Radon barriers: A state-of-the-art review and future opportunities

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Note: This short article will only include some of the findings made in the thesis. To get the whole context and better understanding of the content, refer to the entire thesis.

Abstract

To compare different solutions for radon barriers, potential materials have been studied. Firstly, commercial radon barriers and secondly other materials that might have potential as radon barriers. Multiple properties have been analyzed such as radon diffusion resistance, air tightness and others. The collected information for commercial barriers can be used to give an overview of the strengths and weaknesses of each state-of-the-art barrier and may help visualize their potential. Concrete has potential to work as radon protection if installed properly, therefore, multiple uses, types and challenges with using concrete as radon barriers have been discussed such as cracking and aging. Other potential radon barriers such as PVC sheets and bitumen and more have also been reviewed and some seem to have a satisfactory radon diffusion resistances value. However, their applicability is still unclear. Moreover, the durability of commercial state-of-the-art barriers as well as installations of these products have been evaluated. This study also further explains and introduces some state-of-the-art and future technologies and products that include self-healing concrete, self-healing membranes and bioplastics. Moreover, this study may be used to spark the interest into these technologies for further development and advancements in the field of radon protection.

Radon diffusion

Radon diffusion transmittance is how much radon that goes through a layer for a given time, the unit is m/s. Different materials have varying transmittance values and therefore some materials make much better radon barriers. Radon diffusion transmittance and resistance are opposites and therefore by dividing 1 with the radon diffusion transmittance it becomes the radon diffusion resistance (s/m). Typically for many of the articles used, this value (m/s) was given in the form of a radon diffusion coefficient D (m^2/s) and radon diffusion length l (m). The radon diffusion length is the characteristic distance traveled by the radon atoms during one half-life 3.8 days (Mayya, 2015). The formulas used in the thesis are:

$$l = \left(\frac{D}{\lambda}\right)^{0.5} \tag{2}$$

Where λ is the radon decay constant $2.0833 \cdot 10^{-6} s^{-1}$.

$$R_{RN} = d/D \tag{3}$$

$$R_{RN} = \frac{sinh(d/l)}{\lambda \cdot l} \tag{4}$$

$$\frac{d}{l} \geq 0.8 \tag{5}$$

Where d is the thickness of the material (mm). If thickness divided by the diffusion length equals 0.8 or higher, then formula 4 should be used to determine the radon diffusion resistance as the radon distribution is exponential. If d/l is under 0.8 then formula 3 should be used.

Airtightness

Airtightness also called air permeance or air permeability is a unit for how much air that can pass through a material. The method used in this article for figuring out the airtightness for materials was NBI 167/02, which is used by Sintef (2016) to test radon barriers airtightness. However, the unit used in Norway is l/min, liter per minute, which is common in Scandinavia, but internationally $m^3/(m^2hPa)$ is more usual. So therefore, the tables include both the norwegian and the international units.

$$\frac{l}{min} \cdot \frac{1}{m^2 \cdot Pa} = \frac{m^3}{\frac{1000\,h}{60}} \cdot \frac{1}{m^2 \cdot Pa} \tag{6}$$

Table for radon barrier materials

The two main tables of the paper are presented only in the bachelor thesis, because of their immensity. These tables compare the metrics of commercial radon membranes as well as alternative materials that could potentially be used for radon protection.

Discussion

Even though only 9 products were compared in table for commercial membranes, some general similarities were found; most of the commercial barriers have a radon diffusion transmittance of around 10^{-8} to 10^{-11}. Where most of the products are in the 10^{-8} range. However, Juta's membrane is a very clear outlier as it is a membrane designed for extreme cases.

The typical range of air permeance for these barriers are from 10^{-4} to 10^{-5}. Wallmann radon barrier is a small outlier with a value of $1.6 \cdot 10^{-3}$, which means a high air leakage. The three commercial barriers that had the lowest air leakage was the Canes radon barrier with air tightness at a value of $7.1 \cdot 10^{-5}$ and both Jackon barriers being close runner ups at $8.2 \cdot 10^{-5}$.

Execution of concrete for radon tightness
Concrete tends to crack and therefore typically being an unreliable radon barrier. However, by assuming that four different kinds of concrete in the table for alternative materials do not crack, these materials have been compared with metrics as continuous radon barriers without cracks. The concrete types are common, heavy, aerated and polymer, see full thesis.

In addition, a graph, the figure below, was created to compare the radon tightness of these concrete types directly with the given thickness of 100 mm. Using the radon diffusion resistance from another table and the various kinds of concrete, only polymer concrete had a satisfactory value of radon resistance.

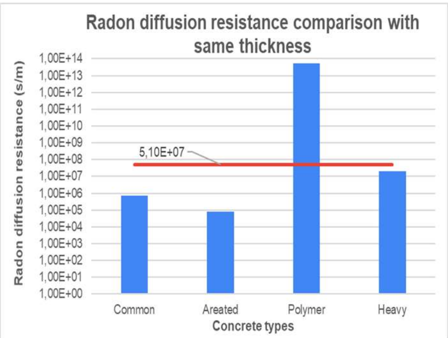

Figure: concrete types compared with the same thickness of 100 mm.

Self-healing concrete
Self-healing concrete could possibly solve concrete cracking. However self-healing from the ancient Romans had not been rediscoved before 2023. The key to the concrete's super durable nature is hot mixing, which consists of an exothermic reaction produced by using quicklime instead of, or in addition to, the slaked lime in the mixture. The concrete cracks will then be filled with calcite and sealed completely when exposed to a significant amount of running water (Chandler, 2023; Seymour, 2023).

Bio plastics
There have been multiple methods and studies to try to find a substitute for plastic and one of these is bio-based plastics. There are several different types of bioplastics, some that are biodegradable and some which are not. These plastics are produced from biological materials or renewable feedstock (Atiwesh, 2021). The non-biodegradable ones are more applicable for use in the building industry, as there are very few instances where one would want a building material to degrade easily. The process of producing bioplastic is very easy to do and replicate (Murray-smith, 2020).

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