soil properties, pages 85ff.

In order to make comparisons between the teachings, new symbols and terms have been introduced in the new teachings: Book: pages 21ff.

Particular attention must be given to the soil angles: For a specified calculation height, they determine the values for force area and weight force, as well as the forces and/or earth stresses in the soil body. The following terms are used for soil angle $\theta$, which current teachings measure on soil bodies clamped in a device: slide angle, failure angle, and shear angle. The new teachings combine slide and failure angles into the natural inclination angle $\beta$, and assign a new meaning to the shear angle. Shear angle $s$ is established when soil slides downwards naturally, thereby forming a slope line ($\tan s = \tan \beta / 2$). Moreover, angle $\beta$ changes if a load/force is applied on the terrain surface. The force flow, whether vertical or horizontal, converts angle $\beta$ to $\beta e$ or $\beta e$‘.

For diverting/distributing the load into the adjacent soil, the force must first be converted into an earth column with equal base area and height *he*, which is

calculated by means of the applied weight force divided by the density of the adjacent soil.
Further explanations regarding soil angle, its measurement, location, and influence on earth pressure calculations are provided in the descriptions of the following images.

New teaching, Book: 2.5.3, pages 66ff.

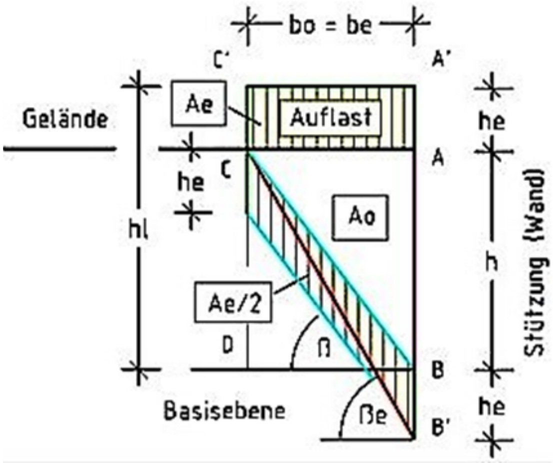



Fig. 30
Force area C-A-B with inclination angle *ß* is modified by the load applied on the terrain surface.

The load, which is marked by area *Ae* in Fig. 30, forms an equally large area in the soil, which is divided into an active and a reactive part. If the load's vertical force dispersal is ensured, the inclination plane under load C-B' with inclination angle *βe* is formed.

New teaching, Book: 2.5.3, page 67

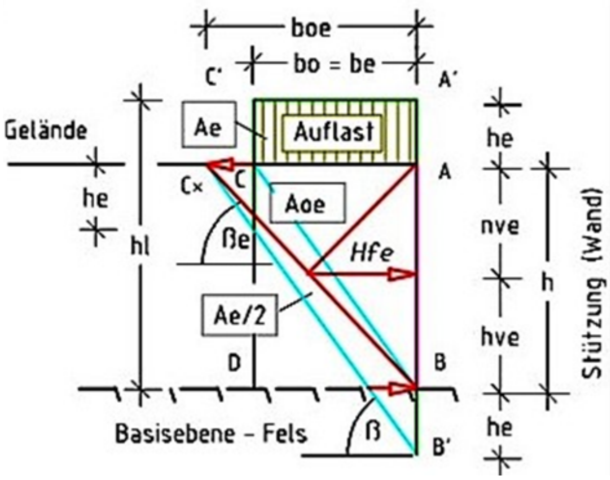



Fig. 31
Force dispersal of the load with impeded vertical force flow, and force diversion in the horizontal direction.

If spreading of the load area *Ae* in the soil below the base plane (point B) is prevented by a barrier layer, load area *Ae* will be extended horizontally up to point $C^X$. This creates the "Inclination plane under load" $C^X$-B with the flattened inclination angle *βe'*.

Angle *βe ≠ βe'*

Also in a concrete sample cube that is put under pressure, the vertical force is converted into horizontal forces.

New teaching – Concise version: 2.12

Fig. 38
Fracture paths in a concrete sample cube

Also in a concrete sample cube that is put under pressure, the vertical force is converted into horizontal forces, resulting in visible fracture paths.

Concise version: 2.12, page 17

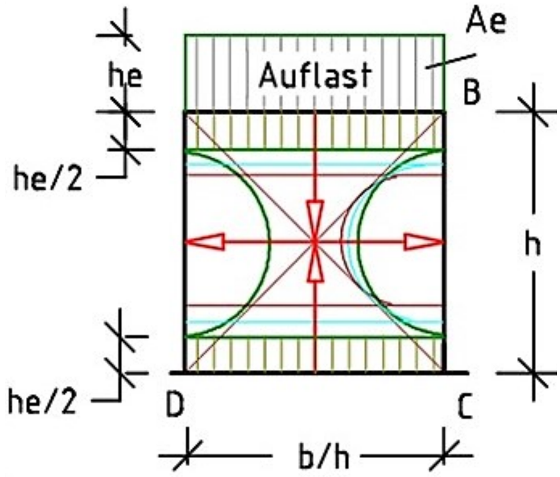
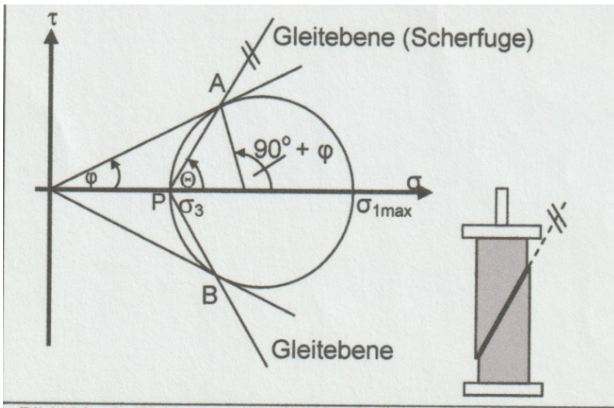



Fig. 39
Initially, the pressure/load builds up vertically, thereby creating the active and reactive force plane with height *he*/2. Subsequently, the surplus force is converted into horizontal forces, which then cause the cube to fracture.

| New teaching, Book: 2.1, pages 49ff. | TMU tutorial: Shear strength 1.6, page I.14f. |
|---|---|
| <br>Fig. 19a<br>Glass cylinder with sand filling<br><br>It should be understandable that similar force paths, as shown in the concrete sample cube, will also occur in a cylindrical body. Based on this assumption, there will hardly be just a "single" fracture plane in the sample body, as suggested by the current teachings in Fig. I06.40. | <br><br>Note:<br>Because vertical force dispersal is impeded in soil bodies clamped in a device, failure angle $\theta$ = ϑ in the sample can only be measured for horizontal force dispersal. Consequently, angle $\theta$ would be identical to inclination angle *βe'*.<br>Fig. 19a gives reason to assume that specified components built into a device will force the shear plane. |

Also the "Deutsche Forschungsgesellschaft for Bodenmechanik" (DEGEBO) at the Technical University Berlin has investigated the topic "Bodenverhalten bei vertikalem Lastauftrag" (soil behaviour under vertical loading), and published the following test set-up in Issue 28, page 122.

DEGEBO Berlin, Issue 28, page 122.

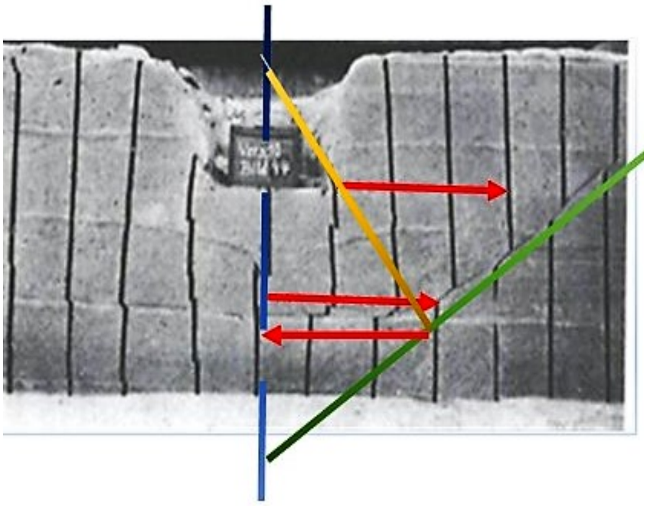


Fig. 01 shows a shallow single foundation in non-cohesive soil, built on a rigid concrete floor.

Also here, the concrete layer impedes the vertical load dispersion into the soil, so that horizontal forces are generated and cause lateral soil shifts.

Earth pressure study: March 2015, 5.5.7, page 19, and Book 2.3, page 55f.

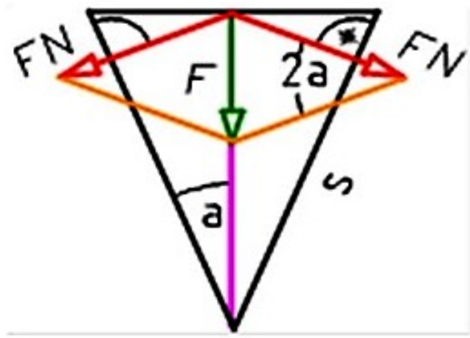



Fig. 26 shows internal forces of the physical wedge with vertical load *F*.

The DEGEBO test set-up and the physical wedge confirm the arrangement of forces, influences, and force conversion previously shown in the figures with impeded vertical force flow.

Apart from the different soil angles, the teachings also use differentiated procedures for the stress distributions. Initially similar, the weight force is determined by means of an earth wedge pointing downwards. While the new teachings retain this wedge shape to determine forces, current teachings use a wedge pointing upwards to verify stresses. Furthermore, they reduce the wedge area by means of a steeper angle.

TMU tutorial: Earth pressure, P.5.3.2, page P.10

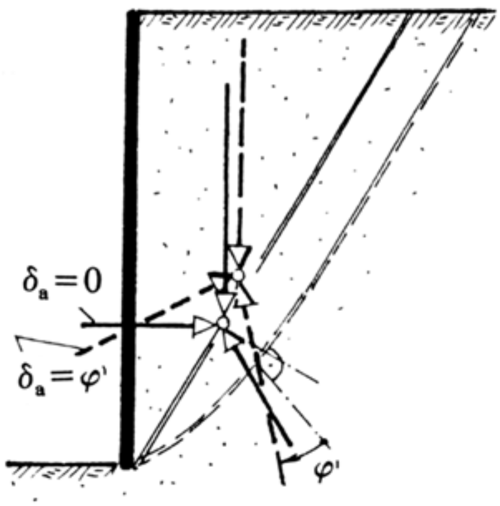



Fig. P05.60
Section and polygon of forces at a single point

Shown is a convex curvature of the fracture area caused by a positive wall rotation, with position and inclination of the earth pressure force in the lower third of the calculation height. Due to the wall's roughness, the wall friction angle $\delta a = \vartheta'$ results, which brings the earth pressure force from the horizontal into the inclined position.

New teaching, Book: 2.6, page 68f.

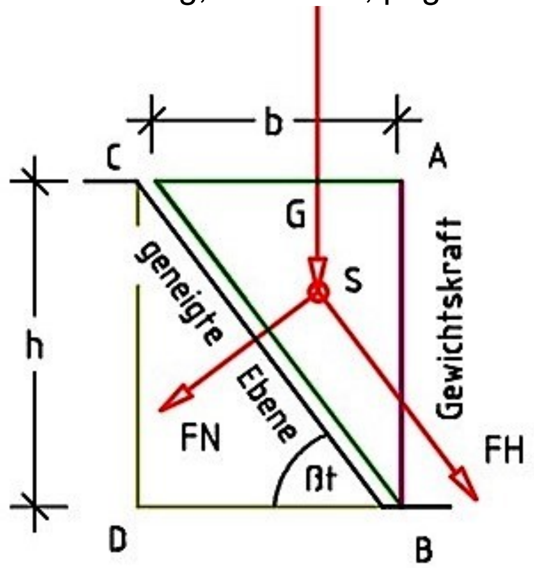



Fig. 32
Earth wedge with weight force *G*, normal force *FN*, and downhill force *FH* applied at the center of gravity S.

The following graphics will demonstrate that when the force is applied at the wedge's center of gravity, a different force diagram than the one shown in Fig. P05.60 results.
The notes below explain wall rotation, friction angle, and incline of the earth pressure force.

**Notes** on Fig. P05.60
Curved fracture planes never occurred in any of the numerous own test setups with dry, moist, and wet soils. Similarly, due to the lack of soil movement behind the wall, it is not possible for wall roughness to generate a wall friction angle $\delta a = \vartheta'$, which could also bring the earth pressure force from the horizontal into the inclined position. The concentration of forces at a single point was investigated in Figs. 32 - 36.
When viewed in a practical context, wall rotation as well as wall tilting, as described in the current teachings, must be seen as construction defects that might be the result of faulty earth pressure calculations.

New teaching, Book: 2.6, page 68f.

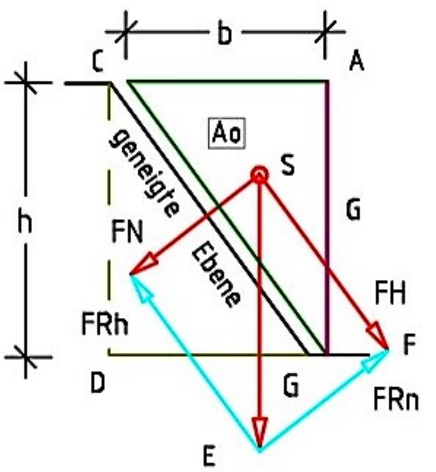



Fig. 33
The parallelogram of forces is formed when *G* is applied below S, and the active and reactive forces of *FN* and *FH* are added.

New teaching, Book: 2.6, page 68f.

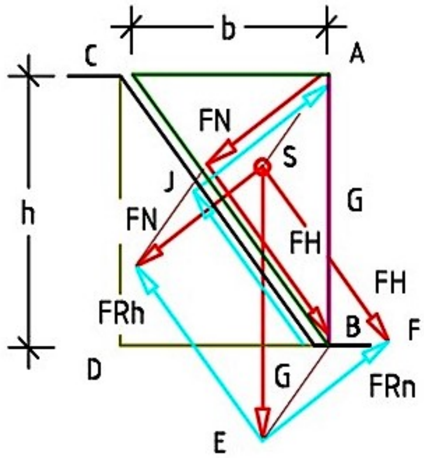



Fig. 34
If force *G* is shifted to plane A-B, also the normal force *FN* and the downhill force *FH* will move to their new positions in the earth wedge.

New teaching, Book: 2.6, page 68f.

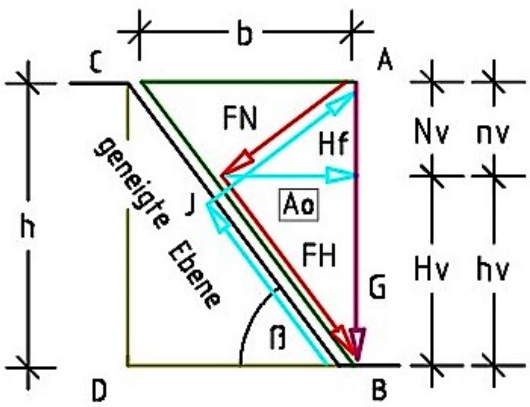



Fig. 35
In earth wedge C-A-B, the active and reactive force directions are assigned to the forces *FN* and *FH* – they are opposed to each other. Active and reactive force directions are combined in earth pressure force *Hf*, and take the same path to the wall that supports the soil.

New teaching, Book: 2.6, page 68f.

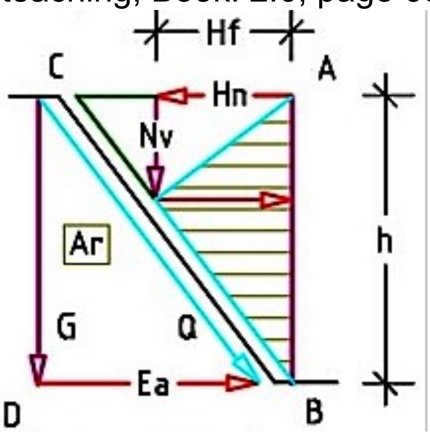



Fig. 36
The weight force from the hatched area with calculation depth *a* corresponds to the vertical force *Hv*. Horizontal force *Hf* can be determined in the same way via the weight force, which is calculated using the wedge area with height *nv* and width *hf* multiplied with soil density.

New teaching, Book: 2.6, page 78.

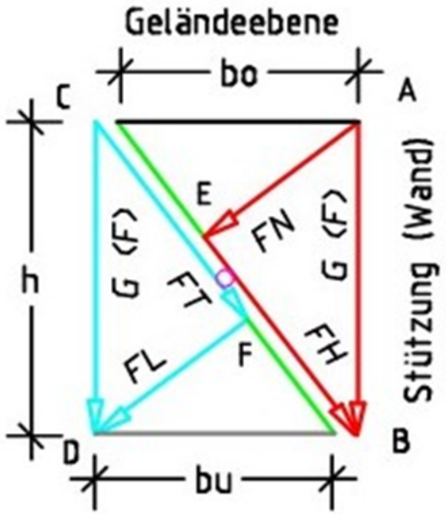



Fig. 41
The new teachings use the term "earth block" for the soil body that is calculated from area C-A-B-D multiplied with calculation depth *a*. Within the block, the active forces are generated above the inclination plane, and the reactive forces in area C-B-D below it.

New teaching, Book: 3.2, page 95.

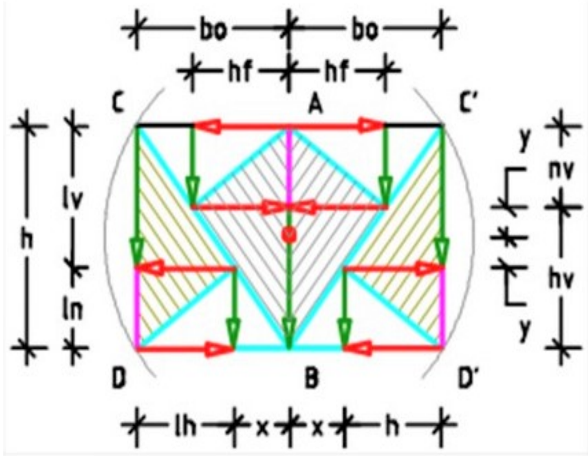



Fig. 53
Shown within a circle are the active and reactive force areas with their dimensions, which can be calculated via the inclination angle *β* of the adjoining soil. In addition, the force directions within the two earth blocks (*bo* • *h* • *a*) indicate the equilibrium of forces. The red dot marks the circle's center.

TMU tutorial: P Earth pressure, page 5.3, page P.10

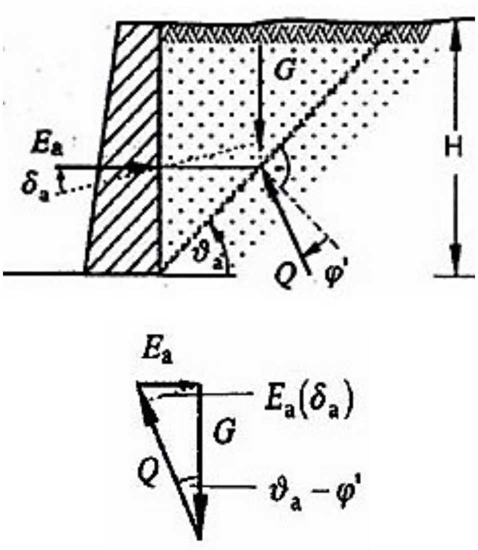



Fig. P05.50
Section and polygon of forces, weight, transverse and earth pressure force at a single point on the fracture plane

Weight force *G* is calculated from the wedge area with height *H* and angle *ϑa*. Earth pressure force *Ea* must be applied equally for all soil types with height *H* / 3.

TMU tutorial: P Earth pressure, page 5.7, page P.14

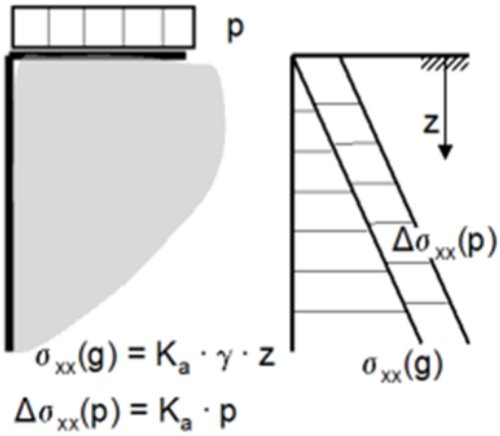



Fig. P05.120
Earth stresses from loaded terrain surface with greatest horizontal earth stress in the base plane.

To calculate the stress, the wedge area shown for calculating the weight force must be changed (Fig. P05.50). The change is made using the specified angle and the vertical reflection of the wedge area. According to this, the greatest horizontal stress occurs in the soil body's base plane.

**Note** on Fig. P05.120
In the writing "Hand-over" – Own test set-up, Fig. 5 – it was proved that no horizontal earth stresses/forces are formed in the base plane of soil bodies against the wall supporting the soil. Consequently, the stipulations of current teachings regarding the position of maximum horizontal stress are likely to be unprovable.

TMU tutorial: Shear strength, page I.5

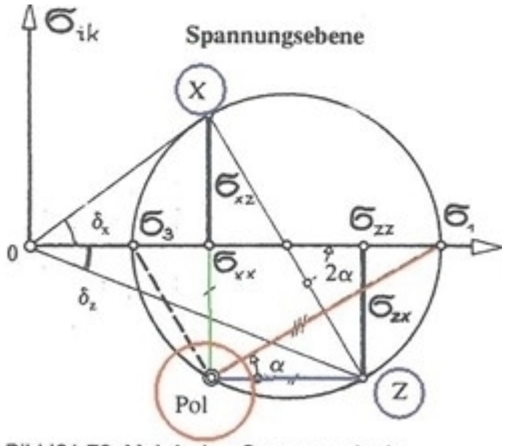
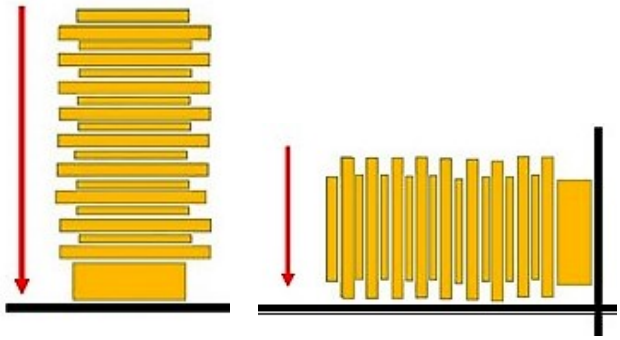



Bild I01.70: Mohr'scher Spannungskreis

The current teachings use Mohr's stress circle to explain the changes in direction of active stresses, including the main stress, as shown in Fig. P05.120.
Under this assumption, the vertical weight force is supposed to be converted into a horizontal force located on the x-axis between stresses *δ1* and *δ3*.

Moreover, stress distribution according to current teachings is countered by the fact that vertical forces or stresses within a body cannot be converted into horizontal forces without external force.



Figs. 402 and 404
The soil pressure under a building obviously changes if the building is tipped onto its side. This example leads to the conclusion that a stress or force conversion using Mohr's stress circle can only lead to faulty results.

## Summary

The aim is to demonstrate to the reader the different approaches for earth pressure calculation according to the current and new earth pressure teachings. For this purpose, graphical material is used and evaluated according to physical basics. Particular attention is given to the main angle, its measurement, and application. It determines the force area's size, weight force, and earth pressure force. Current teachings call this angle "slide angle, failure angle or shear angle"; the new teachings call it "inclination angle".

Previously, the slide angle $\vartheta$ is measured on soil bodies clamped into a device under pressure. Five soil types are declared to be suitable for the preparation of such sample bodies. However, this approach does not take into account the natural soil properties, including the water absorbed by the soil, Fig. 31. Slide angle $\vartheta$ could therefore be compared with inclination angle *βe'*, which only occurs with a loaded terrain surface and simultaneous obstruction of vertical force dispersal due to a barrier layer of concrete or bedrock. Consequently, it would only be permissible to use angle *βe'* for a maximum of 0.1 % of earth pressure calculations carried out. Because current teachings and Eurocode 7 specify the application of slide angle $\vartheta$ for all earth pressure calculations, the results of these calculations can only be faulty.

Just as unrealistic as the specification of slide angle $\vartheta$, is the arrangement of maximum horizontal earth stress/pressure force in the soil body's base plane, Fig. P05.120. The current teachings explain this position with Mohr's stress circle, which is supposed to permit placing the vertical weight force *G* onto the x-axis, where it occupies the distance *δ1* to *δ3*, Fig. I01.70. It is unlikely that any structural engineer will claim that the soil pressure under a high-rise building remains unchanged, if the building is tipped onto its side, Figs. 402 and 404. This should be enough evidence to show that calculation and distribution of earth stresses according to current teachings are absurd.

A further point that leads to faulty results with current earth pressure calculations is the wide range of empiric number values for soil angle, soil properties, and other parameters, which can be freely selected from tables. For tables, see Fig. 1 in writing "Soil characteristics". The huge amount of tabulated values enables characteristics to be selected that provide a more favourable cost framework for the construction project. Similarly, in case of negligence, it also

permits experts to freely attribute fault to one party or the other, i.e. without any factual reference.

The new teachings puts a stop to the free choice of empiric number values, and ensures precise calculation for all soil properties such as density, friction value, inclination angle, shear angle, loadability of soils, and others. These investigations take the properties of soils in the dry, moist, or wet state, and of soils under water into account, as well as the changes that result when soils absorb/disperse water, or are compacted/loosened. Even changing a single soil property creates a new soil type, with its own properties, which means that manipulations with soil properties are impossible.

## Result:

**Calculations of earth pressure according to the specifications of current teachings or Eurocode 7 as well as the corresponding standards and regulations are definitely faulty and can result in structural damage.**

Rework of the following DIN and EN standards is recommended:

DIN 1054 / EC/7, DIN 4020 to DIN 4023, DIN 4030, DIN 18196, DIN 18300, DIN 19682-1+2, DIN 19682-2, DIN 19682-12, DIN EN 1997-1, DIN EN ISO 14688-1, DIN EN ISO 14688-2, DIN EN ISO 14689-1, and others.