SCIENCE - project : Characterisation of microstructure as a tool for prediction of moisture transfer in porous materials : moisture permeability for clay-brick and lime sandstone

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DIVISION OF BUILDING MATERIALS

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SCIENCE - project

CHARACTERISATION OF MICROSTRUCTURE AS A TOOL FOR PREDICTION OF MOISTURE TRANSFER IN POROUS MATERIALS

Moisture permeability for clay-brick and lime sandstone

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Moisture permeability for clay-brick and lime sandstone

Background

The moisture permeability (δ_v) for many modern building materials depends on the relative humidity (RH). Our part in this SCIENCE-project is to measure δ_v as a function of RH for some materials.

Experimental arrangement

The variation of δ_v as a function of RH between about 35 % to about 100 % RH have been investigated with the methodics for the cup method, which have been developed by Lars-Olof Nilsson. RH outside the cups is about 35 % and RH inside the cups are about 60, 75, 82, 85, 90, 95, 98 and 100 %. These RH are brought about with saturated salt solutions (except 100 %). A cup is shown in FIG 1. The bottom is removable and liquid can be filled up in the cup. It means that the liquid surface in the cup can be nearly constant and close to the bottom side of the sample (about 7 to 10 mm.). This is important for open materials. If the distance between the sample and the liquid surface is increased the moisture resistance of the air gap could be big compared to the moisture resistance of the sample. RH on the bottom side of the sample could then be much lower the RH of the salt solution. At the evaluation of the results account has been taken to the moisture resistance of the air gap.

Theory

According to Fick's first law we have

$$g = -\delta_v * \delta v/\delta x \qquad (1)$$

which can be written when g and δx (L) is constant

$$g*L = \int_{v_{ref}}^{v_1} \delta_v * \delta v = \Psi \qquad (2)$$

where Ψ is the fundamental flow potential.

The climate outside the cups is constant (about 35 % RH) = v_{ref}. At the bottom of the samples it is different climates. A relation between the moisture flow rate and the vapour content is then achived according to FIG 2.

Eq.(2) can now bee derived with respect to the variable vapour content (v_1).

$$\delta g/\delta v_1 * L = \delta/\delta v_1 \int_{v_{ref}}^{v_1} \delta_v * \delta v_1 = \delta_v(v_1) \qquad (3)$$

The moisture permeability is achived by determining the slope of the curve in FIG 2 for different vapour contents. When the temperature during the test is constant we can use RH instead of the vapour content.

Results

The moisture permeability has been determined for clay brick and lime sandstone. In FIG 3 to FIG 5 are the measured results for clay brick. FIG 3 shows the fundamental flow potential (Ψ) as function of RH. Every measured results are shown in FIG 3. The spread in the results is big. If it is assumed that the moisture permeability does not depend on RH, but on the depth from the surface of the clay brick we get FIG 5. On the x-axis is the specimen number and number 1 is the specimen that include the clay brick surface. Specimen number 6 or 7 is located in the middle of the clay brick and number 11 or 12 is close to the other surface of the clay brick. In FIG 5 it is clearly shown that δ_v depends on the location in the clay brick. δ_v in the middle of the stone is higher than δ_v at the surface. For specimens 5A-- is the quotient between δ_v in the middle and δ_v at the surface about 3.

The results for lime sandstone are shown in FIG 6 to FIG 9. In FIG 6 the measured results of the fundamental flow potential is shown as a function of RH. Over about 90 % RH there is a strong increase in the fundamental flow potential. When are drawn as a function of the dry density of the lime stone we get FIG 7. Linear regression are made for the specimens with the same RH on the bottom side of the specimen. In FIG 7 it is seen that the higher the density are the lower is (for specimen with the same RH in the cup). The mean dry density for the specimens made of lime sandstone is 1847 kg/m^3. When the fundamental flow potential are read on the curves of linear regression for the densities 1815, 1847 and 1879 FIG 8 is obtained. In FIG 8 is shown as a function of RH and the dry density. It is seen that there is a dependence of the dry density (or porosity) on the fundamental flow potential. In FIG 9 is δ_v shown as a function of RH. The dry density is 1847 kg/m^3. From about 50 % RH there is an increase in δ_v. From about 90 % there is a considerable increase in δ_v.

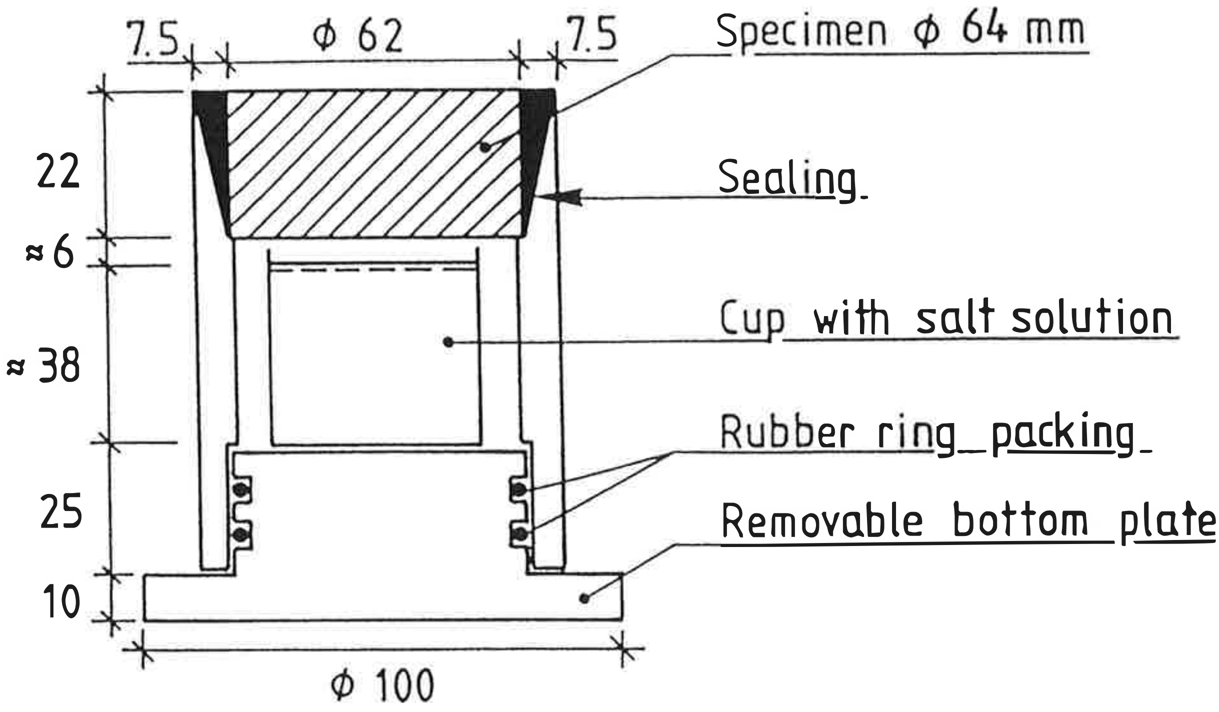

FIG 1 Salt solution cup—Permeability cup.

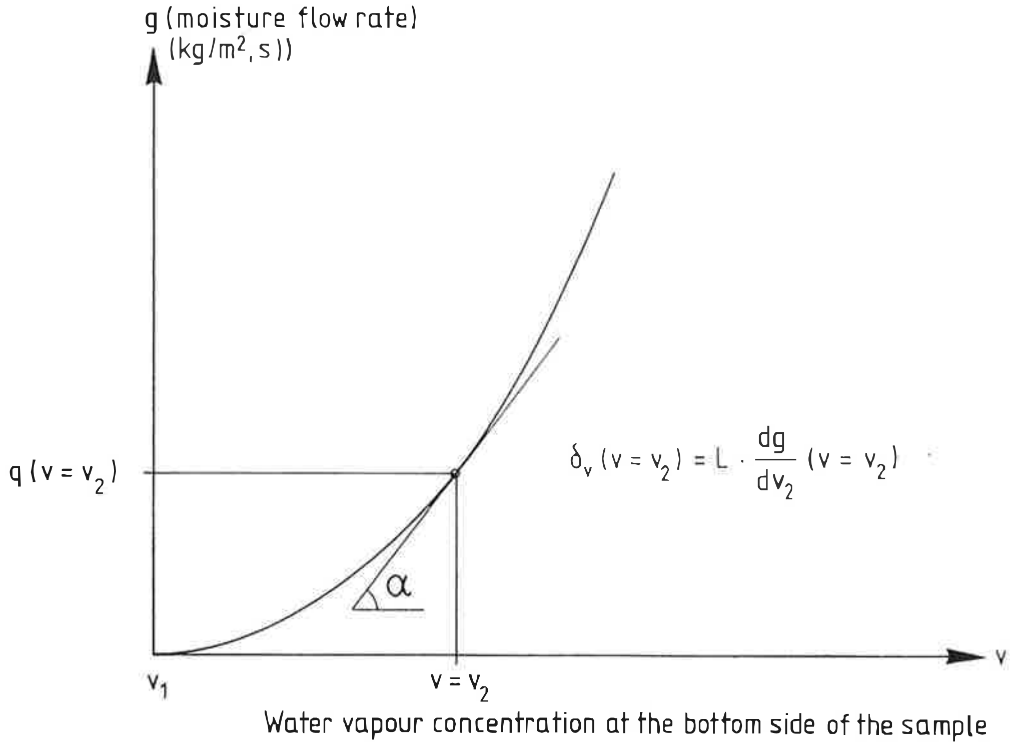

FIG 2 Determination of the moisture permeability

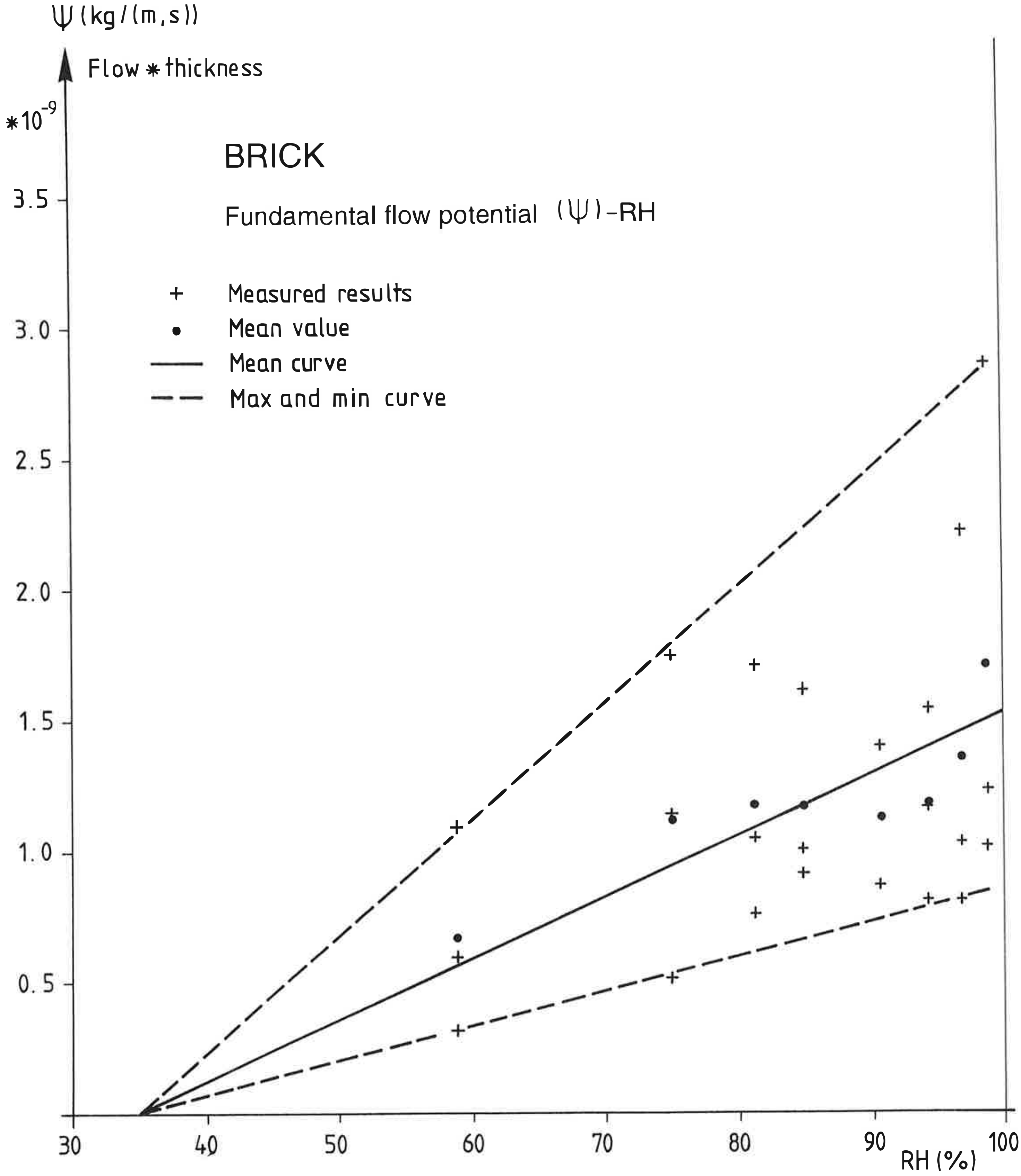
Ψ (kg/(m,s))
Flow * thickness
*10^-9
BRICK
Fundamental flow potential (Ψ)-RH
Measured results
Mean value
Mean curve
Max and min curve
3.5
3.0
2.5
2.0
1.5
1.0
0.5
30
40
50
60
70
80
90
100
RH (%)

FIG 3

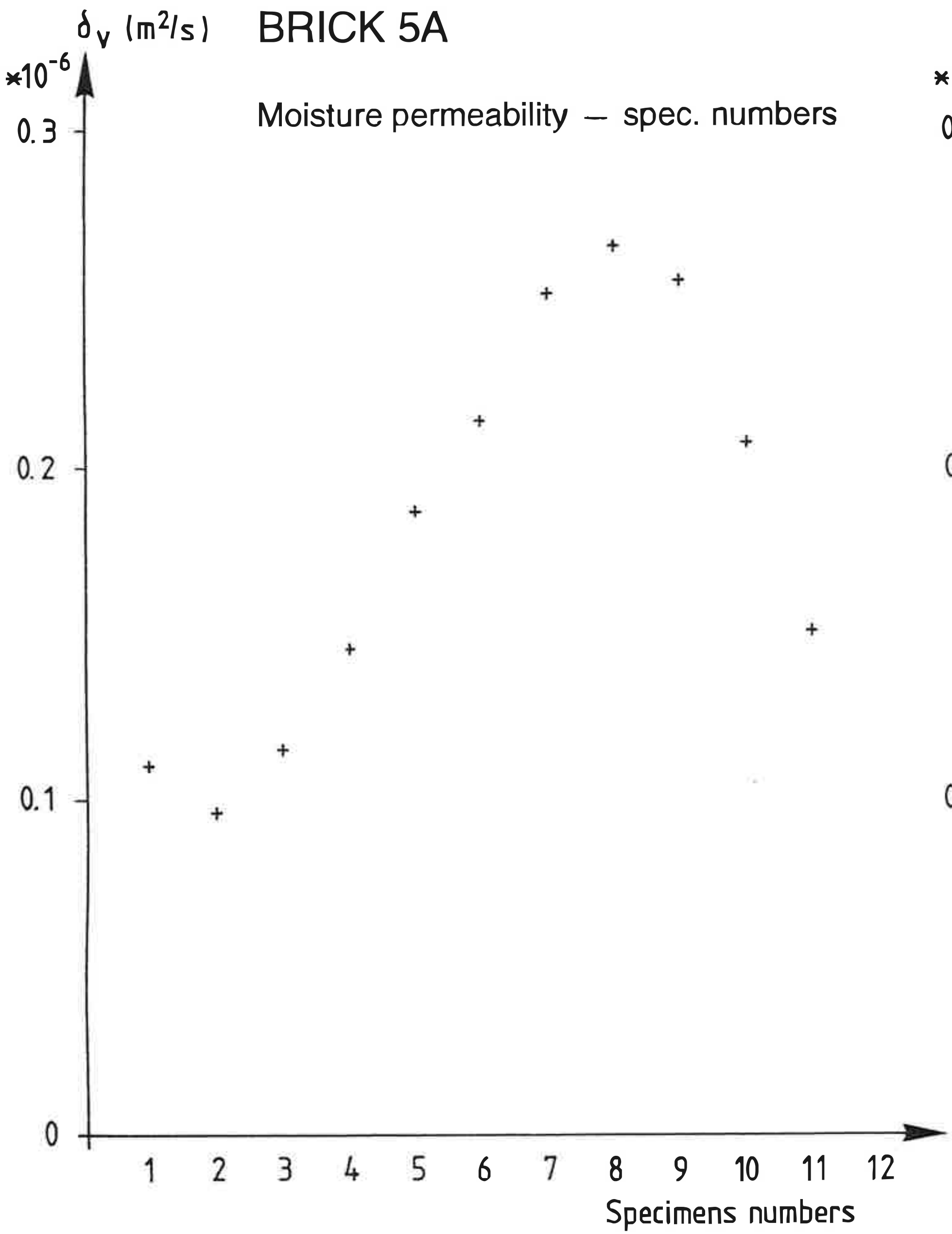
δv (m²/s)
BRICK 5A
*10⁻⁶
Moisture permeability — spec. numbers
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8 9 10 11 12
Specimens numbers

Fig 4

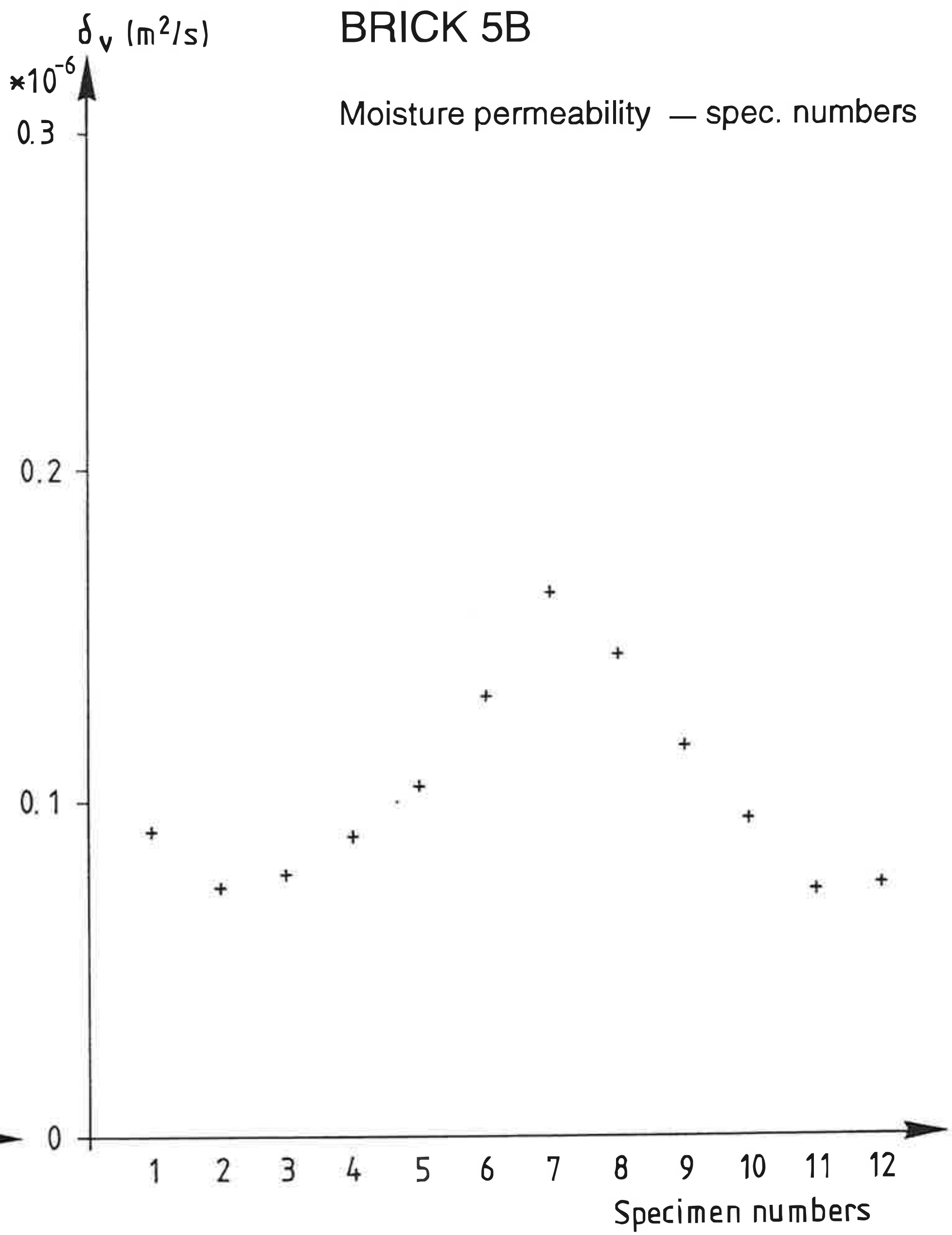
δv (m²/s)
BRICK 5B
*10⁻⁶
Moisture permeability — spec. numbers
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8 9 10 11 12
Specimen numbers

Fig 5

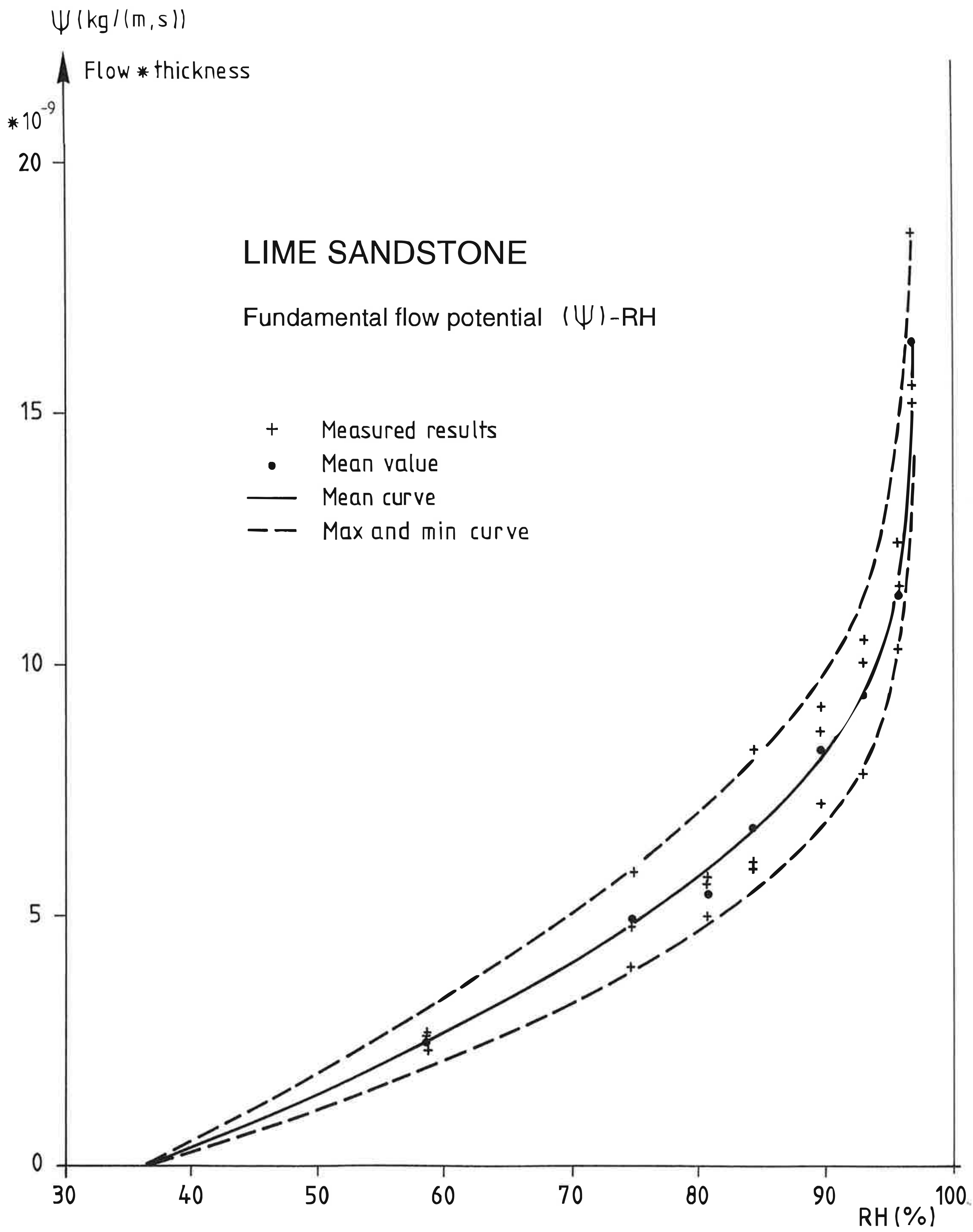
Ψ (kg/(m,s))
Flow * thickness
*10^-9
20
15
10
5
0
LIME SANDSTONE
Fundamental flow potential (Ψ)-RH
+ Measured results
• Mean value
Mean curve
Max and min curve
30
40
50
60
70
80
90
100
RH (%)

FIG 6

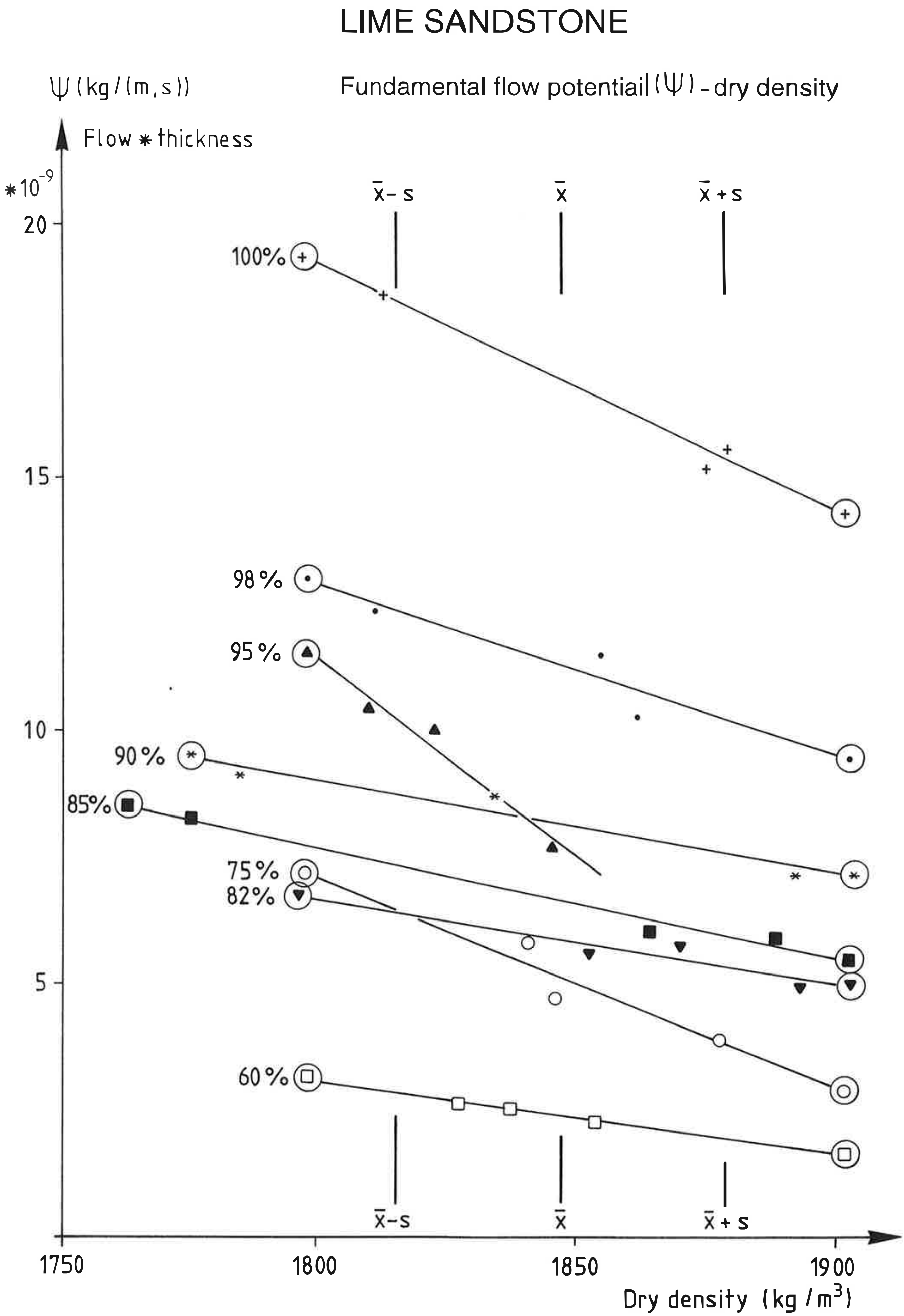
LIME SANDSTONE
Fundamental flow potentiail (Ψ) - dry density
Ψ (kg / (m, s))
Flow * thickness
* 10^-9
20
15
10
5
x̄ - s
x̄
x̄ + s
100%
98 %
95 %
90 %
85%
75 %
82%
60 %
1750
1800
1850
1900
Dry density (kg / m³)

FIG 7

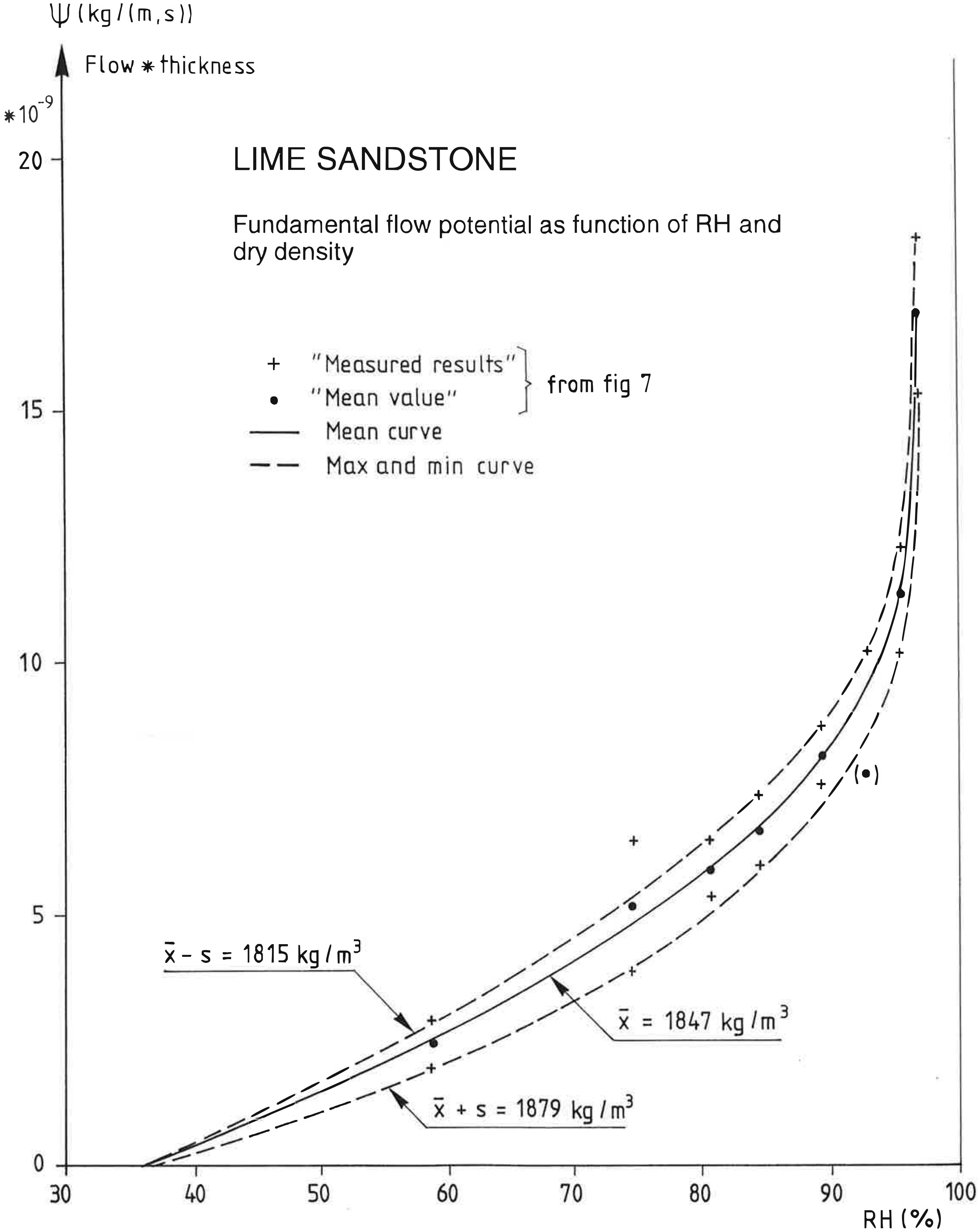
Ψ (kg / (m, s))
Flow * thickness
* 10^-9
LIME SANDSTONE
Fundamental flow potential as function of RH and dry density
+ "Measured results"
• "Mean value"
from fig 7
Mean curve
Max and min curve
x̄ − s = 1815 kg / m³
x̄ = 1847 kg / m³
x̄ + s = 1879 kg / m³
RH (%)
0
5
10
15
20
30
40
50
60
70
80
90
100

FIG 8

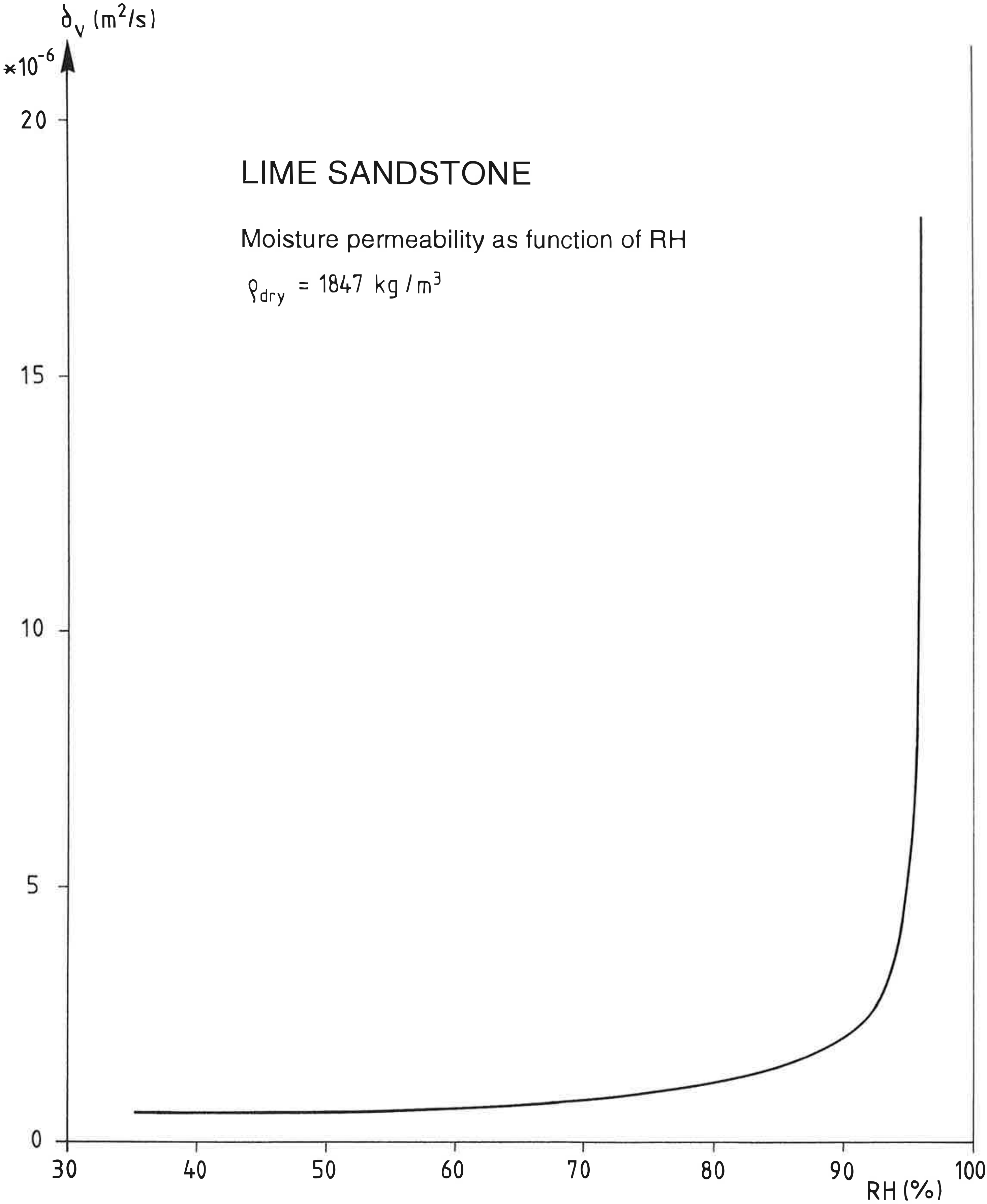
δ_v (m²/s)
*10⁻⁶
20
15
10
5
0
LIME SANDSTONE
Moisture permeability as function of RH
ρ_{dry} = 1847 kg/m³
30
40
50
60
70
80
90
100
RH (%)

FIG 9