REPORT

Date 2006-10-04 | Reference P603728 | Page 1 (4)

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Radon transmittance and permeability of Flexigum
(2 appendices)

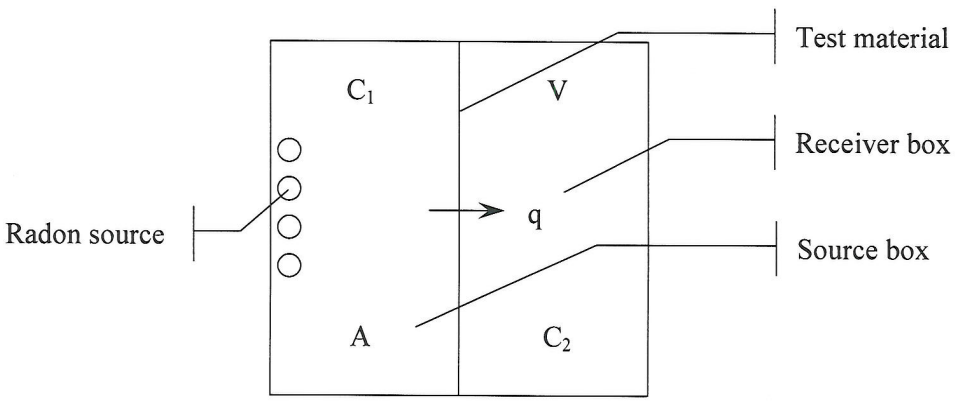
The assignment is to determine the radon transmittance and radon permeability through the material. The material was sent to us by the test sponsor. The sample arrived at SP (SP Swedish National Testing and Research Institute) on 11th September 2006, without visible damages.

Description of the test material

The test material was named Flexigum. The thickness of the test material was 4.3 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 Polo-

nium-218. Radon decay products (RnD) are not gases but particles, and cannot pass the test specimen by diffusion.

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 June 26, 2006.

Test room

Testing was carried out in a room with 43.8-50.5 % relative humidity, and a temperature of 22.5-22.6 °C. The ambient air pressure varied between 986 and 994 hPa during the tests. 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 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

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

where q = density of radon flow (Bq/m^2 · s)
P = radon transmittance (m/s)
C_1, C_2 = 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

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

where t = time (s)
A = test specimen area (m^2)
V = receiver box volume (m^3)
λ = 2,1·10^{-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 commenced 25 September, 2006, and was terminated on 29 September, 2006. The results given in the table below are subject to the following constraints: the surface area of the test material is 0.250 m², and the volume of the receiver box is 0.0286 m³.

Receiver box, C2		Source box, C1		Air pressure[1], hPa
Radon concentration, Bq/m³	Time, s	Radon concentration, Bq/m³	Time, s	
25	3 600	6 134	7 200	994
16	72 000	12 783	79 200	994
15	158 400	18 502	165 600	989
10	244 800	23 624	252 000	986
22	331 200	27 624	338 400	987

The radon transmittance of the material is calculated to

$P < 5.9 \cdot 10^{-10}$ m/s

and the radon permeability (assuming thickness of test specimen 0.0043 m) to

$k < 2.5 \cdot 10^{-12}$ m²/s

Measurement uncertainty

The uncertainty in measured radon content is estimated to ±5 %. Additional uncertainties might arise, primarily from the method of evaluation. This uncertainty is estimated to ±10 %, i.e. the total uncertainty of the measurement is estimated to ±15 %.

Comments

The test results are only valid for the tested specimen.

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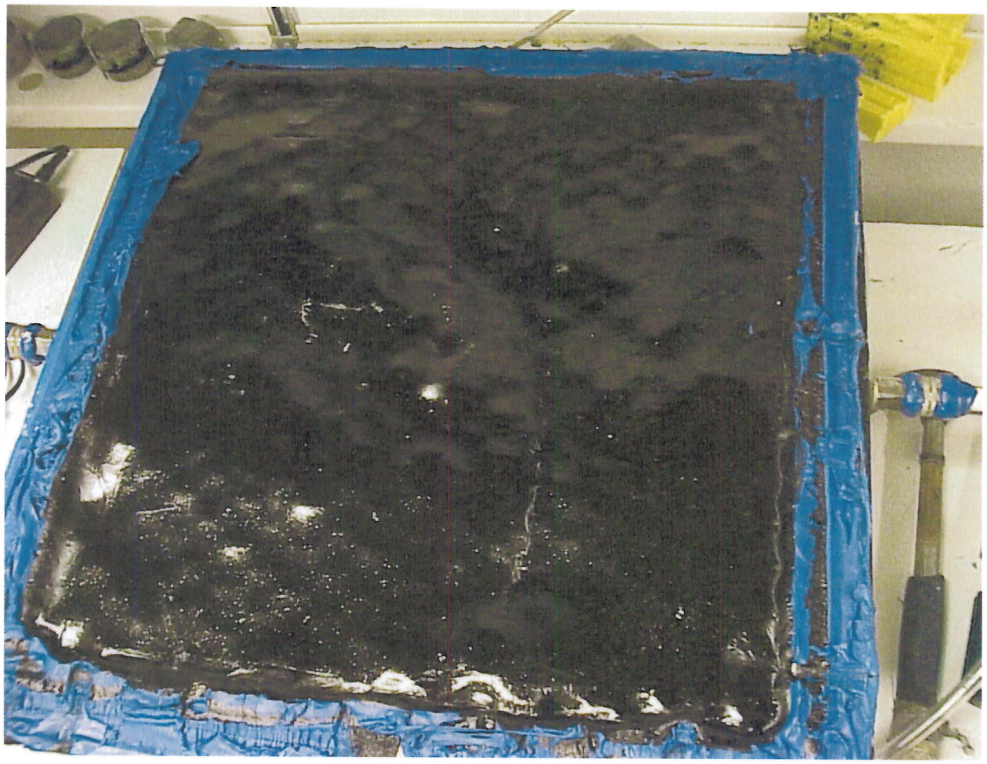
Appendices

Photograph of test material
Photograph of test equipment

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

Appendix 1

Photograph of test material



Appendix 2

Photograph of test equipment