Dimensioning of soil depressurization system for radon remediation in existing buildings

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ABSTRACT

The aim of this study is to help dimension the Sol Depressurization System against radon in existing buildings.

First, various remediation techniques implemented on existing buildings are compared regarding the reduction of indoor radon concentration. The results show that techniques that deal with basements have generally the best efficiency and in particular the Soil Depressurization Systems.

In situ test equipment has been developed in order to dimension these systems. It has been used on different basements such as crawl spaces and cellar. For each case, the test has been conducted before and after the sealing of the interface between the soil and the building. In some cases, depressurization of the basement can be obtained for very low airflow rate in the basement once it is airtight.

An experiment on a high radon level building with a ground floor has also been undertaken. After the sealing of this basement, it is shown that the necessary airflow rate needed to make create an under-pressure field under the floor is very low. The continuous measurement of indoor radon concentration during the experiment shows a significant decrease inside the building when the Soil Depressurization System is activated.

INDEX TERMS

Radon; Remedial measures; Efficiency; Soil depressurization system; Dimension

INTRODUCTION

Radon is a radioactive gas which comes from the degradation of uranium and radium present in variable quantity in the earth's crust and whose solid particles can settle in the lung. In France, a few thousands cases of lung cancer are thus attributed to radon by epidemiologists annually.

The accumulation of radon in buildings results from many parameters. The main source of radon in buildings is generally the ground under the basement. Its entry into buildings is mainly due to the pressure difference between the soil beneath the ground floor and the inhabited volume. This pressure difference is due to temperature differences between indoors and outdoors. It induces airflow from ground porosity to the indoor environment via basement air leakages. So, the intensity of the radon source in a building is generally increasing with temperature differences.

The principles of techniques aiming at decreasing the presence of radon in buildings consist of diluting the radon concentration in the inhabited volume and to prevent radon from coming in from the ground. In practice, from the various possible configurations for existing buildings, many alternative techniques calling upon these two combined principles are used. Nevertheless, the efficiency of the different techniques should be evaluated in order to define best solutions for a given building taking into account the initial radon concentration level.

This paper presents in a first part an analysis of the efficiency of different remediation techniques implemented in existing buildings. The second part presents the results obtained

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during different *in situ* experimentations where the Soil Depressurization System (SDS) has been tested.

EFFICIENCY ANALYSIS OF DIFFERENT REMEDIATION TECHNIQUES

Method

Based on the definition of departments where the radon problem could occur, a measurement campaign has been undertaken in public establishments and, particularly, in schools by the French authorities. For buildings, where indoor radon concentration is higher than 400 Bq/m^3, the action level recommendation, an information feedback has been organized in order to collect information on remediation techniques used and the measurement control level obtained. For this campaign, detection and control measurements were done with a passive sensor exposed during about 5 weeks in a heating season (NF M 60-771).

The results obtained from more than 30 cases are analysed. Information available on remediation techniques is generally only qualitative. They concern the use of natural or mechanical accentuation of building ventilation, of crawl spaces or cellar, sealing techniques, basement ventilation, soil depressurization techniques. The efficiency of remedial solutions regarding the diminishing of indoor radon concentration is defined as follows:

$$\text{Efficiency} = \left(1 - \frac{C^{\text{Rn}}_{\text{final}}}{C^{\text{Rn}}_{\text{initial}}}\right) \times 100 \qquad (1)$$

where $C^{\text{Rn}}_{\text{initial}}$ is the initial concentration obtained during detection measurements and $C^{\text{Rn}}_{\text{final}}$ the final concentration obtained during control measurement.

Results

Figure 1 shows the efficiency previously defined for the analysed cases. The seven remediation families defined in the figure could correspond to combined remediation techniques. They are described as follows:

1: Increase of natural building ventilation
2: Extract mechanical building ventilation
3: Blowing mechanical building ventilation
4: Natural or mechanical basement ventilation
5: Natural building and basement ventilation
6: Sealing interface ground/building and building

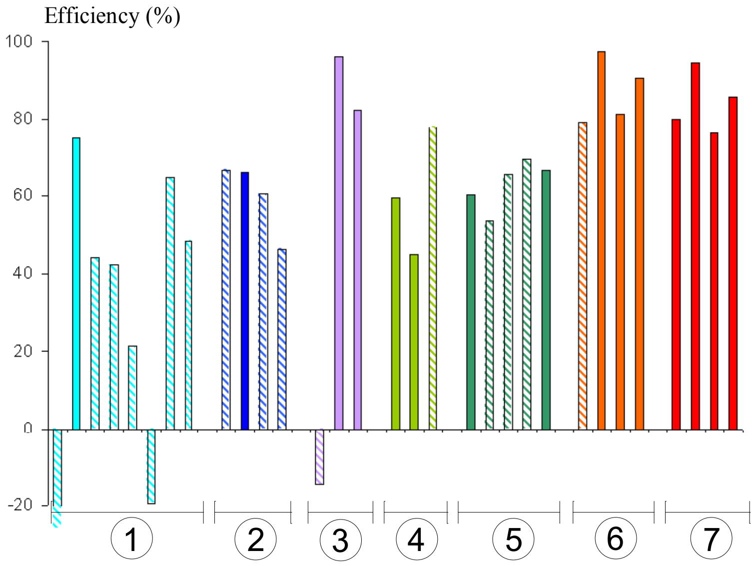

Figure 1 Efficiency of the different remediation techniques.
The hatched results correspond to cases where remediation techniques used did not allow to diminish the final indoor radon concentration lower than 400 Bq/m^3. The negative values of the efficiency correspond to cases where the final indoor radon concentration is higher than the initial one.

Analysis
The sample analysed is too small to conclude too definitively on the efficiency of different techniques. Nevertheless, this analysis enables to mention different points.

Solutions that deal with basements (cases 4–7) have generally a better efficiency than those that only increase the ventilation rate of the building (cases 1 and 2). In these latter cases, level efficiency is considerably varied, principally using natural ventilation which mainly corresponds to opening of windows and additional natural air entrances.

Cases 3 correspond to the blowing mechanical ventilation of building. This particular principle enables not only to control the ventilation rate but also to fight against the natural depression of the building. This technique has a good efficiency except for one case. An error on dimensioning the system or a wrong diagnostic of the building can be put forward to explain this result.

Sealing works at the interface between the basement and the inhabited volume of the building (cases 6 and 7) have a good efficiency, associated with other techniques. There are essential preconditions to any other combined solution.

Particularly, Cases 7 which correspond to the Soil Depressurization Systems have good efficiency. Control measurement is always satisfactory compared to 400 Bq/m^3 for these cases.

Level efficiencies generally observed are consistent with those found in literature (EPA, 1989; Welsh, 1995).

IN SITU **EXPERIMENT OF SOIL DEPRESSURIZATION SYSTEM**
Method
Experiments on a Soil Depressurization System have been undertaken on different buildings. *In situ* test equipment has been developed in order to dimension these systems. Its principle consists in a basement air leakage characterization in order to dimension the necessary airflow to be exhausted from the ground to obtain a depression field in the basement compared with the indoor environment (Figure 2).

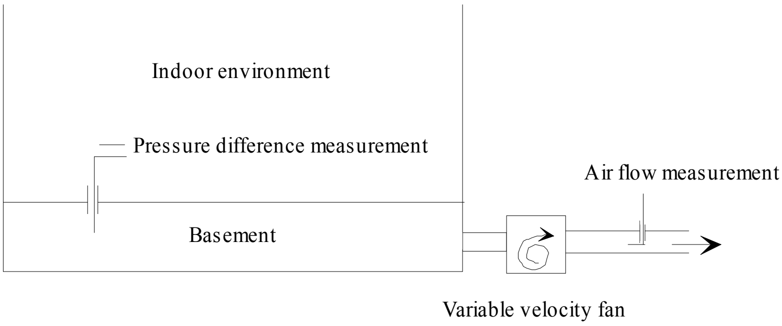

Figure 2 Test principle to dimension the SDS.

Results

The test apparatus has been used on different basements: three crawl spaces and one cellar. For such kind of basements, pressure field generated in it is homogeneous. For each case, the test has been conducted before and after sealing the interface between the soil and the building. Figure 3 shows detailed results obtained for a crawl space with concrete floor.

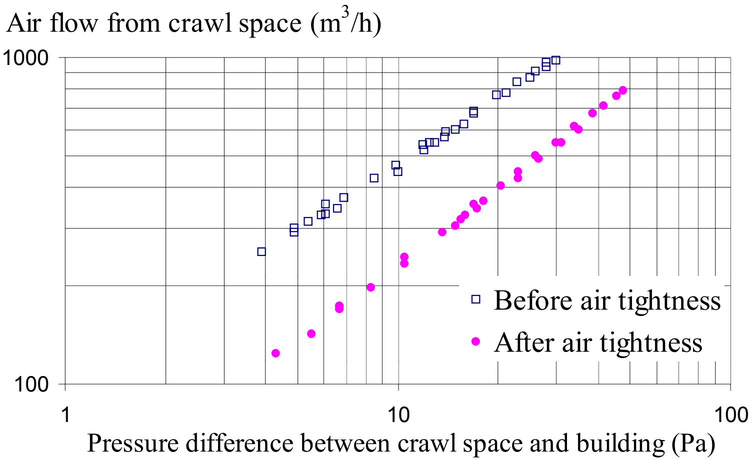

Figure 3 Characterization of air leakage of a crawl space.

Table 1 shows the necessary airflow to be exhausted from the basement to obtain a 5 Pa depressurization, once the basement has been made air tight.

Table 1 Necessary airflow exhausted from basement to obtain a 5 Pa depressurization

	Airflow (m^3 h^{-1} m^{-2})	Ground surface (m^2)	Airflow (m^3 h^{-1})	Airflow (V h^{-1})
Build. 1—crawl space with concrete floor	1.45	92	134	1.4
Build. 2—crawl space with concrete floor	0.2	273	54	0.33
Build. 3—crawl space with wood floor	2.3	37.5	87	7.7
Build. 4—cellar	6.7	10.5	70	3.9

For the two initial cases, depressurization of the basement can be obtained at low airflow rate in the basement once it is airtight, particularly for the second case. For the two other cases, the necessary airflow rate is too high to consider SDS appropriate. It should be preferable to ventilate these basements.

Other in-situ experiments had been undertaken in a high radon level building. It is a one-level recent building, dated 1995, of around 600 m^2.

The basement is mainly a ground floor but technical void is present in the central parts under the concrete floor (Figure 4).

RESULTS

The principle previously described has been applied to this basement. The extract point to create a depressurized field in the basement has been connected to technical void (Figure 2).

First, sealing works were conducted between ground and living environment (pipes, cables, etc.). In the mean time, air leakages between the ground under-floor and the adjacent technical void were voluntarily accentuated in order to facilitate under-floor depressurized field generated by fan from the void. In Figure 2, P1, P2 and P3 correspond to points where the under-floor depressurization field was controlled during the experiment. Figure 5 shows the ground floor air leakage characterization results.

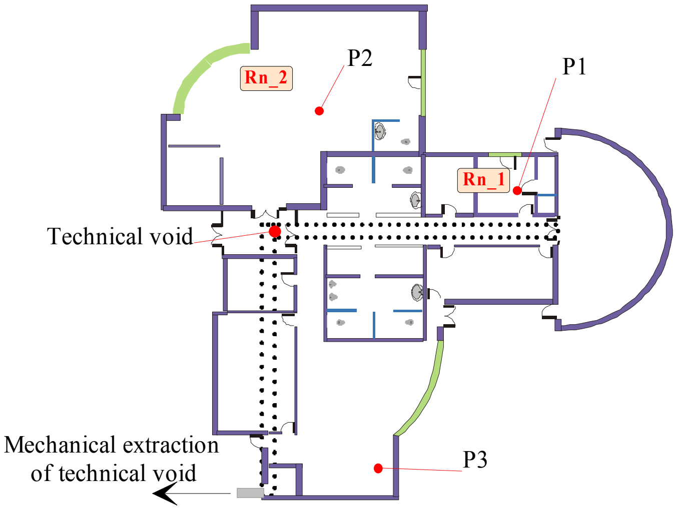

Figure 4 Building plan, with depressure and radon measurement points.

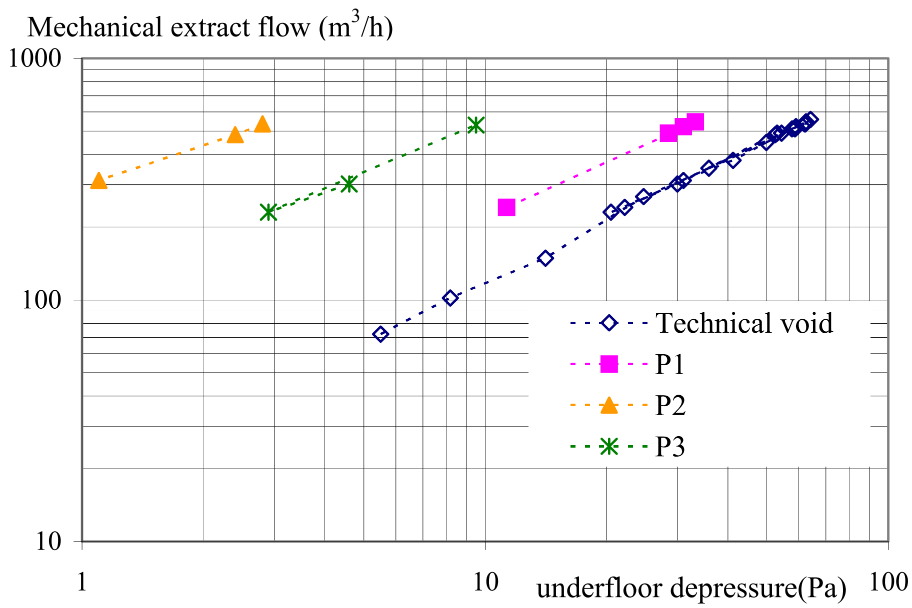

Figure 5 Ground floor air leakage characterization.

Once basement permeability characterization is obtained, the SDS has been tested regarding the indoor radon concentration level consequence. The extract flow from the void chosen for the experiment was about 300 m^3 h^{-1} (0.5 m^3 h^{-1} m^{-2} floor surface). This flow enables to obtain a correct depressurized field except around the P2 point region (Figure 5). Figure 6 shows the indoor radon concentration evolution at point P1 (Rn_1 in Figure 2) from the SDS start.

Analysis

This basement shows a good ability to be depressurized except around P2 point area which corresponds to the farthest part of ground floor from the technical void. SDS shows a very good efficiency to reduce indoor radon concentration significantly where depression in the basement is effective. Other radon measurement has been realized in room of point P2 area. A very slight decrease of radon concentration value has been observed even if the depression value is very low at this basement area. Connections between technical void and the ground under this room should be facilitated in order to optimize the system for this case.

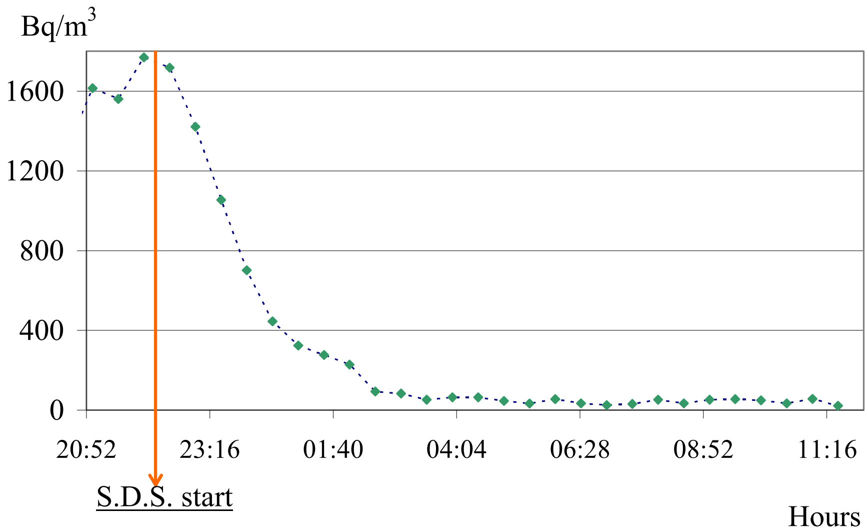

Figure 6 Indoor radon concentration evolution from the SDS start.

CONCLUSION

Different remedial techniques against radon in existing buildings have been analysed. In practice, sealing the interface between the basement and the inhabited volume of the building is an essential precondition to any other combined solution. Blowing mechanical building ventilation technique also seems to be an efficient technique concerning reduction of radon.

One of the best ways to deal with high radon concentration is to use SDS when it is possible. These techniques have very good efficiency regarding reduction of radon concentration. The requirement of the basement to be depressurized depends on many parameters but it is demonstrated in a particular case that an easy test can be undertaken on the basement to dimension and to implement this technique.

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