ARVELA Hannu, MÄKELÄINEN Ilona, HOLMGREN Olli, REISBACKA Heikki. Radon prevention in new construction – Sample survey 2009. STUK-A244. Helsinki 2010, 63 pp + appendices 31 pp.

Keywords: radon, indoor air, dwellings, sample survey, new construction, radon prevention

Abstract

The building code for radon prevention and the associated practical guidelines were revised in Finland in 2003 to 2004. Thereafter, preventive measures have become more common and prevention practices more effective. Consequently, indoor radon concentrations in new construction have been markedly reduced. In this study, the indoor radon concentration was measured in 1 500 new low-rise residential houses. The houses were randomly selected and represented 7 % of houses that received building permission in 2006.

The average radon concentration of all houses measured, which were completed in 2006 to 2008, was 95 Bq/m^3, the median being 58 Bq/m^3. The average was 30 % lower than in houses completed in 2000 to 2005. The decrease was 50 % in provinces with the highest indoor radon concentration and 20 % elsewhere in the country. In houses with a slab-on-ground foundation that had both passive radon piping and sealing measures carried out using a strip of bitumen felt in the joint between the foundation wall and floor slab, the radon concentration was on average reduced by 55 % compared to houses with no preventive measures.

Preventive measures were taken in 50 % of single family houses, and in provinces with the highest radon concentration in 90 % of houses. Active prevention in areas with high indoor radon concentrations has reduced the regional differences in the radon concentration. Slab on ground is the prevailing type of foundation and necessitates careful radon prevention measures throughout the country. The most serious defects were observed in prevention practices in houses with walls made of lightweight concrete blocks that were in contact with soil. The foundation types with the lowest radon concentrations were those with a crawl space and a monolithic slab.

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Extended abstract

The building code for radon prevention and the associated practical guidelines were revised in Finland in 2003 to 2004. Thereafter, preventive measures have become more common and prevention practices more effective. Consequently, based on the results of this sample survey, indoor radon concentrations in new construction have been markedly reduced. The building code for foundation structures requires that radon should be taken into account in all construction work in Finland. Houses should be designed and constructed so that the indoor radon concentration is kept below 200 Bq/m^3.

In this study, the indoor radon concentration was measured in 1 500 new low-rise residential houses. The houses were randomly selected and represented 7% of the 22 716 houses that received building permission in 2006. The selected houses were occupied by November 2008. Altogether, 3 000 dwellings were selected for this study, with an invitation to participate in the study being sent to the house owners. The final participation rate was 52%. Radon measurements lasted for two months from March to May 2009. The alpha track detector used gives the average radon concentration for the measurement period. Questionnaires were used to gather information on the foundation type and other house characteristics, as well as the preventive measures taken in the new construction.

Radon concentration

The average radon concentration of all houses measured, which were completed in 2006 to 2008, was 95 Bq/m^3, the median being 58 Bq/m^3. The average was 30 % lower than in houses completed in 2000 to 2005. The decrease was 50 % in those provinces with the highest indoor radon concentrations and 20 % elsewhere in the country. The decrease compared to houses completed in 1980 to 1999 was more than 40 %. The percentage of houses exceeding the reference level of 200 Bq/m^3 had also markedly decreased, from 16 % to 11 %. The above

comparisons are based on the previous national survey carried out in 2006, in which indoor radon concentrations were measured in 2 267 houses randomly selected by the Population Register Centre of Finland. The geographical distributions of houses in these two surveys are quite similar.

Radon concentrations were by far the lowest in houses with a monolithic slab and those with a crawl space. In both of these classes, the average radon concentration was below 45 Bq/m^3 and the median below 30 Bq/m^3. In houses with a slab-on-ground foundation the average was 96 Bq/m^3 and the median 68 Bq/m^3. In hillside and basement houses with walls in contact with soil, the average and the median were 151 Bq/m^3 and 100 Bq/m^3, more than 50 % higher than in houses with a slab-on-ground construction. The main reason for these elevated values was the defective measures for radon prevention in the block walls in contact with soil. Leakages of radon-bearing soil air through walls in contact with soil also can be seen in the percentage of houses exceeding the reference level of 200 Bq/m^3. This figure was 22 %, as compared to 11 % for single family houses with slab-on-ground.

Impact of radon-resistant new construction

Slab on ground is by far the most prevalent type of foundation for newly-constructed low-rise residential houses in Finland, accounting for 80% of houses on the basis of this study. The key feature of this foundation type regarding radon prevention is the gap between the floor slab and foundation wall. This gap promotes the flow of radon bearing soil air into living spaces. The above figure of 80 % includes 15 percentage points of hillside houses and basement houses, which in fact have a similar joint between the floor and foundation wall at ground level to that in slab-on-ground houses. The guidance for radon-resistant new construction focuses on practices needed in houses with slab on grade and walls in contact with soil. The essential preventive measures are the installation of preparatory radon piping below the floor slab and sealing of the joint between the floor slab and the foundation wall using a strip of bitumen felt. In a passive radon piping system, the discharge is open above roof. The temperature difference and wind create an air flow, which reduces the radon concentration in the pore air of the sub-slab gravel. When needed, one can install a radon fan in the discharge of the piping, which when active effectively reduces the indoor radon concentration.

The impact of preventive measures was assessed through a comparison of indoor radon concentrations in houses with prevention compared to those where no preventive measures had been taken. In this comparison, local reference values from the indoor radon database, including 87 000 houses throug-

hout Finland, were also utilized. Preventive measures had been carried out in 54 % of single family houses with slab on grade. The percentage was 92 % in the six provinces with the highest indoor radon concentration and 38 % elsewhere in the country. Nationwide, the new regulations issued in 2003 to 2004 have doubled the level of prevention activity.

In single family houses with slab-on-grade foundations, passive radon piping and the installation of a strip of bitumen felt reduced the indoor radon concentration by 55 %. The average reduction for radon piping with no sealing measures was 40 %. The effect of prevention can also be clearly seen in the percentage of houses exceeding the reference level. In houses that had taken preventive measures the percentage exceeding this level was 8 %. In relation to the local reference values, this percentage was 29 %. The reference values used were radon concentrations of the postal code areas from the Finnish indoor radon data base. Higher percentages exceeding the reference level were most common in hillside and basement houses, in which radon entry through block walls in contact with soil is the main factor causing the elevated radon concentrations.

Estimates of the impact of preventive measures are subject to uncertainty due to the comparison method and inaccuracies in the questionnaire data. A lower level of prevention activity among those who did not participate in the study may reduce the nationwide estimate. On the other hand, estimates of the impact would probably increase if the defects in the questionnaire data were corrected. It is also noteworthy that the implementation of the preventive measures is often inadequate. Sealing of pipe penetrations in the floor slab was found to be relatively uncommon, and the sealing measures for block walls in contact with soil were generally defective. However, the impact of the preventive measures will increase as the experience of construction companies develops.

According to the results of this study, there is high variation in the prevention activity in different areas of the country. Local authorities require prevention measures commonly in those areas with the highest radon concentrations, which has also resulted in a considerable decrease in indoor radon concentrations. On the other hand, in those areas where no prevention has been taken, indoor radon concentrations have remained as before or have even increased. Radon-resistant new construction practices represent economic investments that also have moisture-related advantageous effects. Prevention measures may decrease also the entry of other harmful substances from soil into living spaces. The effect of passive radon piping is so significant that installation of the piping is recommended throughout the country. Builders should require archi-

tects and all participants in building projects to implement radon prevention measures according to the current guidelines.

The results of this study provide evidence of a strong impact of radon prevention measures. The practices detailed in the prevention guidelines have reduced the indoor radon concentration in houses receiving building permission in 2006 by dozens of percent in comparison with houses built earlier. The requirement for radon prevention in connection with the application for building permission and the widespread and skilled implementation of preventive measures throughout the country could result in an average 50 % reduction in indoor radon concentrations compared to the present housing stock with no prevention. This would considerably reduce exposure to radon and the harmful health effects of indoor radon in the coming decades.