3.2 Unbound Mineral Surfaces

3.2.1 DESCRIPTION

Unbound mineral surfaces are water permeable, multi-layer, waterbonded surfaces made of mixtures of minerals.

Figures 3.2.1a to 3.2.1d show different examples of construction in relation to the quality of the subgrade (waterpermeable or non permeable) and of the availability of construction material for the intermediate layers.

3.2.1.1 Important Factors

For an unbound mineral track the essence of a well-keyed and stable construction is the progressive grading and layering of materials, from very coarse at the base to fine on top. Particle shape, which should be angular rather than rounded, helps to ensure a good mechanical bond throughout. The nearer to the surface, the more careful should be the grading.

The majority of unbound mineral athletics tracks are made up of two to three layers:

a) Foundation layer without or with drainage
b) Middle layer(s) of progressively finer material to blind the bottom layer and act as a key to the surface
c) Running surface relying on moisture holding capacity and particle shape and grading for stability

Figure 3.2.1a
Method of construction
Example 1:
Non-permeable
subgrade difficult to work
1 Unbound mineral layer
2 dynamic layer
3 support layer
4 filter layer
5 subgrade
6 drainage

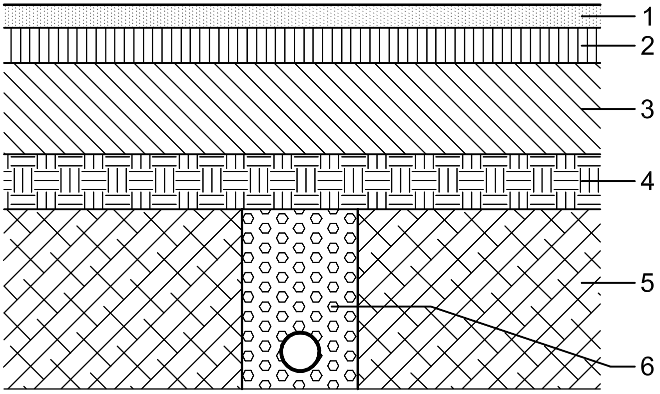


Figure 3.2.1b
Method of construction
Example 2:
Non-permeable subgrade;
lava available as
construction material
1 Unbound mineral layer
2 dynamic layer
3 support layer
4 subgrade
5 drainage

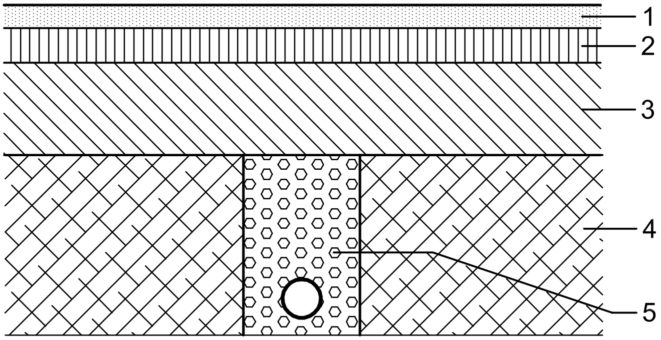


Figure 3.2.1c
Method of construction
Example 3:
Less water-permeable,
load-bearing subgrade;
lava available as
construction material
1 Unbound mineral layer
2 dynamic support layer
3 subgrade
4 drain slit

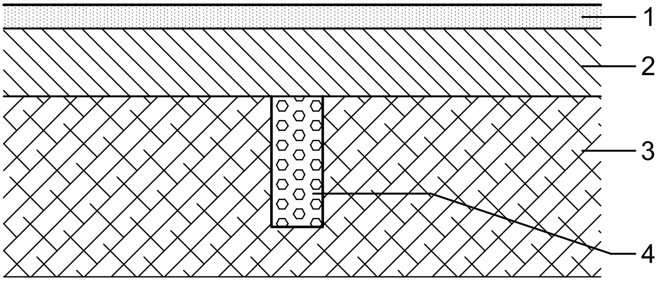
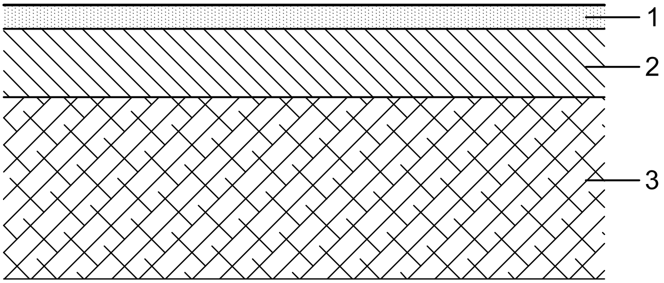


Figure 3.2.1d
Method of construction
Example 4:
Water-permeable,
load-bearing subgrade
1 Unbound mineral layer
2 dynamic support layer
3 subgrade



Although (a) and (b) have much to do with the “feel” of the track, the question of whether a unbound mineral track appears fast or heavy to athletes depends to a large extent on the nature of the actual running surface, e.g. tightness and water content.

It is possible that at some future date the need may arise for an unbound mineral track to be converted to one with a synthetic surface. It is important that it should be so constructed that the conversion can be carried out with the minimum of structural alteration.

To prevent water reaching the track from surrounding areas, it is desirable, wherever possible, for the track to be laid so that no part of its surface is less than 50mm above the finished level of the surrounding ground.

To lay the intermediate and surface layers of the track and maintain the latter properly a copious supply of water is essential. An irrigation system with an adequate water supply is important.

It may be necessary to treat the formation with a total weed killer in accordance with the manufacturers instructions. On ground infested with tap-rooted weeds such as thistle, dandelion and dock, it is imperative that complete elimination should be effected before the foundation is laid.

3.2.1.2 Foundation or Drainage Layer

The material for the foundation of the track and runways should be clean, hard, dry material such as clinker or broken stone, to pass 75mm mesh and be retained on 19mm mesh screens, in even proportions. It should be accurately laid to a uniform depth on a dry and firm formation and firmly consolidated by rolling. The weight of the roller should be just sufficient to wedge the material firmly into place. Too heavy a roller may tend to force the subsoil, particularly if this is clay, up into the filling and so prevent efficient drainage. Also, if the base is too solid it cannot be resilient.

The required depth for the foundation will depend upon the nature of the subsoil and the likelihood of later conversion to a synthetic surface. The minimum recommended depth for an unbound mineral track foundation is 150mm on well drained subsoil. On clay soils, or where conversion to synthetic is a probability, a depth of at least 300mm is generally necessary (See 3.4).

Where the formation is on soft clay, it might be desirable to excavate a further 50 or 75mm and put down a blinding layer of graded stone or clinker ash 19mm gauge to fine, in order to dry up and firm the clay before laying the foundation. Alternatively, a proprietary filter membrane may be used.

3.2.1.3 Intermediate Layers

The purpose of the intermediate layer(s) is to bind the drainage base course and act as a key to the running surface. It should be sufficiently porous to enable water to flow through it during periods of heavy rainfall. Sharp changes in the grading of

materials, particularly in the upper layers, should be avoided as they tend to weaken the mechanical bond between particles and make the surface unstable.
Two or more carefully graded intermediate layers are advantageous from the point of view of improved drainage, stability and resilience. To have only one intermediate layer keeps costs down to a minimum, but cannot provide an optimum construction. If only one layer, this should be of crushed stone, or clinker and ash, graded 19mm to 3mm spread to a consolidated depth of 25mm minimum and well watered and rolled.

The intermediate or blinding layer(s) should be accurately laid either by machine or with the aid of screed strips and straight-edge. Consolidation should be by watering and rolling, a 250kg roller (round edged) across a rolling width of between 600/700mm or its equivalent being sufficient. Except for the first pass, rolling must not take place on a dry surface and must be carried out in transverse directions to avoid waving or rippling. Any hollows apparent after rolling should be scarified and made good with the same material and watered and rolled until a true surface is obtained.

Where there is more than one intermediate layer, the previous layer should be lightly scarified when dry and then dampened, before placing the next layer, so that, when the final rolling takes place, pressure is exerted throughout the entire depth of the structure and a good mechanical bond achieved from the base upwards.

3.2.1.4 Surfacing

The material for the actual running surface should be graded 4.5 or 3mm to fine laid to a consolidated depth of 50mm. Apart from the essential granular texture of the surface, cohesive material should be included, not only to ensure the stability necessary to give the runner a good firm grip with the minimum of surface displacement but also to facilitate maintenance. Care should be taken not to include too great a proportion of cohesive material as this tends to impede surface drainage and makes for heavy going in wet weather. Lack of sufficient binder, on the other hand, is likely to necessitate constant watering in dry weather to prevent rapid disintegration when in use, and wasteful dispersal of the surface material in the form of windblown dust. To obtain the right balance, a careful selection of material is necessary.

Although an approximate ratio for the mixing of materials can be suggested as a guide, it is not advisable to attempt to lay down specific proportions as a standard for all tracks. Not only do climatic conditions vary considerably in different countries, but the properties of the materials available differ greatly according to the source of supply. The use of a proprietary surface should therefore be considered.

The granular materials commonly used in the composition of the running surface include crushed granite or limestone and occasionally hard clinker ash (when available). Other material such as blaes and shale from colliery tips can also be used, provided the particles are sufficiently hard and well shaped. Particles in laminated form are not suitable. A well-balanced mixture should not only bind well, hold moisture and retain resilience, but never get sticky in any weather. It is important that all cohesive substances used should be thoroughly mixed with the granular materials.

Mixtures found to give satisfactory results are:

a) 50-75% of a good binding ash, mixed with 25-50% hard fine ash, crushed limestone or suitable crushed rock
b) Hard fine ash and crushed granite or limestone (ratio approx. 50:50) and binder
c) Crushed granite or limestone and binder
d) Hard fine ash and binder
e) Burnt red shale (blaes) and binder
f) An appropriate proprietary material

When considering the choice of surface, the availability of local materials should be considered. For colouring effect brick dust may be applied to the surface. The surface should be laid as described earlier for the intermediate layer(s). It is important that immediately prior to laying the surface, the previous section is lightly scarified when dry and then damped to provide a good key. Special care must be taken to ensure that the surface is evenly laid to a uniform depth when compaction is complete. The final consolidation of the track should be carried out with a heavier roller of about 600kg across a rolling width of 900mm. Constant rolling with this, accompanied by copious watering for at least a week, should help to firm the track ready for handing over. It does, however, take some time of use and maintenance to create the right surface. On no account should rolling be carried out on a dry surface.

3.2.1.5 Runways

The construction of the edging, foundation and surfacing for the runways should be similar to that of the track except that the surface material on take-off areas should be given special treatment in order to counter the excessive wear and tear from spikes and help to keep the surface firm during use. This may be done by increasing the depth of the surface layer (and the formation) by about 25mm and increasing the proportion of cohesive material in the mixture by doubling the quantity of clay or marl. The treatment should apply to the last 3m before the take-off for the long jump, triple/jump, pole vault, the last 6m before the javelin scratch line and the final 3m of the high jump fan.

On clay soils, underdrainage with outfall to the perimeter drainage system may be necessary to prevent flooding.

The edging to the pole vault runway should be flush with the runway surface for the final 6m and for the javelin 3m.

3.2.1.6 Steeplechase

The running surface and foundation immediately before and after the water jump should be on the same level and to the same specification as the track foundation and surface. If the water jump is situated on the inside of the track, the edging where the steeplechase track leaves and rejoins the main track must be removable. As for the runways to the jumps, the special surface treatment described in the previous section should be given to the final 3m of the approach to the water jump to ensure a firm surface during use.

3.2.1.7 Supervision

It is emphasised that a good specification does not necessarily result in a good job unless the work is efficiently supervised. Whether carried out by contract or direct labour, the work should be planned and directed by somebody with specialised knowledge of track construction. In the case of contract work, the employer's engineer, surveyor, architect or landscape architect should exercise close supervision to ensure that all the operations are carefully carried out in accordance with the specification. Each stage of the work should be aproved by him before the next stage is allowed to proceed.

The person in charge should be capable of correctly interpreting the specification and it is essential that they should have had previous experience of track construction. Faulty workmanship or materials, or wrong methods, cannot be rectified after the track has been made except at considerable expense. There is no doubt that extra trouble taken at the time of construction can do much to avoid maintenance difficulties later on and to keep down the annual cost of upkeep.

3.2.2 PERFORMANCE REQUIREMENTS

3.2.2.1 Introduction

These guidelines for the requirements for sport surfaces with unbound mineral surfaces are intended to provide a uniform interpretation of the concepts, the creation of clearly defined requirements and the preconditions for their testing. The criteria are based on the one hand on national standards, and on the other, on internationally recognised values established by experience. They are recommendations for planning and construction but are also the framework for national standards.

These requirements are based on aspects relating to safety, playing performance and to the technical characteristics of the material. The intention of the safety performance is to offer optimum prevention of injury and consequential damage. The playing performance is aimed at providing the best possible application of the different techniques of each individual sport, distinguishing between championship and casual sport.

These guidelines describe the current state of the art in order to ensure that further development of sports surfaces is not inhibited. Deviations are possible in the course of time and may even be necessary. In such cases it is necessary to check that the intended deviations do in fact represent improvements in the safety and playing performance and in the technical characteristics of the material.

Keeping to the guidelines alone is no guarantee for the success of the design and does not exclude the liability of the planner and installer. The construction of a durably flawless sports surface requires sufficient experience and continuous quality control during manufacture.
For the planning and construction, local conditions (climate, substratum, available materials) must be taken into account as well as the special requirements of the sports facility.

3.2.2.2 Properties Pertaining to Protection and Sport Functions

a) *Protection and sport functions*

Safety aspects are understood to be the properties of a sports surface which reduce the danger of injury from a fall and which relieve the strain on the biomechanism of the athlete when running or jumping. Sports aspects are the properties of the sports surface which contribute to the best possible application of the techniques of the different sports by the most economic utilisation of the energy expended by the athlete.

b) *Resilience*

Resilience is the deformation of a sports surface under load. The degree of deformation depends on the particle shape, the particle size distribution and the water content of the surface. The resilience is achieved when the sports surface complies with the requirements for these various parameters.

c) Slope formation, flatness and nominal height requirement

Slope: For athletics tracks and runways, the slopes should be in accordance with the competition regulations.

Flatness: Deviation under a 4m straightedge may not exceed 10mm.

Nominal height: Deviation may not exceed 5mm.

Note: The individual layers of the sports surface above the subsoil must be produced with the same slope.

3.2.2.3 Material Properties

a) *Particle size distribution*

On running tracks the grading curve of the surface material shall be between the limiting grading curves according to figure 3.2.2.3. If it is outside these, the following percentages shall not be exceeded:
Particle fraction = 3.15mm and larger, maximum 5% by weight
Particle fraction = 0.02mm and smaller, maximum 16% by weight

b) *Water permeability*

The surface material shall have a minimum water permeability of 0.06 mm/min for 0 - 3mm particle mixture.

c) *Wear*

The surface material shall be highly resistant to wear. When determining the wear resistance, using the method of test described in 3.2.3.3.3 (Method of Test for Abrasion), the area beneath the limiting particle curve shall be at least 70% of the initial value.

d) *Weathering resistance*

The surface material shall be highly resistant to weathering. When determining resistance to weathering, using the method of test described in 3.2.3.3.4 (Method of Test for Resistance to Frost), the area beneath the limiting particle curve shall be at least 95% of the initial value.

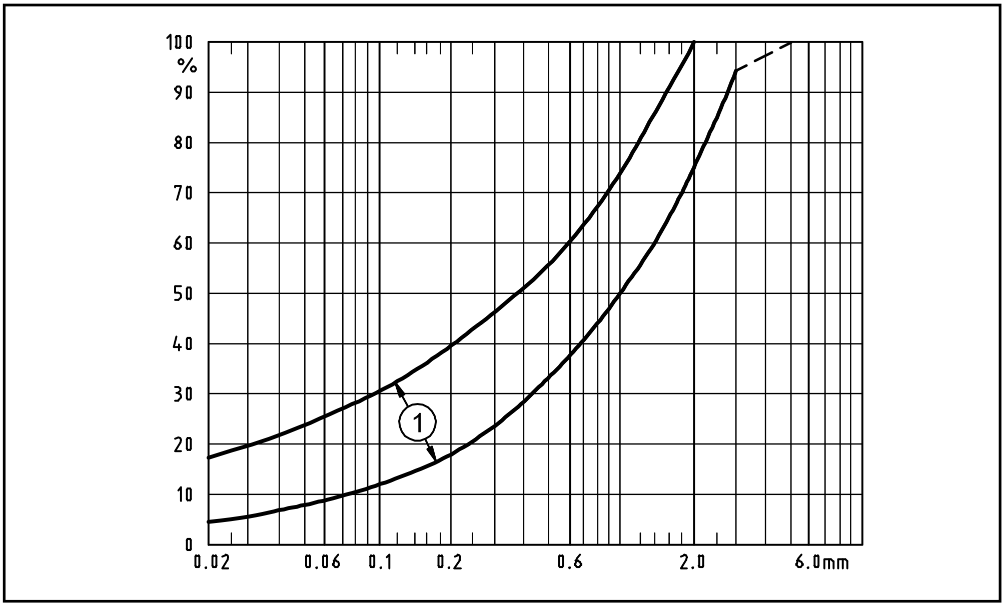


Figure 3.2.2.3 - Particle distribution limits for unbound mineral surface materials
1 Limiting particle curves

e) Surface shear resistance

Surface shear resistance is the resistance of the surface to the shear stress from its use in sport. The surface shear resistance shall reach a minimum value of 50kN/m^2.

f) Contents of pollutants

The content of pollutants shall not exceed the values stipulated in national regulations.

3.2.2.4 General

a) Tendering, placing of order, execution and acceptance

The following points are recommended as preventive measures by the customer to avoid incurring damage to the sports surface.

- Preliminary examination of the construction ground
- Observing the rules for tendering, placing of order, execution and acceptance
- Checking the qualifications of the supplier before placing the order
- Tendering for the sports surface including substrate and foundation as a package
- Placing of order in general for surface, substrate and foundation with a single installer
- Storage of retained samples in a suitable location
- Retention of the test certificates of the supplier as well as the tender and order documents

b) Utilisation

For the retention of the optimum water content it is generally necessary to provide irrigation systems depending on the precipitation conditions at the respective location. “Pop-up” installations are recommended. The water should contain as few insoluble mineral components (e.g. iron) as possible.

c) Marking

The markings must be made in accordance with the regulations of the IAAF.
The marking materials to be used may be in powder form, dissolved colours or plastic profiles. The marking agents shall not have an etching effect and they shall not alter the sports function of the surface.

d) Inspection and maintenance

Regular inspection and maintenance of surfaces is necessary to maintain their properties. As a rule the following maintenance work is necessary:

- Levelling the surface with a levelling frame or screen after every intensive use to re-establish the flatness (Before this operation the worn surface areas must be filled in with moist material by hand and compacted.)
- Irrigation if the surface is too dry (Care must be taken to prevent material being washed away. During prolonged dry periods a soaking irrigation of 20 litres/m^2 is necessary over a period of 10 to 18 hours.)
- Maintaining the compactness of the surface by occasional rolling (On overused surfaces after the levelling operation or after the effect of frost.)
- Maintaining the grain composition by mixing the surface with a spiked harrow or other revolving implement while protecting the dynamic layer
- Removing hollows or bumps in the surface

Depending on the frequency of use, surfaces have to be skimmed, levelled and rolled. Overused areas must be corrected by the addition of material. With regard to water permeability a constant check must be made on changes in the proportion of fine particles as a result of wear and the effect of the climate.

3.2.3 TESTING

3.2.3.1 Support Layer

3.2.3.1.1 Method of Test for Water Permeability

a) Apparatus (Fig 3.2.3.1.1a)

- Test cylinder with a diameter of 150mm with slip-on ring, bottom plate and steel plate
- Counterfloor (Fig 3.2.3.1.1b)
- Sintered bronze filter plate, SIKA B 200, 200 mm in diameter and with a thickness of 4mm
- Compression device with a drop weight of 4.5 kg and a drop height of 450mm.
- Stop watch
- Metal ring approx. 40mm in diameter to which two test prods are fastened perpendicular to its level (Length of the test prods above the test surface shall be 55mm and 45mm.)
- Weighing scales with an error margin of ±1.0g
- Vessel with a diameter of ±400mm and a height of ±150

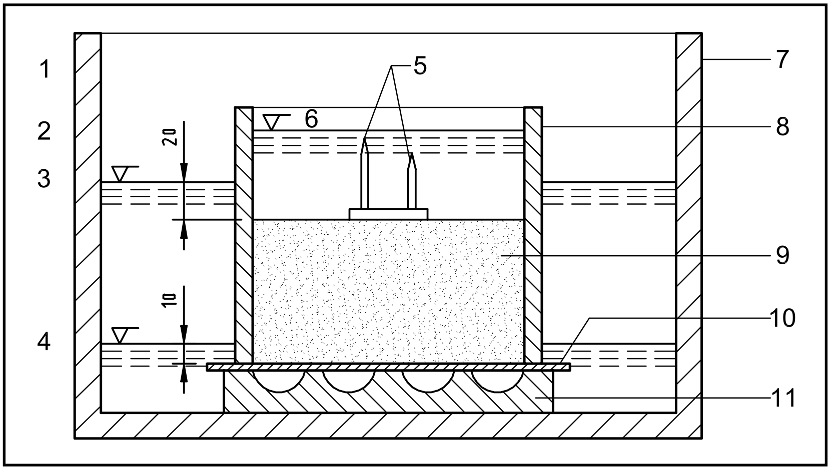


Figure 3.2.3.1.1a Method of test for water permeability
(Measurements in mm)

1 External water level
2 position C
3 position B
4 position A
5 test prods
6 internal water level
7 vessel
8 test cylinder
9 test piece at height h
10filter plate
11support for the filter plate

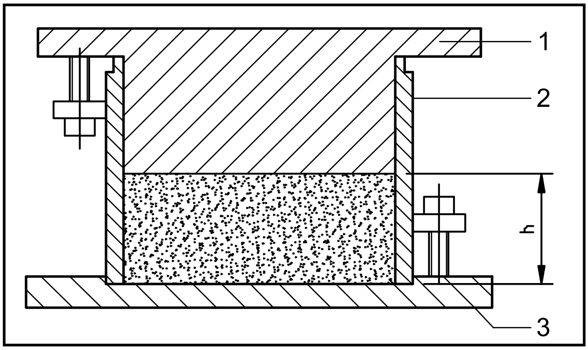


Figure 3.2.3.1.1b Method of test for water permeability, counterfloor for swaying the test

1 Counterfloor
2 cylinder for proctor test
3 bottom plate

b) Test Procedure

Prior to testing remove all granules with a diameter of d>22mm from the sample and ascertain proctor values from the granule mixture 0/22 mm in the form of reference values.

Prepare the test piece as instructed under Section 3.2.3.3.1 b. Place test piece with a water content of w=0.7 WPr into the test cylinder and compress to Q=0.95 Qr±0.02g/cm^3. To do this, place the steel plate, on which the impacts of the compressor are evenly distributed, onto the surface of the uncompressed test piece. Select the quantity required so that after compression the height of the layer amounts to 60 mm. Calculate the quantity required for this on the basis of the following formula:

$$Gn = 0.95\ QPr\ \left(1 + 0.7\ \frac{WPr}{100}\right) x\ h\ x\ A$$

where: Gn = weight of the wet sample in g
QPr = Proctor density in g/cm^3
WPr = optimum water content in %
A = area of compressed sample in cm^2
h = height of compressed test piece measured in cm

After compression, place the counterfloor on top, turn the test cylinder, remove the floor plate and replace with the filter plate. Turn the test cylinder again and place into the vessel. Fill the vessel with water until a level of 20mm above the surface of the compressed test piece is attained outside the test cylinder (external water level, water level position B). When a water level has formed on the test piece surface, place the ring with the test prods onto this, taking care to avoid any scouring, fill the test cylinder with water until the test prods are covered with water (internal water level, water level position C). After this, drain the water from the vessel until the external water level has sunk to a height of 10mm above the filter plate (water level position A) at which it is held constantly. The internal water level must be kept at the height of the top test prod until the measurement is taken. Measure in seconds the time it takes for the internal water level to drop from the top to the lower test prod. For each test three readings are required.

c) Results

The water permeability is expressed in terms of k*. It is calculated by the following formula:

$$k^* = \frac{\Delta h}{t} \times \frac{h}{h + 4.0}$$

where: k* = water absorption factor in cm/s

Δh = difference in water levels between the test prods measured in cms

t = time it takes for the water level to drop between the test prods measured in seconds

h = height of compressed test piece measured in cm

Note the mean value of three tests.

3.2.3.2 Dynamic Layer

3.2.3.2.1 Method of Test for Water Permeability

The test shall be carried out as instructed under Section 3.2.3.1. Select the quantity required so that after compression the height of the layer amounts to 60mm.

3.2.3.2.2 Method of Test for Shearing Resistance

a) Apparatus (Fig 3.2.3.2.2a to 3.2.3.2.2c)

Shearing resistance device, consisting of:

- Torque spanner or shear force transducer with indicator (calibrated) (A suitable motor operated apparatus for measuring the moment of torsion may also be used.)
- Yoke
- Holding device
- 121mm diameter shear plate, weighing 1.5 kg with 8 spikes of 18mm in length (Fig 3.2.3.2.2b)
- 250mm diameter test cylinder with bottom plate and steel plate

Compression device with a drop weight of 15 kg and a drop height of 600 mm.
Built-in gauge (Fig 3.2.3.2.2c)
Indenter approx. 100 mm in diameter
Wooden ram approx. 250 g in weight
Weighing scales with an error margin of ±1.0 g

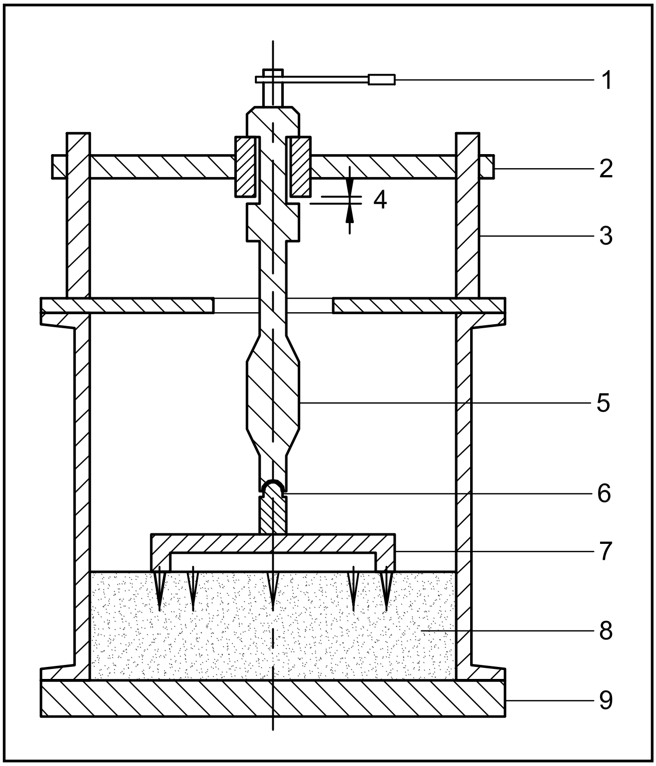
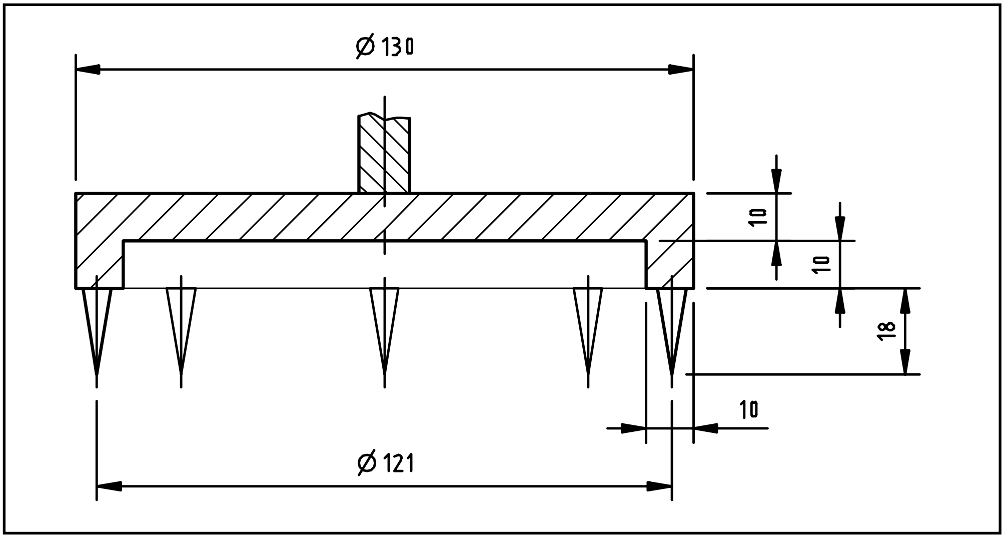


Figure 3.2.3.2.2a - Method of test for shearing resistance
(Test appliance)
1 Torque spanner
2 yoke
3 holding device
4 opening, 0.3mm to 0.5mm
5 shaft possibly with instrument for measuring torsion
6 joint with torsion-proof connection
7 shearing plate after pressing in
8 test piece
9 test cylinder

Figure 3.2.3.2.2b - Measurements for the shear plate
(Measurements in mm)



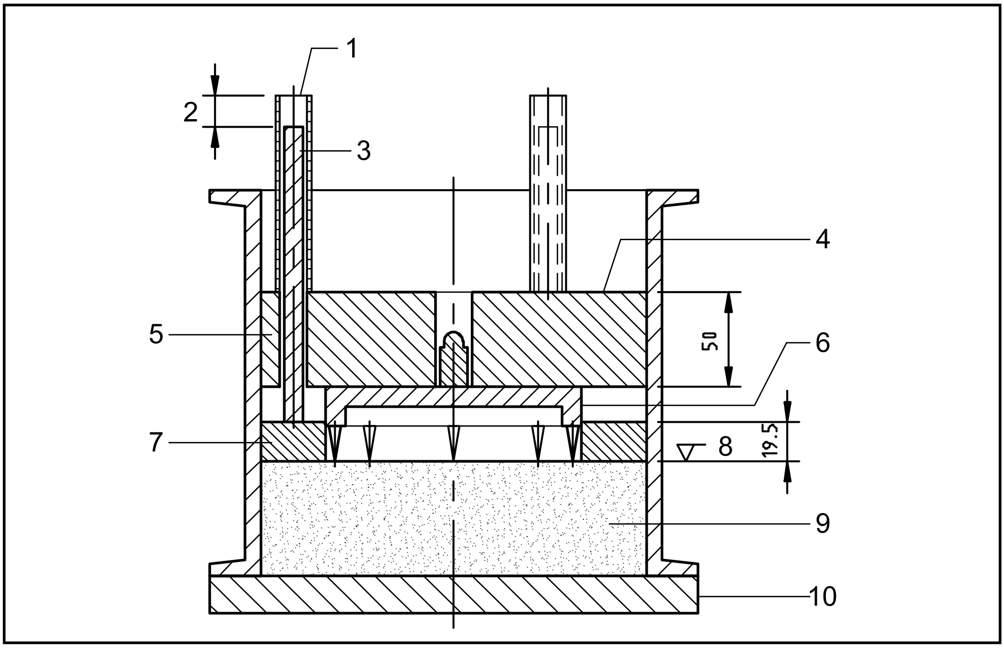


Figure 3.2.3.2.2c - Built-in gauge for the surface shearing device
(Measurements in mm)

1 Tube (copper - zinc -plating)
2 depth of penetration of the shearing plate
3 guide bolts, 3 pcs. displaced by 120°
4 surface of the built-in gauge for hammering and pressing
5 top part of built-in gauge
6 shearing plate prior to pressing in
7 lower part of built-in gauge
8 test piece surface
9 inserted test piece
10 test cylinder

b) Procedure

Moisten the test piece until it has a water content of W = 0.7.WPr and compress in the test cylinder to Qd = QPr. To do this place the test piece in one position, distribute uniformly and evenly and gently press down with an indenter. Then place the steel plate, on which the impacts of the compression device are evenly distributed, onto the surface of the uncompressed test piece. Select the quantity so that after compression the height of the layer is 60mm. Calculate the quantity required for this by using the following formula:

$$Gn = QPr\,(1 + 0.7\,\frac{WPr}{100}) \times h \times A$$

where: Gn = moisture content of the test piece in g
QPr = Proctor thickness in g/cm^3
WPr = optimum water content in %
h = height of compressed test piece in cm
A = area of compressed test piece in cm^2

After compression, turn the steel plate and lift off. Remove any granules which may be lying loose on the test piece. Then insert the lower part of the built-in gauge and the shear plate attached to its recess. Finally, place the upper part of the built-in gauge on top. Apply manual pressure to the upper part causing the spikes to penetrate the test piece. By hammering gently in addition with the wooden ram, the upper part, and hence the shear plate, are driven down until the guide bolts of the lower part are flush with the copper tubes of the upper part.

Remove the built-in gauge and mount the holding device with yoke and measuring apparatus and connect to the shear plate (Fig. 3.2.3.2.2b).

The shear plate may not be subjected to any additional vertical load. Therefore, prior to shearing off, a vertical means of escape of 0.3 mm to 0.5 mm must be available for the shear plate. Rotate the shear plate with the torque spanner evenly so that after one second the moment of torsion corresponds to a shearing tension of $Ts = 50\ kN/m^2$. Maintain this load constantly for 2 s and then increase steadily up until breaking point. Record the maximum moment of torsion.

A minimum of three tests must be conducted. The test piece may not be used repeatedly. Record the mean reading of three tests.

c) Results

Calculate the shearing resistance of the surface using the following formula:

$$Ts = \frac{Mmax}{\pi \frac{D^2}{2} (H + \frac{D}{8})}$$

where: T_S = shearing resistance in kNm^2.
M_{max} = maximum moment of torsion in kNm^2, whereby the bearing friction must be deducted from the reading
D = diameter of the shear plate in mm
H = length of the spikes in mm

3.2.3.2.3 Method of Test for Abrasion

a) Apparatus

Abrader 150 mm diameter test cylinder with slip-on ring, base plate and steel plate
Compression device with a drop weight of 4.5.kg and a drop height of 450 mm
Apparatus for dry sieving Weighing scales with an error margin of ±1.0 g

b) Test Procedure

In all, 16kg of test material is required for the test. Add sufficient water until the water content for the whole material reaches 0.7WPr. Then divide the test material into two parts weighing approx. 6 kg each for the abrasion tests and one part of approx. 4kg. in weight to determine the base granulation line.

Fill the test cylinder with one part in three layers of uniform thickness. Select a height for the layers so that the test cylinder is filled by the compressed material and any projection of not more than 10mm extends into the slip-on ring. Compress each layer with 22 impacts from the compressor.
To do this, place the steel plate, onto which the impacts of the compression device are evenly distributed, onto the surface of the uncompressed test piece.
After compression, remove the vessel and mix the extracted material well with the remaining test piece. Conduct this procedure five times in all.
Finally, wash the test piece over the 0.125 mm sieve, dry and mechanically sieve for a duration 10 minutes to establish the grain size distribution.
The test must be conducted on at least one further test piece of 6 kg in weight, Also wash the uncompressed material over a 0.125 mm sieve, dry and sieve to determine the base granulation line (mechanical sieving for duration of 10min).

c) Results

The tests will produce 1 grain size distribution in its initial state and 2 grain size distributions after compression. Calculate the differences between the proportions of the base granulation line and those after the test load. This will also produce the grain sizes for which the greatest differences have been established. Record the mean of three differences to establish the resistance to abrasion. This will be found among the grain sizes with the largest difference in proportions and among the neighbouring grain sizes.

3.2.3.3 Unbound Mineral Surface

3.2.3.3.1 Method of Test for Water Permeability

a) Apparatus

Compression device (Fig 3.2.3.3.1), consisting of:

- Frame with dial gauge holder
- Supports
- Compression apparatus with a drop weight of 2.5 kg and a drop height of 300mm, the base of which is spread to a diameter of 70mm
- Dial gauge, graduated to scale 0.01mm
- Acrylic glass cylinder with an internal diameter of approximately 70mm and a height of ±100mm; which may be used at each end for a maximum of 10 times.
- Sintered bronze filter plate, SIKA B 200, 100mm in diameter and 4mm thick

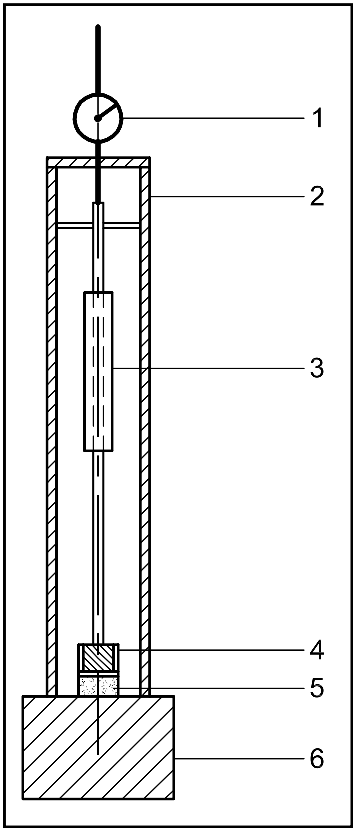


Figure 3.2.3.3.1
Method of test for water permeability
1 Dial indicator
2 ram frame
3 drop weight
4 acrylic glass cylinder
5 test piece
6 support

Stop Watch
Metal ring of approx. 40mm diameter, on which two test prods are attached perpendicular to its plane; length of the test prods above the surface of the test piece 55mm and 45mm
Weighing scales with an error margin of ±0.1g
Vessel of ±200mm diameter and ±110mm height
Pippette with a nominal volume approx. 25cm^3
Air tight container with 5000cm^3 content
Spray bottle
Stirring apparatus with 100 to 250 revolutions/min; stirring tools must ensure a minimum possible fragmentation of grains.
Rubber roller, Shore-A-Hardness 60 to 80.
Apparatus for determining the content of water

b) Preparation of Test Piece

b.1) Types of Test Pieces

A distinction must be made in the test between the following types of test pieces:

a) building materials in unprocessed state, not previously subjected to compression
b) building materials already installed in tamped surfaces and subjected to compression.

In the event of case a), dry preparation as instructed below in b.2) will only be required, whereas for case b), a structural preparation as described below in b.3) will be needed.

b.2) Dry Preparation

Dry the approx. 4000 g test piece which will be used to determine the water permeability at a temperature of 70°C until a constant weight is attained and then moisten to 0.7 WPr. To do this, place the test piece into a stirring apparatus, the container of which shall be moistened beforehand with a sponge, and mix with the quantity of water required. The quantity of water required is applied using a spray bottle, whereby the quantity of water may not exceed 60 g/min. After moistening, remove the test piece from the apparatus and from this sever a part of the sample in order to record the water content. Pack the main test piece air-tight and store for a minimum of 16 hours; record the water content of the severed sample.

Store the main test piece for a further 16 hours. As soon as the actual water content reaches a level which is distinguishable from the target value by no more than W=0.5%, the main test piece can be used for producing the test sample. The quantity of material required for this Gn is calculated on the basis of the precise dimensions of the apparatus and the fixed data.
Dimensions of the acrylic glass cylinder:
D = Diameter in cm
h = Height of compressed test piece = 40mm
W_e = Test water content 0.7 WPr +/- 0.5%

Fixed data:

= Proctor thicknesses in g/cm^3
= Optimum water content in %

$$Gn = Q_{Pr}\ (1+\frac{We}{100})\cdot h\,\frac{D2}{4}\ \cdot\pi \text{ in g}$$

Remove three test samples G_n from the main test piece according to weight and place in air-tight containers ready to be manufactured into test samples. Clamp the acrylic glass cylinder into a frame (Fig. 3.2.3.3.1). Before filling with the test substance, moisten all surfaces which will come into contact with this with a damp sponge.

b.3) Structural Preparation

Divide the samples into the grain groups > 0.5mm and < 0.5mm by washing in a sieve with a mesh width of 0.5mm. The siftings (< 0.5mm) are concentrated by filters, dried at 60°C to 70°C and finally crushed so finely that they can pass through the 0.63mm sieve. A rubber roller serves this purpose well.

The grain group >0.5mm is also dried at 60°C to 70°C after which it is mixed with the dried and crushed grain group < 0.5.mm and moistened evenly to a water content of W = 0.7 WPr. The water must be applied by spraying. After the water has been added, store the test piece air-tight for a minimum period of 16 hours until it is ready for use for the water permeability test.

For material prepared in this way, the grain size distribution is determined by means of wet sieving. The content of fine parts < 0.063mm may not deviate by more than 2% from the corresponding value for the untreated material.

c) Manufacture of Test Specimen

Divide the sample for a test piece into four approximately equal parts and fill one after the other evenly into the sample mould, level out and press down using a wooden stamper. Before placing the compression device, make sure that the thickness of the test piece is homogenous; its surface shall be horizontal and even.

For the compression, place the filled test mould onto a base with at least 50 kg of mass. Prior to compression determine the original height of the uncompressed test piece; afterwards, compress the test piece until the required end height has been acquired (40 ±0.05) mm.

d) Method of Test

Once the test piece has been compressed, remove the acrylic glass cylinder from the compression device and place onto the filter plate which has been saturated with deaerated water and place into the vessel described previously (Fig 3.2.3.3.1). This is then filled within a period of 8 to 10min. with deaerated water so that the external water level lies 20mm above the surface of the test piece (water level position B). The test piece must remain in this condition for a minimum period of 16 hours. Place the ring with the test prods onto the surface of the test piece and fill the acrylic glass cylinder with deaerated water until the test prods are sufficiently covered (water level position C). Keep the water level at this height until measurement. A method of test using suspended prods is permissible.

Lower the external water level (water level position B) to a height of 10mm above the filter plater (water level positon A) and keep constant. Then record the time in full it takes for the internal water level to drop from the top to the lower test prod. The water must have a temperature of (20 ±2)°C.

Take this reading at least three times per test and record the mean value. At least three tests are required.

e) Results

The water permeability is expressed in terms of the water absorption k*. It is calculated by the following formula:

$$k^* = \frac{\Delta h}{t} . \frac{h}{h + 4.0}$$

where: k^* = water absorption factor in cm/s
Δh = difference in water levels between the test prods measured in cms
t = time it takes for the water level to drop between the test prods measured in seconds
h = height of compressed test piece measured in cm

3.2.3.3.2 Method of Test for Shearing Resistance of the Surface

See 3.2.3.2.2.

3.2.3.3.3 Method of Test for Abrasion

a) Apparatus

Abrasion device, consisting of:

- Abrasion testing machine with horizontal-eccentric rotation on 4 rubber metal connections of types A, B or C, 40mm in diameter, 30mm in height, Shore-A-hardness 55, suspended and attached to a rigid concrete abutment, 15mm eccentricity, 300 revolutions/min
- Steel plate with a diameter of 148mm and 16mm thick, with rounded edges r =1mm, made of hardened steel.

Cylindrical shell of hardened steel (Fig 3.2.3.3.3)
5 test sieves with a mesh width of 0.09mm, 0.125mm, 0.25mm, 0.71mm and 2.0mm Weighing scales with an error margin of ±0.1g

b) Test Procedure

First wash the building material in the 0.09mm sieve. Dry the sieve retainings, divide by means of mechanical sieving (duration of 10min) into individual grain groups and then compose into test specimens in compliance with the Table 3.2.3.3.3:

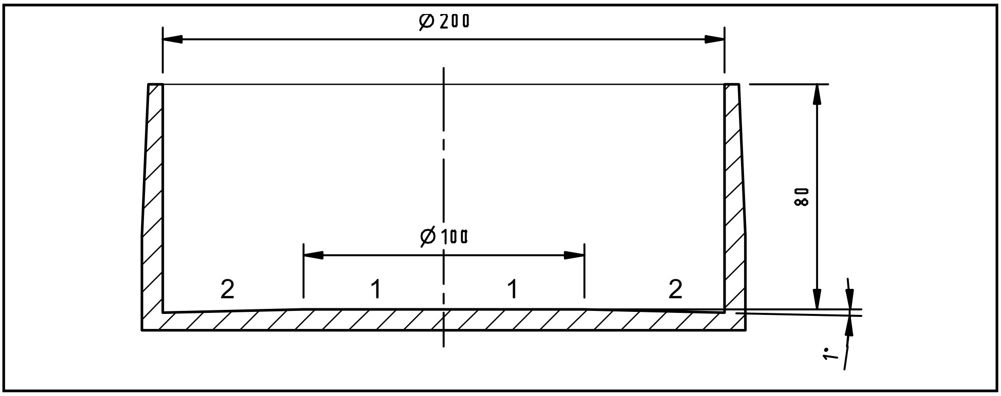


Figure 3.2.3.3.3 - Cylindrical shell of abrading device (Measurements in mm)
1 Even surface, 2 sloped surface

COLUMN	***1***	***2***
Line ***1***	***Grain Group (mm)***	***Weight (g)***
2	0.09/0.125	20
3	0.125/0.25	65
4	0.25/0.71	160
5	0.71/2.0	255

Table 3.2.3.3.3 - Composition of Test Specimens

Heat the dry test piece immediately before the test to a temperature of 105°C for a minimum of 2 hours. Place in hot condition into the shell and spread out evenly. Place the steel plate onto the test piece and agitate in the abrading machine with 2400 revolutions for 8 minutes.

After the abrasion test, determine the grain size distribution again (duration of sieving 10 minutes).

At least three tests shall be conducted using new test pieces each time.

c) Results

The size reduction of the grains is described by the ratio of the distribution of retainings before and after the abrasion test. The distribution of retainings is equal to the area which is enclosed on the semi-logarithmic granulation line diagram, by the perpendicular through d = 0.09mm and the granulation line.

3.2.3.3.4 Method of Test for Resistance to Frost

a) Apparatus

5 test sieves with mesh widths of 0.09mm, 0.125mm, 0.25mm, 0.71mm, 2.0mm.
Weighing scales with an error margin of ±0.1g.
3 tin cans, content approx. 1000 cm^3

3 plastic bags
Air-conditioning cupboard
Dry cupboard

b) Procedure

First wash the building material in the 0.09mm sieve. Dry the sieve retainings, divide into individual grain groups by sieving and then compose into test specimens in compliance with the Table in 3.2.3.3.3 above.

Place the dry test piece into a can, fill with 300cm^3 of distilled water, pack air-tight into a plastic bag and place into the air-conditioning cupboard. Lower the temperature in the air-conditioning cupboard step by step until the sample has reached a temperature of -20°C. The cooling phase lasts around 18 hours in all. Finally allow the can to thaw at a temperature of +70°C for 6 hours.

This freezing-thawing process must be carried out overall 25 times.

After the freezing-thawing process, dry the test piece at a temperature of 105°C and determine the grain size distribution again (duration of sieving 10min).
At least three tests must be carried out using new test pieces each time.

c) Results

The size reduction of the grains is described by the ratio of the distribution of retainings before and after the abrasion test. The distribution of retainings is equal to the area which is enclosed on the semi-logarithmic granulation line diagram, by the perpendicular through d = 0.09mm and the granulation line.