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Study of impact of the radiation on concrete structure behaviour

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Fine aggregate mixed-Portland cement concrete was exposed to the doses of 1.6 to 1.8 ·10^6 Gy (1.6 to 1.8 ·10^8 rad) with a rate of 0.5 to 4.5 kGy per hour under the temperature 24±3°C in a gamma radiation cell with a gamma source of 172 TBq (^{60}Co).

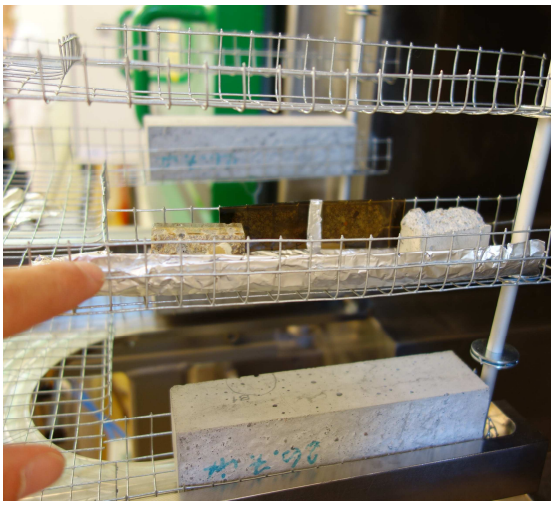

Figure 1. Samples of the first batch introduced in the irradiation cell with the cobalt ^{60}Co source of 172 TBq

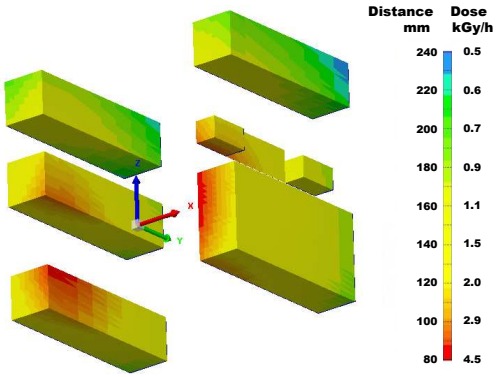

Figure 2. Distribution of the distances from the ^{60}Co source i.e. from the centre of axes x, y, z and corresponding gamma radiation dose after removing the first batch and adding the second one

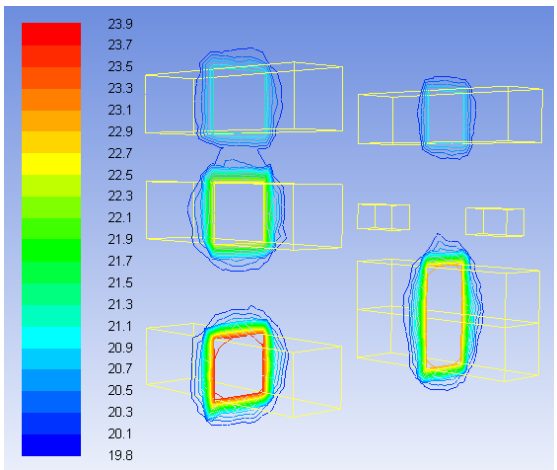

Figure 8. Distribution of the temperatures within cross-section of the prisms (40 x 40 x 160 mm) in °C

The composition of the concrete was selected according to the sample size and the requirements of the standards. Also to fit to the Czech NPPs composition taking into account their fine aggregate composition, i.e. siliceous sand 0 ÷ 4 mm.
Little prisms 40x40x160 mm made of standardized siliceous sand 0 ÷ 2 mm were tested after 21 days in the gamma radiation cell non-destructively by ultrasonic and resonance methods to check the change of the E-modulus of irradiated concrete (see Figures 4 and 5).
All samples were taken out of the cell after next 27 days and tested non-destructively and destructively. Smaller pieces of dimensions 20x20x40 or 0.1x20x40 mm (Figures 1 and 2) were targeted for the microscopic assessment. Results of scanning electron microscope can be seen in Figure 3.

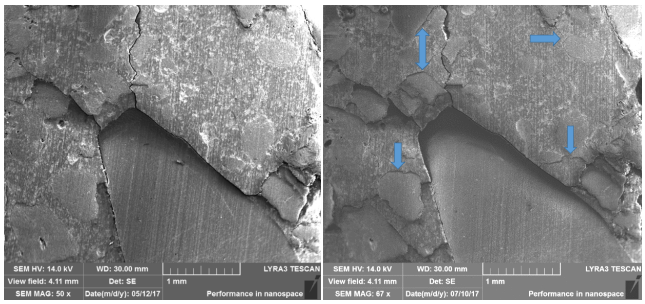

Figure 3. SEM micrograph of the concrete before (left) and after irradiation (right). Presence of micro-cracks between aggregate and cement paste after irradiation

Figure 4. Non-destructive testing of samples after 21 days of irradiation by ultrasonic method

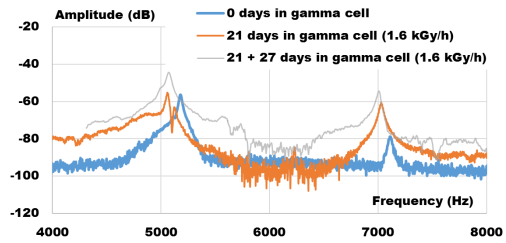

Figure 5. Records of resonance method impact-echo. Lower peak-frequency is caused by lowered E-modulus. The dependency is described as $E \sim f^2$

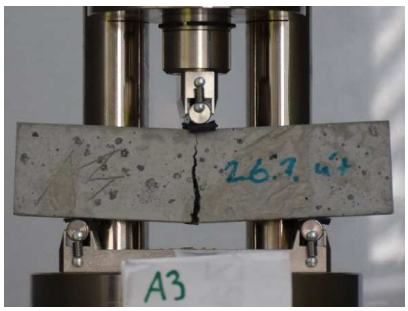

Figure 6. Broken reference sample A3

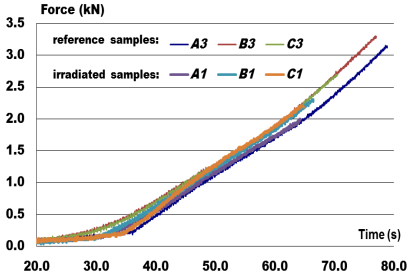

Figure 7. Records of 3-point bending test of prisms. Breaking forces are about 30 ± 9% higher for the reference samples

CONCLUSIONS

The strongest effect of the gamma irradiation seems to be:

1. Decrement of the tensile strength by 30 % (Figures 6 and 7) due to the micro-cracks.
2. Occurrence of micro-cracks (Figure 3) which should be forced by hydrogen produced by water radiolysis. Hydrogen production was studied in paper [1].
3. Increment of the temperature by about +3°C in the centre of the sample (Figure 8).
4. The values of E-moduli changed -1 to -5 % after the mid-term irradiation (0.8 to 1.2 ·10^6 Gy) and stayed nearly the same after another 27 days in gamma cell (1.6 to 1.8 ·10^6 Gy).

REFERENCES

1.KONTANI, O., SAWADA, S., MARUYAMA, I., TAKIZAWA, M., SATO, O., Evaluation of Irradiation Effects on Concrete Structure: Gamma-Ray Irradiation Tests on Cement Paste. POWER2013-98099 (2013).

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