TK04 - Fragments and Powder

Determining thermal conductivity using 2-phase tests

Principle

To determine the thermal conductivity of fragments or powder (k_F), the material is mixed with water and the thermal conductivity of the mixture (k_M) is measured using a half-space test. The thermal conductivity of the fragments is calculated from the conductivity of the mixture, the known thermal cpnductivity of water and the volume share v of water in the sample.

$$k_M = (k_W)^{v} * (k_F)^{(1-v)}$$

The result is the thermal conductivity of a non-porous solid composed of the fragment material (so-called matrix thermal conductivity). The method is valid for fragments with a thermal conductivity lower than the 15-fold conductivity value of water:

$$k_F < 15 * k_W$$

Hence the thermal conductivity of the sample materail may not exceed a value of approx. 7.5 W $m^{-1}K^{-1}$. Otherwise choose another suitable fluid.

Executing 2-phase tests

For 2-phase tests, a sample container is available whose inner diameter exactly matches the size of the Standard HLQ half-space probe. We recommend to use the hydraulic pressure device with gage (available as an option for TK04) designed to apply controlled contact pressure to half-space probes.

The total probe volume is calculated from the sample container's diameter and its fill level. The water volume contained in the sample is determined from the water weight and the known density of water at sample temperature. The water weight is determined by weighing the sample before and after adding the water. The sample material must be dried before starting the test to avoid errors in the calculation of the water content.

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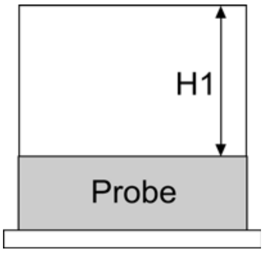
Step-by step instructions

1. Insert the probe into the empty sample container and measure the height H1 (i.e. the distance between the probe surface and the upper edge of the container). You will need this measure to later calculate the sample volume (see step 7).



2. Fill the container with dry sample material. Wet material must be dried before starting a 2-phase test, otherwise it would be impossible to correctly determine the moisture content. Make sure that the sample surface does not contain coarse or sharp-edged components which could damage the probe.

   Tip: The fill level should be as high as possible to keep the relative errors of volume and weight determination low. The probe should not protrude above the edge of the container, because it could get jammed when applying contact pressure, hence the maximum fill level is approx. 3 cm below the upper edge.

3. Weigh the container with the dry sample material (you will need the weigth to later determine water content).

   W_{dry} =

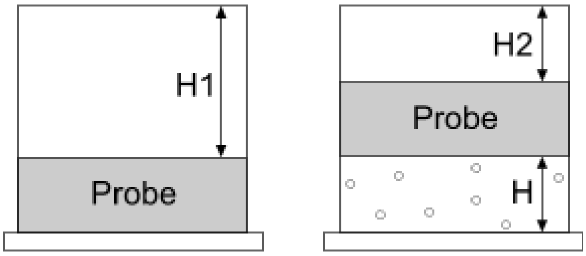
4. Saturate the sample **completely** with water.

   Tip: The water should have stood in the laboaratory for one day before using it to saturate the sample. Otherwise the sample should stand at least over night before starting the test in order to reach thermal equilibrium.

5. Place the probe on top of the sample, put it in the pressure device and slowly increase the contact pressure to 5 - 10 bar. **Never exceed a contact pressure of 10 bar (approx. 1.7 kN).** Water is pressed out of the sample mixture and escapes through the lateral notches of the probe body. Remove the excess water with a cloth to avoid errors when determining the weight of the saturated sample.

6. Perform a standard thermal conductivity test as for solids. To reduce the probability of convection occuring in the wet sample, choose a low heating power (Power Control approx. 1.5 to 2.0). For detailed information regarding the correct choice of heating power and Power Control, please consult the TK04 manual (chaper 3.3 *Executing a Measuring Series*). The result is the thermal conductivity k_M of the mixture.

7. Remove the container with the probe from the pressure device and determine the height H2 (i.e. the distance between the upper probe surface and the upper edge of the container). Calculate the sample volume.



H1 = (see step 1)
H2 = distance of of probe surface to the upper edge of the sample container
sample height: H = H1 - H2
inner radius of the sample container: r = 4,4 cm
sample volume: $V_S = \pi * r^2 * H$

8. Carefully remove the probe, making sure that no sample material remains at the probe body (this would cause errors when weighing the sample). A handle is included with the sample container which can be screwed on the probe body and simplifies removing the probe. If sample material should stick to the probe, put it back in the container. Then weigh the sample container with the saturated material to later calculate water content.

$W_{saturated} =$

9. Determine the volume share v of water in the sample:

$W_W = W_{saturated} - W_{dry}$

The density ρ_W of water at sample temperature is assumed to be known. The total volume V_S of the sample has been determined in step 7.

$v = W_W / \rho_W / V_S$

Tip: The sample temperature can be taken from the *dwl* file of the first measurement (temperature value at time 0 before the beginning of the heating phase).

10. Calculate the thermal conductivity k_F of the solid phase (fragments or powder)

The thermal conductivity k_W of water at sample temperature is assumed as known, the volume share v of water in the sample has been determined in step 9.

$k_M = (k_W)^v * (k_F)^{(1-v)}$

$k_F = (k_M * (k_W)^{-v})^{1/(1-v)}$

k_F	thermal conductivity of fragments / powder	
k_W	thermal conductivity of water at sample temperature	
k_M	thermal conductivity of the mixture	
W_{dry}	dry sample weight (including container)	
$W_{saturated}$	moist sample weight (including container)	
W_W	weight of the water contained in the sample	
H1	see step 1	
H2	see step 7	
H	$= H1 - H2$	sample height
r	$= 4{,}4$ cm	inner radius of sample container
V_S	$= \pi * r^2 * H$	total sample volume
ρ_W	density of water at sample temperature	
v	$= W_W / \rho_W / V_S$	volume share of water in the sample