REPORT

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Test of Radon Transmission and Permeability

(3 appendices)

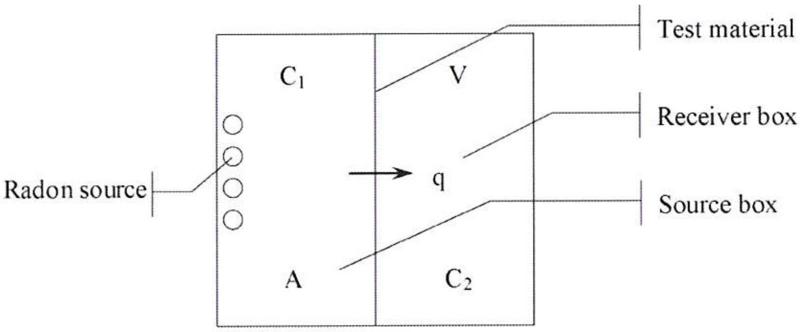
The assignment was to determine the radon transmittance and radon permeability through one material. The material was sent to us by the client. The sample arrived at SP (SP Technical Research Institute of Sweden) on 13 April 2012, with no visible damage.

Description of the test material

The tested material was named ASTROFLEX 4000 SUPRA with a thickness off 3 mm. A photo of the material is shown in Appendix 1.

Test equipment

Testing was carried out in a test chamber comprising of two stainless steel boxes. Each box measured 500 x 500 mm. The depth of the receiver box was 104 mm and the depth of the source box was 170 mm. The test sample was placed between the boxes. The sides were then carefully tightened, to ensure an airtight connection between the boxes. 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 was 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 through the test specimen by diffusion.

Instrumentation

The radon concentration on each side of the test specimen was 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 26 October 2011.

Test room

Testing was carried out in a room with following conditions: a relative humidity of 50-51 %, and a temperature of 22.8-23.2 °C. The ambient air pressure varied between 979 and 986 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/m^3 before and <50 Bq/m^3 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 through 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/m^2 · s)
- P = radon transmittance (m/s)
- $C1, C2$ = radon concentration on both sides of the test specimen (Bq/m^3)

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 (m^2)
- V = receiver box volume (m^3)
- λ = $2.1 \cdot 10^{-6}$ decay constant (s^{-1})

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

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

or

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

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

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

From equation (5) P is calculated.

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

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

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

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

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

The test for material ASTROFLEX 4000 SUPRA commenced on 23 April 2012 and was terminated on 27 April 2012. The results given in the table below are subject to the following conditions: the surface area of the test material 0.2470 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	
13	21 600	2 773	28 800	982
16	86 400	8 119	93 600	982
16	172 800	13 435	176 400	979
27	270 000	19 899	284 400	980
47	356 400	23 614	370 800	986

The radon transmittance of the material is calculated to
$P = 1.17 \cdot 10^{-9}$ m/s
and the radon permeability (assuming thickness of test specimen 0.003 m) to
$k = 3.509 \cdot 10^{-12}$ m^2/s

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

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Appendices

1. Photograph of test sample
2. Photograph of test equipment
3. An example of calculation of indoor radon concentration

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

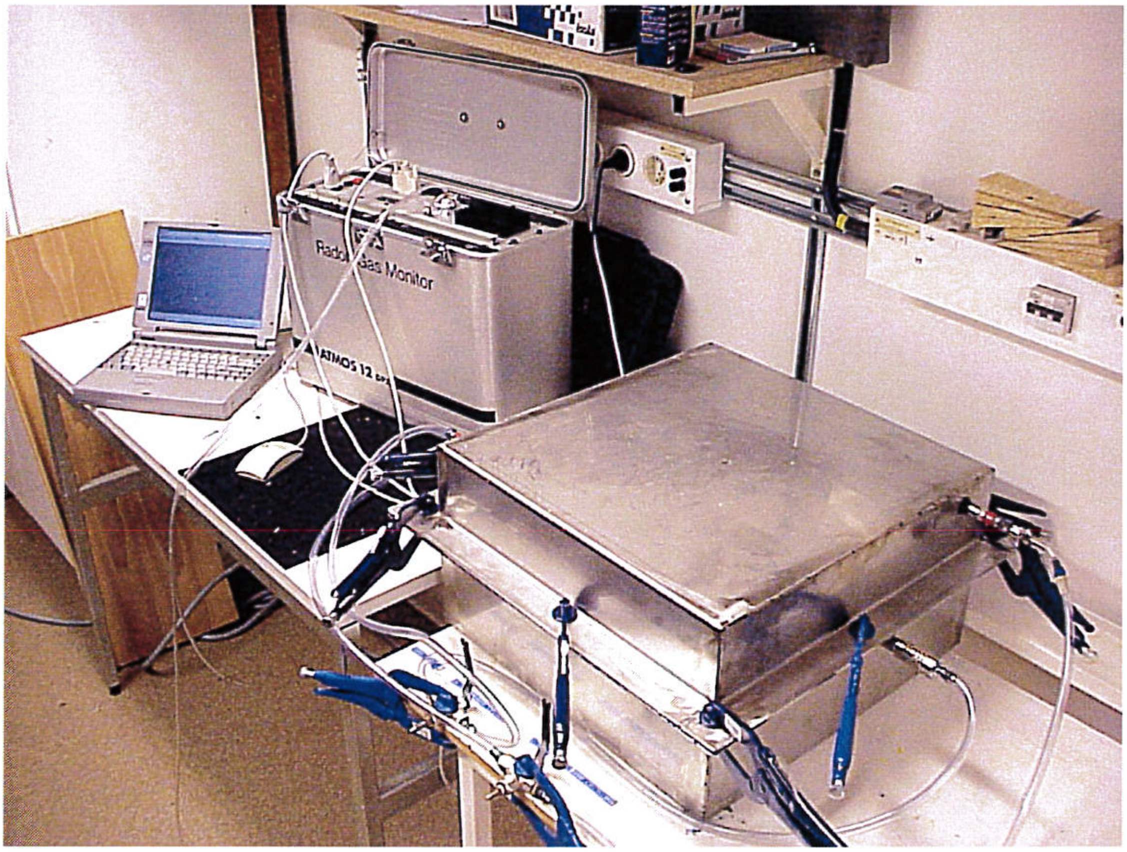
Appendix 1

Photograph of test sample

ASTROFLEX 4000 SUPRA

Appendix 2

Photograph of test equipment



Appendix 3

An example calculation of indoor radon concentration in a building with a 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 m³
Surface area A = 12 m² (to the ground)
Radon concentration in the ground C_g = 50 000 Bq/m³
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 ASTROFLEX 4000 SUPRA, P is calculated to $1.17 \cdot 10^{-9}$ m/s (see test report).

Assuming that C_i is small compared to C_g this gives a radon flow rate q = 0.00006 Bq/m²s.

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 approximately 0.2 Bq/m³ plus the outdoor radon concentration (C_e), which is assumed to be 0 Bq/m³. (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 approximately 0.9 Bq/m³.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 with no joints.