BLOWER DOOR METHOD IN RADON DIAGNOSTICS

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The main goal of what we call „radon diagnostics“ is to identify the radon sources and its infiltration pathways into the indoor atmosphere of the house. There are several important indoor radon sources: underground water supply, building materials and soil air that is transported by the diffusion and convection into the house through the building envelope constructions and cracks and other leakages. In following text the only soil source of the indoor radon will be assumed.

Usually, the attention is aimed on determining the mean radon concentrations. It is well known, that the actual indoor radon concentration is a result of two competitive phenomena, the radon infiltration and impact causing ventilation. Moreover it is proved, that at certain configuration of the cracks and leakages, the radon infiltration is the growing function of the ventilation.

Building constructions that are in contact with subsoil should create most tight interface between the soil underground and indoor. Effect of these constructions is specified by their composition, age and technical and technological state.

The building envelope (the floor, outer walls, roof) delimits the indoor space in which the microclimate usually substantially differs from the outdoor atmosphere. The outdoor climate and indoor microclimate differ in all parameters like temperature, air pressure, humidity, aerosol concentration and distribution and air flow/wind.

The microclimate parameters often vary for different parts of the building. It significantly depends on number of dwellers and their residential habits, as far as heating and ventilation is concerned. From this point of view the measurement of the mean indoor radon concentrations predicate more about human activities instead of the radon infiltration into the building.

New approach is aimed at characterising the buildings and quantifying parameters of the constructions that are in contact with the subsoil independently on residential habits and weather conditions.

The new method is based on the analysis of different infiltration parameters of the building envelope and of those parts of building constructions that are in contact with subsoil (floors and the parts of the walls that are below the terrain level).

For ventilation are used intentionally made openings (windows, doors, ventilation slots, and other openings), or other mechanically driven systems. Substantial part of ventilation air flows through the small openings, cracks and slots that originally should be tight, or should be tight under certain circumstances. For example the doors and windows should be tight especially in winter times.

The indoor – outdoor temperature difference causes the stack effect that further results in outdoor – indoor pressure difference. The pressure difference varies with the vertical height of the building. At certain level, called neutral level, the pressure difference is zero. If some leakages are located below the neutral level, the outer air infiltrates into the building. Through

the openings located above the neutral level, the air flows into the outdoor atmosphere. The *pressure difference* Δp that drives the airflow within the leakages and cracks is thus a function of vertical coordinate h of the opening $\Delta p(h)$.
If the building is naturally ventilated, the certain volume of the outdoor air infiltrates into the indoor through the leakages beneath the neutral level. The same volume of air must at the same time leave the indoor through the leakages situated above the neutral level. The volume of air, that passes trough all the leakages above or under the neutral level during one hour, expressed in units of the building (room) volume is called *ventilation rate* k_n (h^{-1}).

The concentration of the radon in the outdoor air is about 10 to 20 Bq/m^3 and for reasons of this paper can be neglected. As was mentioned above the radon inputs into the indoor predominantly from the soil air. For most building constructions, all these soil air infiltration pathways are located below the neutral level. All soil radon activity that enters into the building (room) is *radon supply rate* Φ ($Bq \cdot h^{-1} \cdot m^{-3}$).

Because the infiltration of the radon is driven by the pressure difference Δp, the idea of the artificially produced pressure difference is handy. For this reason the technique of blower door combination with continual radon monitors can be used. In addition the indoor – outdoor pressure difference and the volume of the air blowing out of the room is monitored. The blower door fan ensures the defined indoor – outdoor air pressure difference. The ventilator power is regulated so, that the stable pressure difference can range from about 5 Pascals to some 100 Pascals, depending on the room volume and its envelope. This pressure difference may be interpreted as the soil air - indoor pressure difference. Moreover using this technique the pressure difference is ensured to be constant over the whole building envelope and does not show the height dependence.

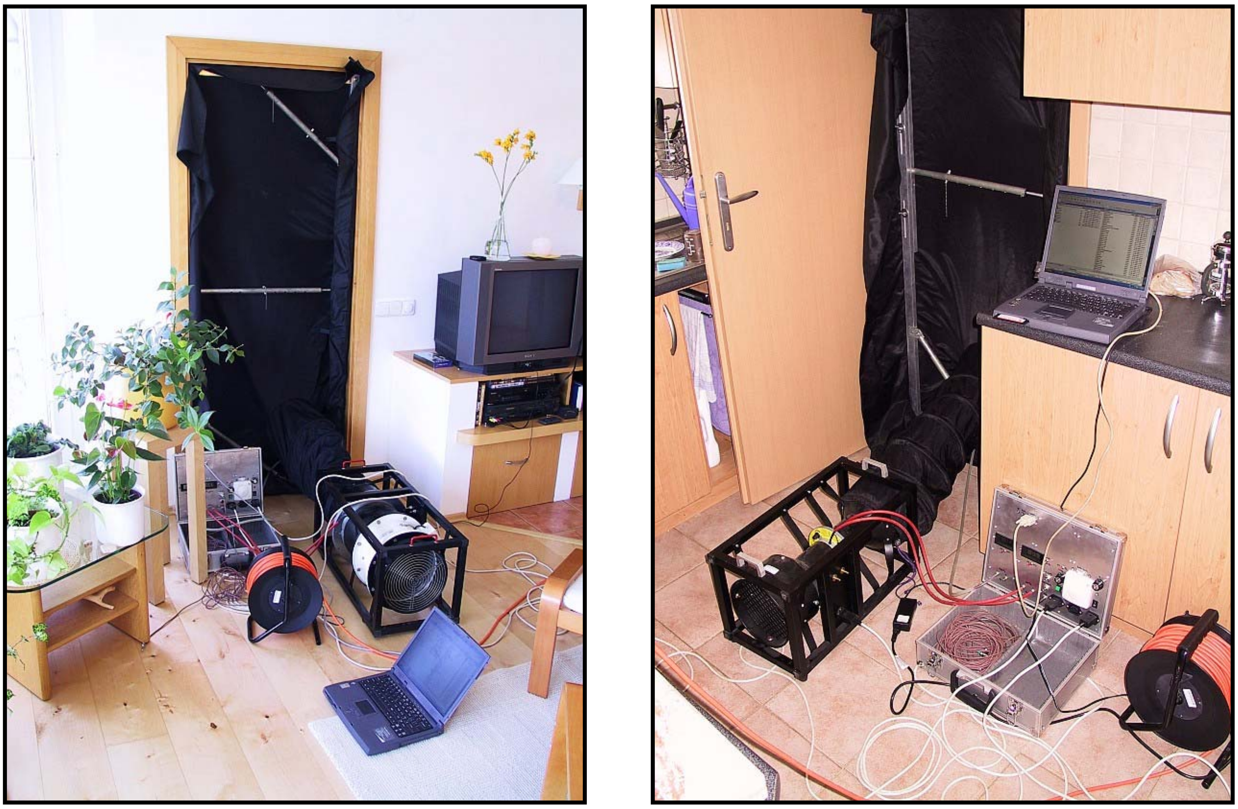

Fig1. The blower door technique.

Suppose, that blower door is installed in a doorframe of a room with volume V. The stationary state is established and the blower door fan blow out of the room volume of air per unit time Q. Indoor – outdoor pressure difference is Δp. Normal temperature and pressure conditions is assumed, the small pressure deviations (in one order of Pa) can be neglected. It means that the outdoor air must infiltrate the room through the cracks, slots and other openings by the same volume rate Q. The ventilation rate caused by the blower door fan is $k_{BD} = \frac{Q}{V}$. It has to be noticed, that this ventilation rate differs from that natural k_n. The principal difference between these cases is that for blower door the indoor – outdoor pressure difference is the same in all levels (heights) of the room, while in the case of natural ventilation the indoor – outdoor pressure difference is a function of height and neutral level with exists $\Delta p(h_N)=0$.

It is experimentally proved, that the airflow rate Q can be expressed as a power function

$$Q = c_{BD} \cdot (\Delta p)^{n_{BD}} , \qquad [1]$$

where c_{BD} is the flow coefficient and n_{BD} is a flow exponent. The n_{BD} flow exponent characterises the airflow through leakages and openings. If all dimensions of the openings and pressure differences had such values, that the airflow through them was turbulent one, then the n_{BD} value is 0,5. If these parameters supported in all cases the laminar airflow, the n_{BD} should be one. Under real situations the value of n_{BD} will be somewhere between 0,5 and 1, depending on predominant character of the airflow.

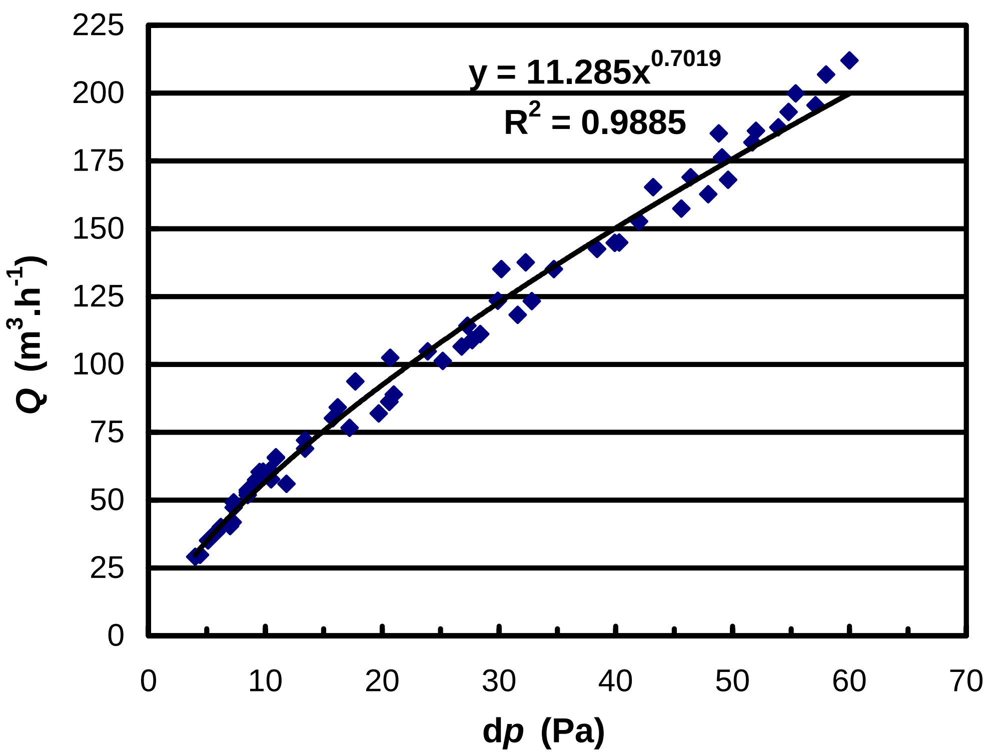

Fig 2. The blower door characteristic. The artificial ventilation rate as a function of a pressure difference.

If the blower door together with the appropriate continuous radon monitor is used, then the time course of the radon concentrations a_V can be interpreted as a build up curve for the model of a volume with constant radon supply and constant ventilation (zero radon concentration at t=0)

$$a_V = \frac{\Phi}{\lambda + k_{BD}} \cdot \left(1 - e^{-(\lambda + k_{BD}) \cdot t}\right), \qquad [2]$$

where λ is the radon decay constant. The requirement for constant ventilation is well fulfilled and, when the pressure difference Δp is kept constant during blower door test, the requirement for constant radon supply is also met. This procedure represents a tool to determine both ventilation rate k_{BD} and radon supply rate Φ, for different values of pressure difference Δp.

Analogically to the air infiltration through the envelope of building we can assume, that the soil air infiltration has similar characteristics and the radon supply rate can be expressed [3]

$$\Phi = c_{Rn} \cdot (\Delta p)^{n_{Rn}}, \qquad [3]$$

where the c_{Rn} and n_{Rn} are the soil air flow coefficient and the soil air flow exponent.

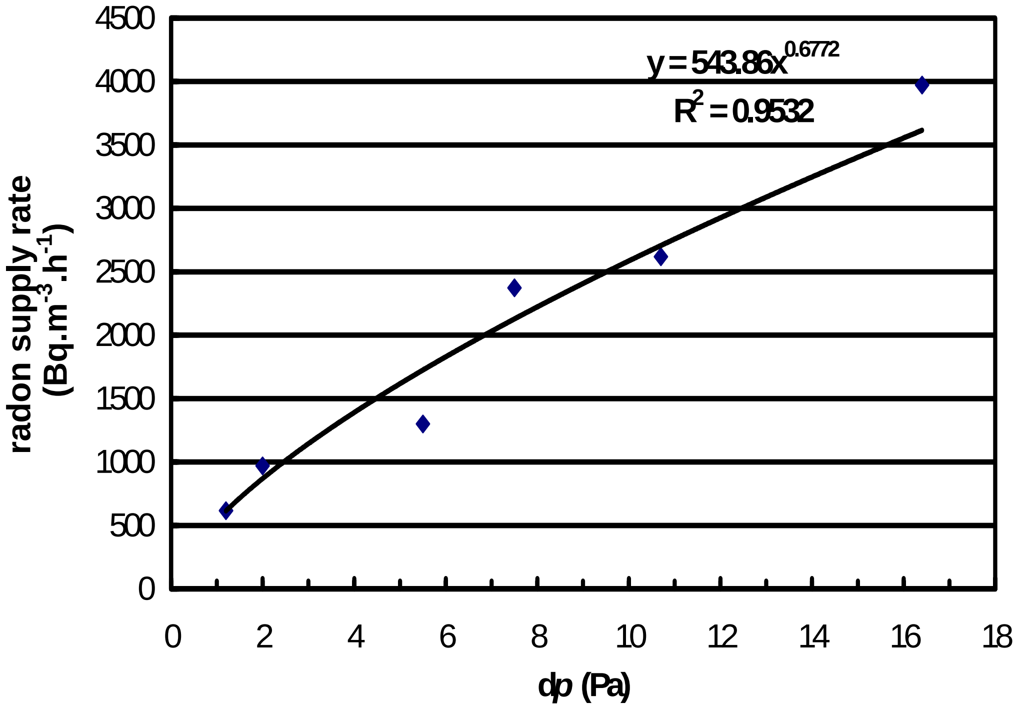

Fig 3. The blower door test. The radon supply rate dependence on pressure difference.

The blower door technique allows accomplish these measurements for pressure differences from about 5 Pa to some 100 Pa.

The soil radon infiltration pathways are usually situated on floors (that are in contact with subsoil) and in lower parts of walls. In situations with natural ventilation when the indoor – outdoor pressure difference changes with height we can assume, that the pressure difference that drives the soil air infiltration is represented by pressure difference at the floor level.

It is well known that in family houses naturally ventilated the long-term indoor – outdoor pressure difference at floor level rarely exceeds value 2 Pa. The radon supply versus pressure difference can be extrapolated and a real value of the radon supply rate at 1,5 or 2,0 Pa can be assessed.

The ratio $T = \frac{\Phi}{c_S}$ may be considered to be a transfer factor quantifying the radon barrier quality for separate parts of the building. Other quantitative parameters, for instance stationary concentration at certain pressure level $a_{V(\Delta p)} = \frac{\Phi}{Q}$, can be used for verification of the model presumptions.

Several experiments were carried out to confirm the model applicability. The results indicate eligibility of this approach. However more extensive set of data is needed to suggest the most suitable quantitative parameters and proper reference levels as well.