Challenges and opportunities arising from different ventilation approaches: controlled experiments conducted at the Canadian Centre for Housing Technology

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SUMMARY

KEYWORDS

Indoor radon, depressurization, built environment, ventilation

1 BACKGROUND

The ingress of naturally occurring radioactive radon gas from the soil into buildings can occur both by convection through any openings in the foundations as a result of pressure differentials and by diffusion across an airtight barrier (World Health Organization 2009). Residential ventilation systems and exhaust devices can affect indoor radon concentrations if they result in depressurization of the conditioned spaced relative to the outdoors or to the soil below the foundations or if they supply outdoor air directly. Balanced mechanical supply and exhaust ventilation (MSEV) systems tend to dilute the indoor radon concentration; however, some depressurization of the lower level can result from the air distribution if air is primarily supplied to upper level rooms and exhausted from lower level rooms. Mechanical exhaust only ventilation (MEV) systems depressurize the conditioned space and rely on the resulting infiltration of air across the building envelope that can be above and below grade. Higher indoor radon concentrations have been reported for the larger depressurization of 5-9 Pa in MEV houses relative to 2-3 Pa in MSEV houses (Arvela et al. 2014). In this study, indoor radon concentrations were measured in the National Research Council (NRC) Canadian Centre for Housing Technology (CCHT) semi-detached net-zero energy-ready smart house during depressurization testing using a duct blaster, and the depressurization resulting from typical exhaust devices was evaluated. Indoor radon concentrations were also measured during depressurization testing in a smaller NRC test house.

2 METHODS

The Canadian Centre for Housing Technology (CCHT) research facility is located in Ottawa, Canada, and enables testing and monitoring of building technologies in full sized Canadian housing. The depressurization testing was conducted in the full-size two storey semi-detached twin houses (mirrored about the party wall) constructed to the Canadian 2012 R-2000 standard that have an airtightness of about 1.5 air change per hour at 50 Pa (Figure 1). Both houses had a natural gas furnace, a central air conditioner, and energy recovery ventilator (ERV). A duct system distributed conditioned outdoor air and re-circulated throughout the houses. A 20-mil polyethylene radon barrier was installed during the construction of the basement and foundation. Depressurization testing was also conducted in an older, smaller NRC test house with a main floor and basement that had a 6-mil polyethylene membrane installed beneath concrete slab foundation as a vapour barrier. This test house had electrical baseboard heaters, a split air conditioning unit, a ducted heat recovery ventilator (HRV), and no exhaust device.

Prior to the depressurization testing, the mechanical supply and exhaust ventilation (MSEV) system and exhaust devices were turned off and sealed in all the test houses. The furnace and the recirculation fan were turned off in the semi-detached house in the first round of testing and running in the semi-detached houses during the second round of testing. The indoor radon concentration and differential pressures were measured during a 48 hour period on each floor of the semi-detached house at three levels of depressurization, achieved using a duct blaster installed on the first (ground) floor through a slot in the garage door in M24E: -5 Pa, -10 Pa, and -20 Pa relative to the outdoors. The differential pressure between the basement and the subslab area was also measured. Representing MEV conditions, the relative depressurization on each floor was measured in M24F during a 30 minute operation period for each exhaust device that vented directly outdoors, individually and in combination: a range hood, two bathroom fans, and a clothes dryer. The smaller experimental house had electric heating only and no recirculation while the HRV (MSEV) was turned off and sealed. Indoor radon concentrations were measured using continuous radon monitors every 10 minutes in the semi-detached houses (AlphaGuard) and every hour in the smaller test house (CorentiumPro).

Figure 1: CCHT semi-detached twin houses

3 RESULTS AND DISCUSSION

The indoor radon concentrations and differential pressures measured in the depressurization testing conducted in M24E using the duct blaster were plotted in Figure 2. The highest radon concentrations were measured in the basement during each test, and were highest for the most modest depressurization scenario at -5 Pa relative to outdoors. Stratification of indoor radon was evident when the furnace and the recirculation fan were turned off, as shown in Figure 2A, with the lowest radon concentration on the second floor. Building depressurization would have resulted in infiltration of outdoor air on the upper floor diluting the radon concentration and soil gas infiltration across the foundations in the basement increasing the radon concentration. Nearly uniform indoor radon concentration was observed across all floors when the furnace and the recirculation fan were turned on, as shown in Figure 2B. The indoor radon concentrations on all floors were higher under a building depressurization of -5 Pa when the recirculation fan was turned on than the baseline average indoor radon concentration of 174 Bq/m^3 measured over a two-week period for M24E with the ERV turned off, suggesting that more infiltration occurred across the foundations at -5 Pa. At higher building depressurizations, the indoor radon concentrations were lower than the baseline average indoor radon concentration, suggesting that higher infiltration of outdoor air occurred across the above ground building envelope at depressurizations of -10 Pa and -20 Pa. The average indoor radon concentration in M24E with the ERV operated continuously over the two-week period was 94 Bq/m^3, confirming the effectiveness of balanced MSEV ventilating the house at 0.27 air changes per hour.

By contrast, in the smaller CCHT test house, the indoor radon concentration in the basement rooms increased with increasing depressurization. This pattern was consistent with the increasing indoor radon concentrations reported for increasing house depressurization conducted using a blower door testing in France (Collignan, Lorkowski, and Améon 2012).

During the MEV testing, depressurization of close to -5 Pa on each floor of M24F was measured during the operation each bathroom fan and the clothes dryer, while the range hood and combinations of exhaust devices resulted in depressurizations that ranged from -15 to -40 Pa. This research suggests that radon infiltration at depressurization of about -5 Pa may be an issue of concern, despite being considered low enough to prevent spillage of combustion products from combustion appliances that do not have direct supply and exhaust vents. Basements tend to be occupied spaces in Canada that include bedrooms and family rooms.

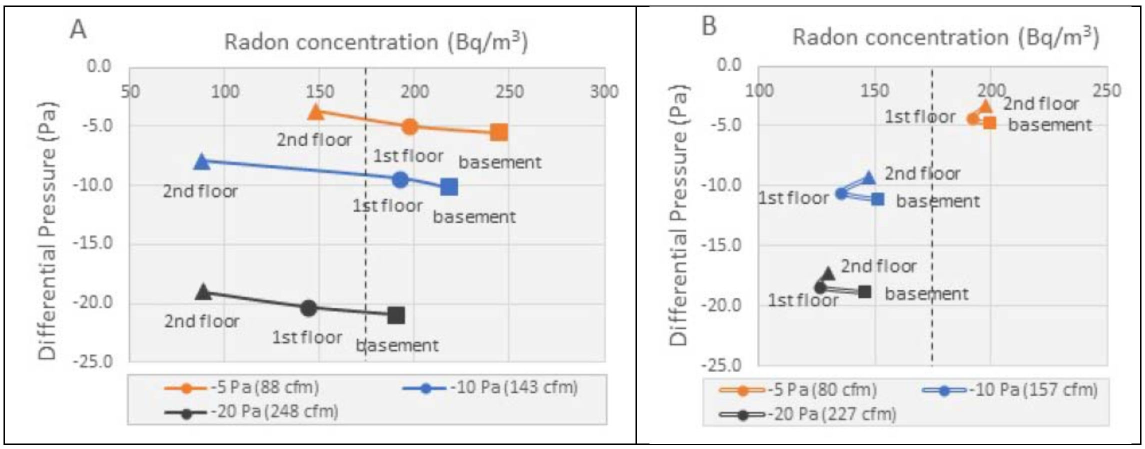

Figure 2: Radon concentration and differential pressure measured in M24E in the basement, first (ground) floor and second floor during depressurization in CCHT using a duct blaster located on the first (ground) floor with: A) furnace and recirculation fan off, and B) furnace and recirculation fan on. The dotted line shows the average indoor radon of 174 Bq/m^3 measured during a two-week period in M24E when ERV was turned off.

4 CONCLUSIONS

Increased indoor radon concentrations were measured during the depressurization testing conducted in the CCHT semi-detached net-zero energy-ready twin houses and in the smaller test house. The highest indoor radon concentrations occurred for the lower depressurizations resulting from single exhaust devices (bathroom fan, clothes dryer) operating under a typical MEV condition. Balanced MSEV was an effective strategy for radon control in the twin houses.

5 REFERENCES

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