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Test of radon transmission and permeability on two materials (3 appendices)

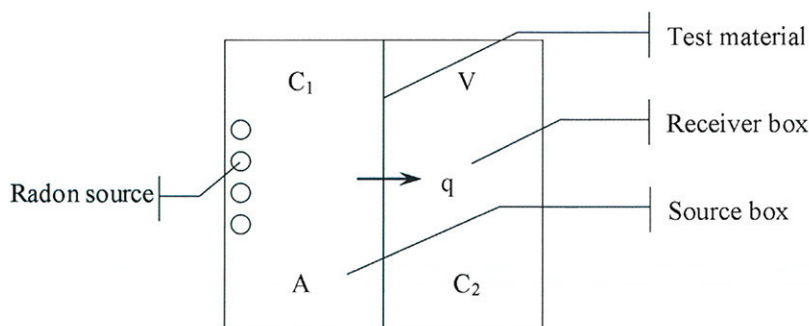
The assignment is to determine the radon transmittance and radon permeability through the material. The material was sent to us by the test sponsor. The sample arrived at SP (SP Technical Research Institute of Sweden) on 16 June 2008, without visible damages.

Description of the test material

The test materials were named RMB 400, thickness 0.4 mm, and Blackline 1000, thickness 1,0 mm.

Test equipment

Testing is carried out in a test chamber comprising two boxes of stainless steel. Each box measures 500 x 500 mm. The deep of the receiver box is 104 mm and the deep of the source box is 170 mm. The test sample is placed between the boxes. Then the sides are tightened very carefully, so that the connection between the boxes is airtight. A diagram of the test apparatus is presented in Figure 1 below.



The designations C_1 , V etc. are described under Theory.

Figure 1. Test equipment

Radon source

The radon source is a block of aerated concrete which contains a small amount of radium. The radioactive decay of radium will produce radon gas (Rn-222) which is emitted to the atmosphere in the source box. Rn-222 is also radioactive and its first decay product (RnD) is Polonium-218. Radon decay products (RnD) are not gases but particles, and cannot pass the test specimen by diffusion.

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Instrumentation

The radon concentration on each side of the test specimen is determined by instruments of type Atmos 33, SP No. 202266, produced by Gammadata in Sweden. The measuring principle used in these instruments is to determine the concentration of Polonium-218 and convert it into radon concentration assuming an invariable relationship between the Rn and Po concentrations.

The instrument was calibrated at the Swedish Radiation Protection Institute on August 27 2007.

Test room

Testing was carried out in a room with following conditions: a relative humidity of 44-49 %, and a temperature of 22.1-22.8 °C. The ambient air pressure varied between 975 and 1002 hPa.

These conditions were continuously monitored throughout the full duration of the test (5 days). The background radon activity in the room was <50 Bq/m³ before and <50 Bq/m³ after the test.

Theory

The emission of radon from the radon source will lead to a build-up of the radon concentration in the source box and a difference in radon concentration between the source and receiver box. This difference will cause a flow of radon by diffusion through the test specimen. Only the radon gas (Rn) and not the radon decay products (RnD) will pass the test specimen.

The radon transmittance is determined by measuring the radon concentration on both sides of the test specimen, as the radon is flowing through the test material.

In evaluating the radon transmission, it is assumed that the radon concentration in both the source and receiver box is increasing linearly with time during a time interval t_1 to t_2 . Radon gas decomposition is considered only in the receiver box.

The density of radon flow through the test specimen is written

$$q = P \cdot (C_1 - C_2) \quad (1)$$

where q = density of radon flow (Bq/m² · s)
 P = radon transmittance (m/s)
 C_1, C_2 = radon concentration on both sides of the test specimen (Bq/m³)

The differential equation for the radon concentration build-up in the receiver box (C_2) is

$$\frac{dC_2}{dt} = P \cdot (C_1 - C_2) \cdot \frac{A}{V} - \lambda \cdot C_2 \quad (2)$$

where t = time (s)
 A = test specimen area (m²)
 V = receiver box volume (m³)
 λ = $2.1 \cdot 10^{-6}$ decay constant (s⁻¹)

With $C_1 = a + b \cdot C_2$ equation (2) becomes

$$\frac{dC_2}{(a + b \cdot C_2 - C_2) \cdot \frac{P \cdot A}{V} - \lambda \cdot C_2} = dt \quad (3)$$

or

$$\frac{dC_2}{a + C_2 \cdot \left(b - 1 - \frac{\lambda \cdot V}{P \cdot A} \right)} = \frac{P \cdot A}{V} \cdot dt \quad (4)$$

Integration between t_1 and t_2 and C_2^1 and C_2^2 gives

$$\frac{1}{b - 1 - \frac{\lambda \cdot V}{P \cdot A}} \cdot \ln \left[\frac{a + \left(b - 1 - \frac{\lambda \cdot V}{P \cdot A} \right) \cdot C_2^1}{a + \left(b - 1 - \frac{\lambda \cdot V}{P \cdot A} \right) \cdot C_2^2} \right] = \frac{P \cdot A}{V} \cdot (t_1 - t_2) \quad (5)$$

From equation (5) P is calculated.

Sometimes the radon resistance (Z s/m) rather than the radon transmittance is used

$$Z = \frac{1}{P} \quad (6)$$

For test specimens made of homogenous materials radon permeability can be determined

$$k = \frac{d}{Z} = P \cdot d \quad (7)$$

where k = radon permeability (m^2/s)
 d = test specimen thickness (m)

The first readings of C_1 and C_2 are taken at the earliest 4 h after the test commenced and further readings are taken once or twice every day.

Calculation and presentation of transmittance/permeability is done as soon as both the C_1 - and C_2 -curves are linear with time. The results are presented for the whole period with linear curves, normally a period of 2-6 days.

Test results

RMB 400

The test commenced on 1 September 2008, and was terminated on 5 September 2008. The results given in the table below are subject to the following constraints: the surface area of the test material is 0.239 m², and the volume of the receiver box is 0.026 m³.

Receiver box, C ₂		Source box, C ₁		Air pressure ¹ , hPa
Radon concentration, Bq/m ³	Time, s	Radon concentration, Bq/m ³	Time, s	
5	21 600	3 225	25 200	991
51	82 800	10 061	104 400	987
185	183 600	16 290	201 600	975
295	262 800	20 452	273 600	978
486	345 600	22 610	356 400	979

The radon transmittance of the material is calculated to

$$P = 1.3 \cdot 10^{-8} \text{ m/s}$$

and the radon permeability (assuming thickness of test specimen 0.0004 m) to

$$k = 5.2 \cdot 10^{-12} \text{ m}^2/\text{s}$$

Blackline 1000

The test commenced on 8 September 2008, and was terminated on 12 September 2008. The results given in the table below are subject to the following constraints: the surface area of the test material is 0.240 m², and the volume of the receiver box is 0.026 m³.

Receiver box, C ₂		Source box, C ₁		Air pressure ² , hPa
Radon concentration, Bq/m ³	Time, s	Radon concentration, Bq/m ³	Time, s	
12	21 600	2 884	28 800	989
17	90 000	8 740	97 200	992
74	180 000	17 180	219 600	994
170	273 600	20 638	284 400	996
240	349 200	24 223	363 600	1002

The radon transmittance of the material is calculated to

$$P = 7.7 \cdot 10^{-9} \text{ m/s}$$

and the radon permeability (assuming thickness of test specimen 0.001 m) to

$$k = 7.7 \cdot 10^{-12} \text{ m}^2/\text{s}$$

¹ Recorded in connection with the reading of the radon concentration in the receiver box.

² Recorded in connection with the reading of the radon concentration in the receiver box.

Measurement uncertainty

The expanded uncertainty of the measurement is estimated to ± 21 %, including coverage factor $k = 2$. The uncertainty of temperature is ± 2 °C and of relative humidity ± 5 % in the test room.

Comments

The test results are only valid for the tested specimen.

SP Technical Research Institute of Sweden
Energy Technology - Building Physics and Indoor Environment

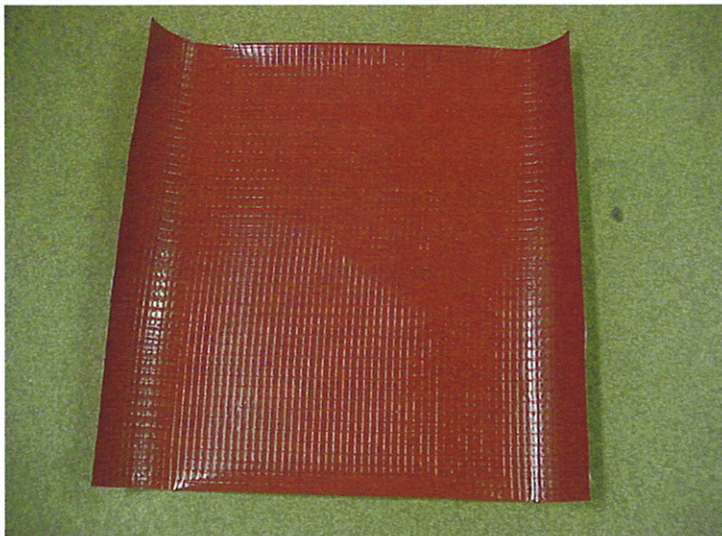
Handwritten signature of Ingemar Nilsson in blue ink.

Ingemar Nilsson
Technical Manager

Handwritten signature of Eva-Lotta Kurkinen in blue ink.

Eva-Lotta Kurkinen
Technical Officer

Photographs of test sample



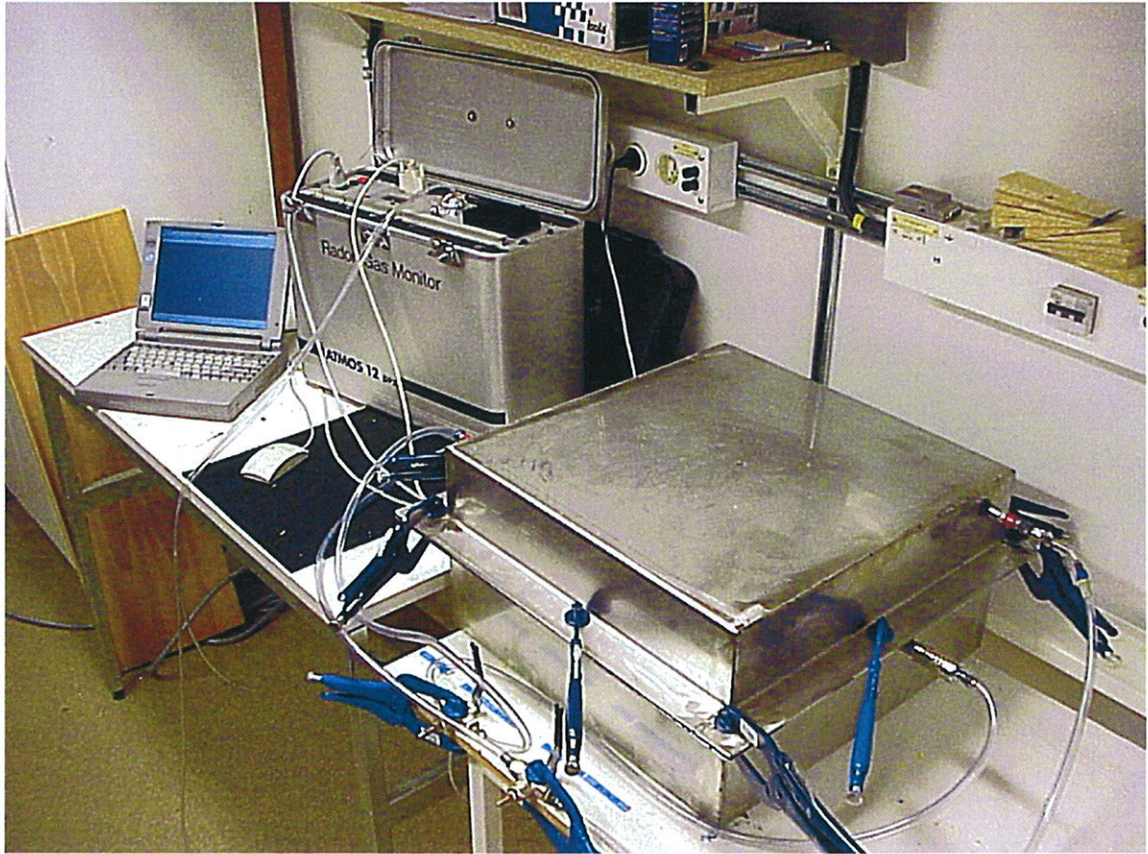
RMB 400



Blackline 400

Appendix 2

Photograph of test equipment



An example of calculation of indoor radon concentration in a building with ground radon barrier

The following calculation assumes that there are no radon-emitting materials in the structure of the building.

Given

Room volume $V = 29 \text{ m}^3$

Surface area $A = 12 \text{ m}^2$ (to the ground)

Radon concentration in the ground $C_g = 50\,000 \text{ Bq/m}^3$

Ventilation air change rate in the room $n = 0.5$ air changes/h

Calculation

The radon flow, q , from the ground to the building is given by

$$q = P \cdot (C_g - C_i) \quad \text{Bq/m}^2\text{s}$$

where P = the radon transmittance

C_i = the indoor radon concentration

For the material RMB 400, P is calculated to $1.3 \cdot 10^{-8} \text{ m/s}$ (see test report).

Assuming that C_i is small compared to C_g this gives a radon flow rate $q = 0.00065 \text{ Bq/m}^2\text{s}$.

The indoor radon concentration, C_i , can be expressed as the outdoor concentration, C_e , plus the quantity of radon emitted to the indoor air from the ground.

The indoor radon concentration,

$$C_i = C_e + \frac{q \cdot A \cdot 3600}{n \cdot V}$$

This gives an indoor radon concentration of about 2 Bq/m^3 plus the outdoor radon concentration (C_e), which is assumed to be 0 Bq/m^3 . (Note: this applies also for the other example given below.)

The same calculation as above, except for an air change rate of 0.1 air changes/h, gives an indoor radon concentration of about 10 Bq/m^3 .

In 'normal' cases, there is a concrete floor layer against the ground, which also contributes to the radon resistance, thus further reducing the indoor radon concentration.

Note

This type of calculation can be used for barriers applicable to protect against ground radon. It assumes that joints, inlets and connections are radon tight. The value of P in the calculation above, is valid for the material RMB 400.