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# Expert report no. 321000278-1

**Work order date** : 05/03/2020

**Client:** PERI GmbH
Rudolf-Diesel-Straße 19
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Germany

**Work order:** Analysis of the shielding protection provided by a 300-mm-thick concrete wall against radiation measuring 100 keV, 200 keV, 300 keV, 450 keV and gamma radiography devices with selenium-75 and iridium-192 on the basis of DIN standards 54113 and 54115.

**Test object:** 300-mm-thick concrete wall with cone-shaped recesses on both sides and iron connecting element cast into the concrete.
Iron connecting element (Spannstab DW15) and
Cone-shaped recesses (KM-PER/LAV311)

## Introduction

Cast concrete walls are used to lower the intensity of ionised radiation. Wall thicknesses of up to 1 metre are required for radiation energy in the range of several hundred kiloelectron volts (keV). Formwork elements that are connected using steel tie rods are used to produce such concrete walls. The formwork elements are connected to one another using these steel tie rods at roughly every 1 to 2 square metres of wall surface. These connecting elements remain in the concrete wall after the concrete has been poured and has hardened. This process also produces cone-shaped recesses on both external sides of the concrete wall in the areas near the connecting elements.
The connecting elements (steel tie rods) and also the cone-shaped recesses may reduce the absorption capacity of the concrete wall.

The objective is to estimate the absorption capacity of a 300-mm-thick concrete wall, whose concrete density is 2.3 g/cm$^3$, on the basis of the DIN standards 54113 and 54115. The radiation energy levels 100 keV, 200 keV, 300 keV and 450 keV of X-ray tubes and gamma radiography devices, which feature the nuclides Se-75 (maximum gamma energy of 270 keV) and Ir-192 (maximum gamma energy of 900 keV), shall be considered.
After the poured concrete has hardened and the formwork elements have been removed, the cone-shaped recesses in the areas near the steel tie rods that remain in the concrete wall are closed with concrete cones. They are fixed in the recess with an adhesive (Dichtungskleber-3).

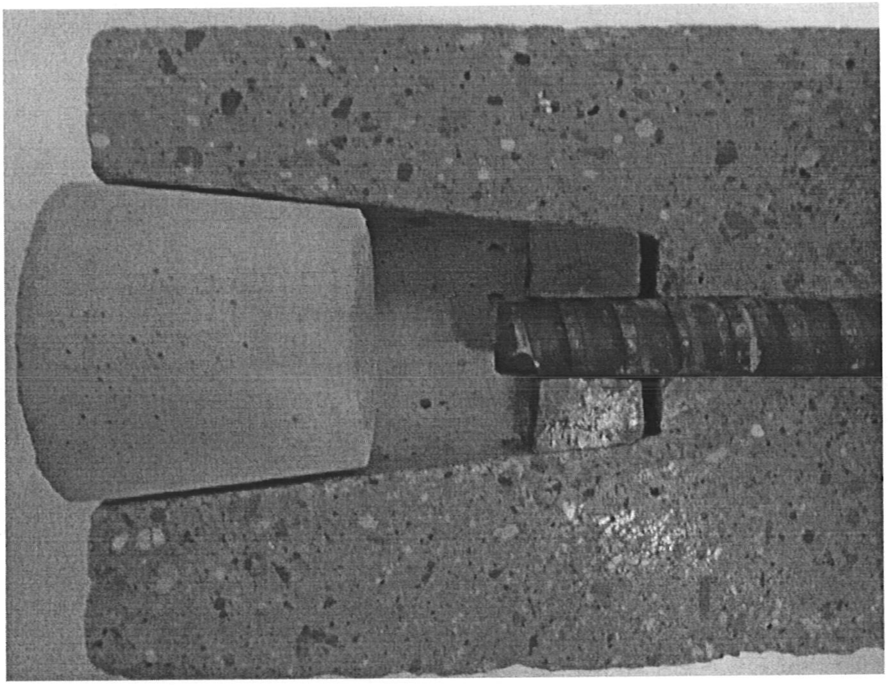
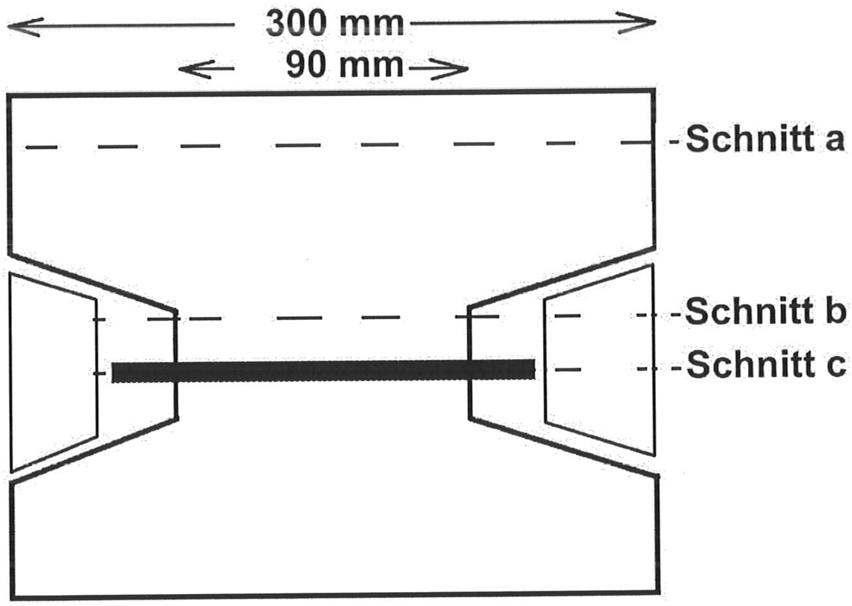


Photo 1: Cross-section of a cone-shaped recess. A lead disc and a concrete cone have been inserted into the recess. The lead disc surrounds the steel tie rod. Photo provided by the client.




Sketch 1: Cross-section of masonry with cross-sections a, b, c.
Cross-section a: 300 mm concrete (density 2.3 g/cm$^3$)
Cross-section b: 90 mm concrete (2.3 g/cm$^3$) plus 2 x 52 mm concrete cone (2.3 g/cm$^3$)
Cross-section c: 170 mm concrete (8.0 g/cm$^3$) plus 2 x 52 mm concrete cone (2.3 g/cm$^3$)
Examples of parts used: : Betonkonus UNI 58/52 (Art.Nr.: 031643), Dichtungskleber-3 (Art.Nr.: 131709), Spannstahl DEW15 (Art.Nr.: 030030).

## Preliminary considerations

In order to ensure that the shielding capacity of the 3 different materials (lead with a density of 11.0 g/cm$^3$, concrete (2.3 g/cm$^3$) and iron (8.0 g/cm$^3$) is comparable at the different radiation energy levels of 100 keV to 900 keV, the different masonry structures (see cross-sections a, b, c in sketch 1) are converted to lead equivalents. The lead equivalent is the layer thickness of lead that exhibits the same level of shielding protection against ionised radiation as the given layer thickness of the material actually used.

| | Layer thickness in [mm] | 100keV | 200keV | 300keV | 450keV | Se-75 | Ir-192 |
|---|---|---|---|---|---|---|---|
| | | Lead equivalent in [mm] | | | | | |
| Concrete | 300 | 5,2 | 4,7 | 8,5 | 15,0 | 11,8 | 27,5 |
| Iron | 300 | 46,0 | 18,8 | 23,0 | 30,0 | 75,0 | ca. 120,0 |
| Concrete | 170 | 3,2 | 2,2 | 3,5 | 6,0 | 5,2 | ca. 28,0 |
| Iron | 170 | 26,2 | 10,6 | 13,1 | 17,0 | 38,6 | ca. 70,0 |

Table 1: shielding capacity of a 300-mm-thick and a 170-mm-thick layer of concrete or of iron at different radiation energy levels. Example: at a radiation energy level of 100 keV, the radiation intensity is lowered to the same extent by a 5.2-mm-thick layer of lead or a 300-mm-thick layer of concrete.

## Variations in material density

Density variations in the iron connection parts are acceptable because the shielding effect of the iron connecting parts (see cross-section b) are always far greater than that of the concrete wall.
Density variations in the approximately 52mm long concrete cone in the range from 1.9 g/cm³ to 2.3 g/cm³ change - when using 2 concrete cones (resulting material thickness 104mm) - maximally the lead equivalent by approximately 0,5 mm lead.

## Shielding capacity of a concrete wall with steel tie rods

The following tables detail the lead equivalent of the concrete wall at the different segments (cross-sections a, b, c) at different radiation energy levels (100 keV to 900 keV, for Ir-192 and for Se-75).
The lead equivalents in the areas around cross-sections b and c must, at the very least, reach the lead equivalent of the area around cross-section a so that the shielding capacity is equal across all segments of the concrete wall. If this is not the case, an additional shielding layer (e.g. lead) must be integrated into the areas around the cross-sections b and/or c.

Cross-section a: 300 mm concrete (density 2.3 g/cm$^3$)
Cross-section b: 90 mm concrete (2.3 g/cm$^3$) plus 2x 52 mm concrete cone (2.3 g/cm$^3$)
Cross-section c: 170 mm iron (8.0 g/cm$^3$) plus 2x 52 mm concrete cone (2.3 g/cm$^3$)

| Radiation energy | 100keV | Lead equivalent in [mm] | Additional layer of lead required in [mm] |
|---|---|---|---|
| Cross-section a | | 5,2 | |
| Cross-section b | | 3,1 | 2,1 |
| Cross-section c | | 27,6 | |

| Radiation energy | 200keV | Lead equivalent in [mm] | Additional layer of lead required in [mm] |
|---|---|---|---|
| Cross-section a | | 4,7 | |
| Cross-section b | | 2,5 | 2,2 |
| Cross-section c | | 11,7 | |

| Radiation energy | 300keV | Lead equivalent in [mm] | Additional layer of lead required in [mm] |
|---|---|---|---|
| Cross-section a | | 8,5 | |
| Cross-section b | | 4,3 | 4,2 |
| Cross-section c | | 14,6 | |

| Radiation energy | 450keV | Lead equivalent in [mm] | Additional layer of lead required in [mm] |
|---|---|---|---|
| Cross-section a | | 15,0 | |
| Cross-section b | | 7,0 | 8,0 |
| Cross-section c | | 19,3 | |

| Radiation energy | Se-75 | Lead equivalent in [mm] | Additional layer of lead required in [mm] |
|---|---|---|---|
| Cross-section a | | 11,8 | |
| Cross-section b | | 5,5 | 6,3 |
| Cross-section c | | 41,1 | |

| Radiation energy | Ir-192 | Lead equivalent in [mm] | Additional layer of lead required in [mm] |
|---|---|---|---|
| Cross-section a | | 27,8 | |
| Cross-section b | | 15,3 | 12,5 |
| Cross-section c | | 75,9 | |

Comments
Any gaps that may be present between the inserted cones are not taken into account in the theoretical calculations according to DIN standards 54113 and 54115. Even if the cones are fixed with a sealing adhesive (e.g. Dichtungskleber-3, density 1.74 g / cm$^3$), the level of shielding protection against ionised radiation of the sealing adhesive is lower than that of the other used wall materials. Therefore, make sure there are no gaps around the cones inserted into the concrete wall.

## Summary

Compared to the area around cross-section a (concrete wall thickness of 300 mm), the concrete material thickness around cross-section b is lower. Lead material with a thickness of at least 12.5 mm must be inserted into the area of cross-section b so as to ensure the same level of shielding capacity as cross-section a. This additional material should be added to the side of the wall that faces the radiation.

Dortmund, 8th May 2020
On behalf of

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Scientific employee

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