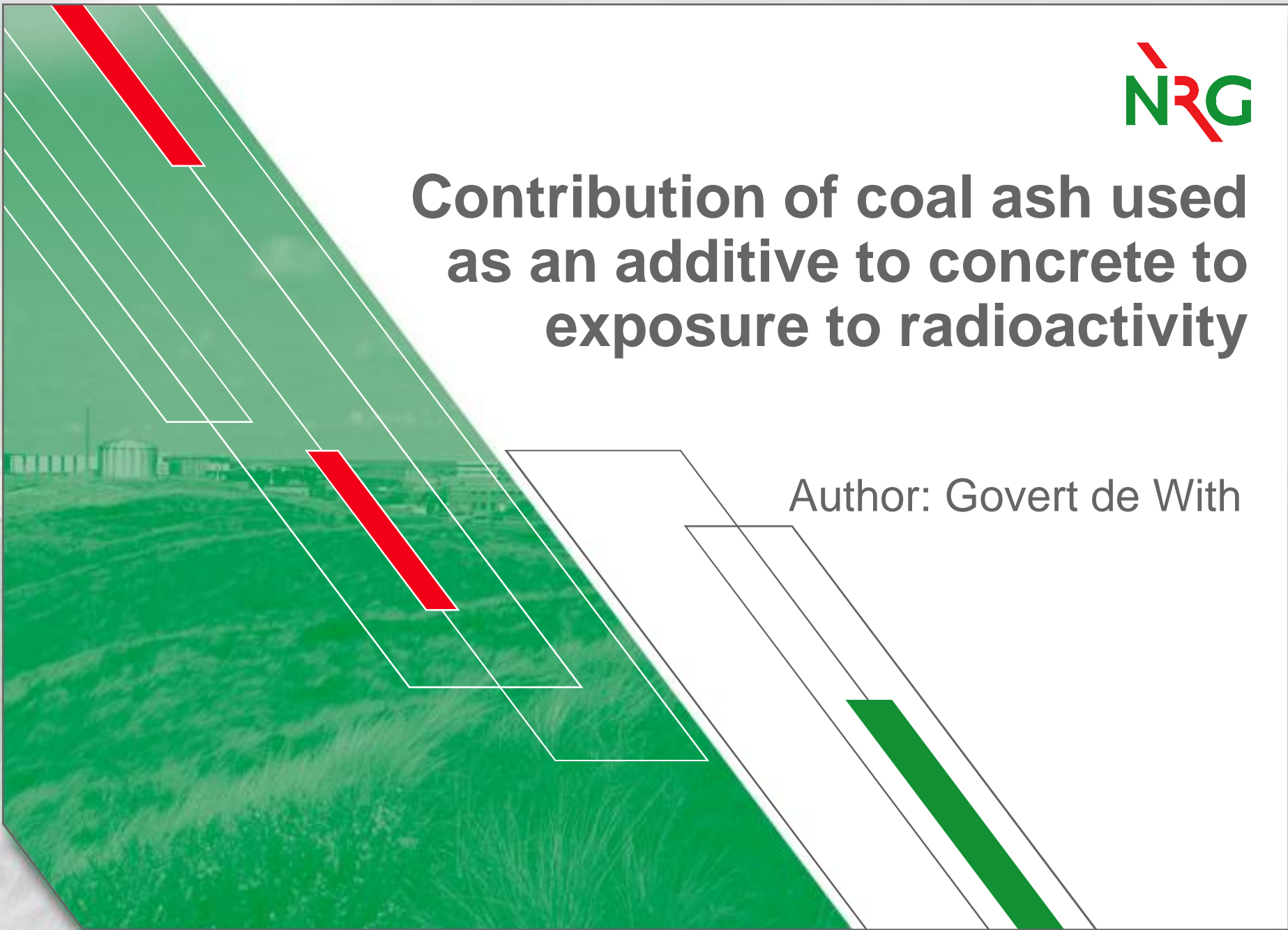


Contribution of coal ash used as an additive to concrete to exposure to radioactivity

Author: Govert de With



Contents

1. Introduction
2. Measurements
3. Dose assessment
4. Conclusions

1.1 Introduction

- Radon exhalation measurements on 5 concrete samples
- Gamma spectrometry on 5 types of concrete, for each type 3 samples are tested
- Measurement on radon exhalation according to NEN 5699
- Measurement of the activity concentration according to NEN 5697
- Assessment of the external and internal radiation exposure for a typical room dimension

2.1 The radon exhalation measurement



- The radon exhalation rate is determined according to NEN 5699
- The samples are enclosed in a container that is purged with nitrogen gas with a relative humidity of 50%.
- The exhaled radon, carried along with the nitrogen gas, is trapped on silica gel at -190°C .
- After sufficient radon has been trapped, the nitrogen stream is stopped and the trapping agent analysed by liquid scintillation counting.
- The results are expressed as mass exhalation rates by normalizing the amount of exhaled radon per kg material.

2.2 Results from the measurement

Sample code	Exhalation rate					
	Weight (kg)	($\mu\text{Bq/s}$)		($\mu\text{Bq/kg/s}$)		(%)
		x	SD	x	SD	SD
7013	14.34	90.3	5.0	6.3	0.3	5.5
7014	14.40	87.2	19.8	6.1	1.4	22.6
7015 (check!)	14.30	103.7	2.1	7.2	0.1	2.0
7017	14.42	84.4	15.9	5.9	1.1	18.9
7019	14.52	84.4	10.2	5.8	0.7	12.1

2.3 The gamma spectrometry measurement



- The radioactivity concentrations are determined according to NEN 5697.
- According to this method the density dependent photo peak efficiencies are determined for the gamma-ray energies 352 keV (^{214}Pb), 583 keV (^{208}Tl), 911 keV (^{228}Ac) and 1,461 keV (^{40}K).
- Four calibration standards are assembled with increasing densities.
- The standards are placed into Marinelli beakers with a volume of about 1 litre, weighted and closed radon-tight.
- A waiting time of at least three weeks is taken into account before counting the samples.

2.4 Measured activity concentration

Sample code	Weight (kg)	Activity concentration (Bq/kg)							
		²²⁶ Ra		²²⁸ Th		²²⁸ Ra		⁴⁰ K	
		x	SD	x	SD	x	SD	x	SD
7013-A	1.443	34	2	6	1	6	0	48	3
7013-B	1.441	35	2	7	1	7	0	49	3
7013-C	1.523	35	4	6	1	6	1	46	2
7014-13	1.418	36	2	9	1	8	1	75	3
7014-14	1.544	33	3	9	1	8	1	68	5
7014-15	1.379	37	2	10	1	9	1	78	3
7015-13	1.474	36	4	10	1	10	1	48	2
7015-14	1.477	37	4	11	1	10	1	50	2
7015-15	1.512								
7017-16	1.432	41	2	10	1	10	1	74	3
7017-17	1.505	40	2	8	1	9	1	73	3
7017-18	1.476	40	2	10	1	9	1	73	3
7019-20	1.544	36	2	9	1	9	1	55	3
7019-21	1.430	38	2	10	1	8	1	59	3
7019-22	1.148	47	4	11	1	11	1	72	3

3.1 Assessment from external radiation



- **External radiation**

External:
$$E_{\text{ext},i} = \frac{\sum(A_n * m_n / m_{\text{ref}} * F_{\text{dose}})}{\sum A_n * c_{\text{l-eff}}}$$

- Dose factor needs to be computed for each substructure

$$F_{\text{dose}} = k_{\text{Ra-226}} * a_{\text{Ra-226}} + k_{\text{Ra-228}} * a_{\text{Ra-228}} + k_{\text{K-40}} * a_{\text{K-40}}$$

- Nuclide specific conversion coefficients to compute the dose factor at reference density are provided.

Ra-226	0.90 nGy×h ⁻¹ per Bq×kg ⁻¹
Th-232	1.10 nGy×h ⁻¹ per Bq×kg ⁻¹
K-40	0.08 nGy×h ⁻¹ per Bq×kg ⁻¹

3.2 Exposure from external radiation

- The absorbed dose varies between 0.2 and 0.26 mSv.

Sample code	D (Sv/j)
7013	2.0E-04
7014	2.3E-04
7015	2.2E-04
7017	2.6E-04
7019	2.5E-04

3.4 Radon concentration from the building materials

- The contribution from building materials to the radon concentration varies between 15 and 19 Bq/m³
- The equilibrium factor is computed to be around 0.35, which is lower than the default 0.4
- The progeny concentrations are used to compute the EEC

Sample code	Activity concentration (Bq/kg)			
	²²² Rn	²¹⁸ Po	²¹⁴ Pb	²¹⁴ Bi
7013	16.2	13.5	5.3	2.6
7014	15.6	13.0	5.1	2.5
7015	18.6	15.6	6.1	2.9
7017	15.1	12.6	4.9	2.4
7019	14.9	12.5	4.9	2.4

3.5 Total dose assessment

- The absorbed dose radon is between 0.55 and 0.62 mSv.
- As a result the total dose rate varies between 0.78 and 0.83 mSv/y.

Sample code	Dose assessment			
	hours (h)	Cf (Sv/(Bq h/m ³))	DRn222 (Sv/j)	DTot (Sv/j)
7013	7000	9.00E-09	5.74E-04	7.79E-04
7014	7000	9.00E-09	5.62E-04	7.93E-04
7015	7000	9.00E-09	6.23E-04	8.28E-04
7017	7000	9.00E-09	5.51E-04	7.82E-04
7019	7000	9.00E-09	5.49E-04	8.04E-04

END