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Evaluation of the Durability of a Nuclear Bomb Shelter Made with Anti-Sievert® Concrete

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ABSTRACT

We have developed Anti- Sievert® concrete, which is a concrete reinforced shielding function as a building material that shields the influence from radioactive materials and its radiation. Cement, water, aggregate, sand material, Anti- Sievert® # 210, Anti- Sievert® # 216 formulation was optimized as those materials constituting Anti- Sievert® concrete. As a result, we realized shielding concrete with high fluidity to realize construction suitability by concrete pump[1]. Anti- Sievert® concrete has a shielding function of about 3 times as compared with ordinary concrete with respect to X ray (100 kV), and shows strength of more than 50 N/mm^2. The durability characteristics against nuclear explosion using Anti-Sievert® concrete were simulated and reported in this paper.

INTRODUCTION

We developed shielding concrete as a building material that shields the influence from radioactive materials and radiation. This concrete is a material compounded with Anti-Sievert® (high density ceramic material). We optimized the formulation of cement, water, aggregate, sand material, Anti-Sievert® #210 and Anti-Sievert® #216 which are materials constituting Anti-Sievert® concrete mixed with high performance water reducing material.

Assuming a shelter using Anti-Sievert® concrete, the durability characteristics against nuclear explosion was simulated. As a result, it was confirmed that Anti-Sievert® concrete has high strength and shows excellent durability.

PREPARATION OF THE ANTI-SIEVERT® CONCRETE

Anti- Sievert® shielding material

Lead is a typical material that shields radiation such as γ rays, and X-rays. Generally, the mass absorption coefficient for γ rays, X-rays, etc. depends on the density of the substance. However, from the viewpoint of safety and economy, a Brite crystal material is the most effective for radiation shielding. Especially materials for concrete, other choices will be difficult.

Evaluation of concrete using Barite crystal[2] has been conducted, but it is not sufficient in terms of fluidity and strength as concrete. We have developed a combination of fluidizing agents for improving fluidity by utilizing extremely fine Barite. Anti-Sievert® #210 shielding material is made of a uniform powder having a particle size of micrometer order as its main material.

The Anti-Sievert® concrete

1) Standard formulation

The concrete mixed with the Anti-Sievert® #210 and #216[1] that shows radiation shielding function was prepared. Table 1 shows the standard formulation of the Anti-Sievert® concrete. Cement used ordinary portland cement.

Component	Water	Cement	Sand	Stone	Anti-Sievert® #210	Aggregate	Anti-Sievert® #216
Mixing amount (kg/m^3)	165	350	550	140	350	900	7

Table 1 Standard formulation of the Anti-Sievert® concrete

2) Concrete adjustment

Cement, sand, stone, the Anti-Sievert®#210 and aggregate were put in a mixer and pre-mixed for 10 seconds, then water and the Anti-Sievert®#216 were added and mixed for 120 seconds. Figure 1 shows the mixer used.

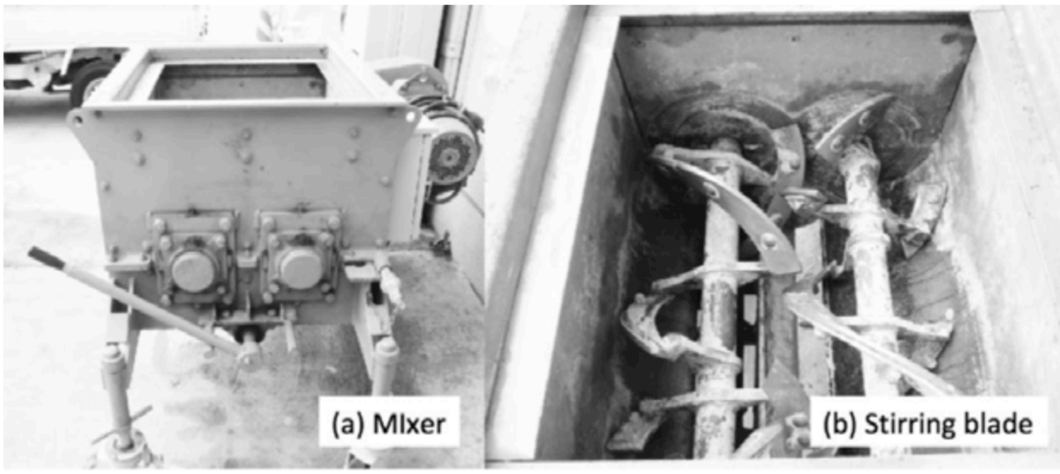

Figure 1 Photographs of a mixer for test production of the Anti-Sievert® concrete. (a) shows appearance of the mixer, (b) shows blender blade of the mixer.

SIMULATION

About blast pressure

In this report, the blast pressure was calculated by Hopkinson-Cranz's scale rule. Assumed nuclear explosion size is 50 kton.

W: Equivalent amount of TNT (kg), R: Distance from the explosive center (m), K: converted distance (m),

ρ_{so}: Maximum blast pressure (kPa)

$$\rho_{so} = 476.2 \times K^{-1.40} \quad (1)$$

In this equation, $K=R/W^{1/3}$, W=50,000,000.

Simulation

Strength simulation of Anti-Sievert® concrete with the ρ_{so}: maximum blast pressure (kPa) was carried out using MidasGen (KOZO KEIKAKU ENGINEERING Inc.) program system.

Mises stress was calculated using the distance from the hypocenter and the Anti-Sievert® concrete thickness as parameters. In addition, the Anti-Sievert® concrete assumed area is 2 × 2 (m^2).

X-ray shielding effect

The X-ray shielding effect was carried out under the condition of using an X-ray apparatus (ML-452 type by AErON International Corporation), X-ray tube focus-sample distance: 1500 mm, sample-measuring instrument distance: 50 mm.

RESULTS AND DISCUSSION

Compressive Strength of Anti-Sievert® Concrete

Figure 2 shows the compressive strength of Anti-Sievert® concrete at several water/cement ratios. The compounding amount of Anti-Sievert® #210 was 350 kg/m^3. When the water/cement ratio was 0.47, the compressive strength was 50 N/mm^2 or more. This compressive strength is twice that of general concrete.

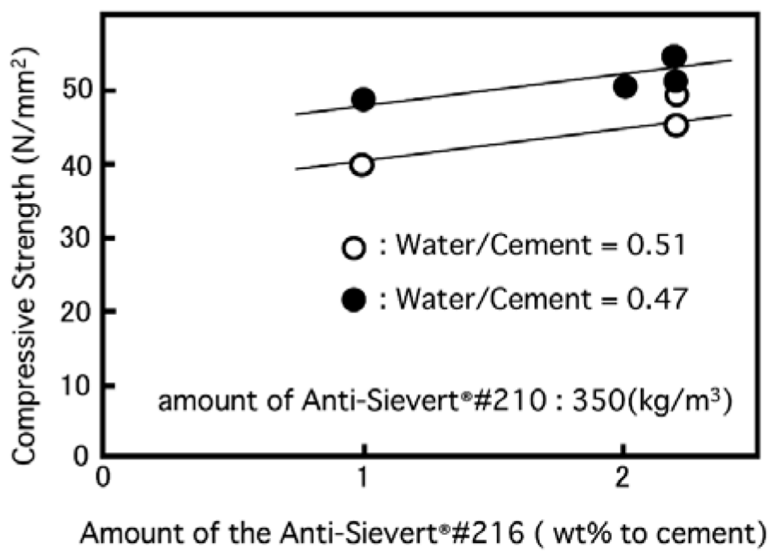

Figure 2 Compressive strength of the several Anti-Sievert® concretes.

X-ray shielding properties of Anti-Sievert® concrete

Figure 3 shows the relationship between the shielding property Sa of Anti-Sievert® concrete and general shielding property So of concrete and the applied voltage generating X rays. It is understood that Sa/So becomes larger as the applied voltage, that is, the energy of the X-rays becomes smaller, and shows a larger shielding effect than general concrete.

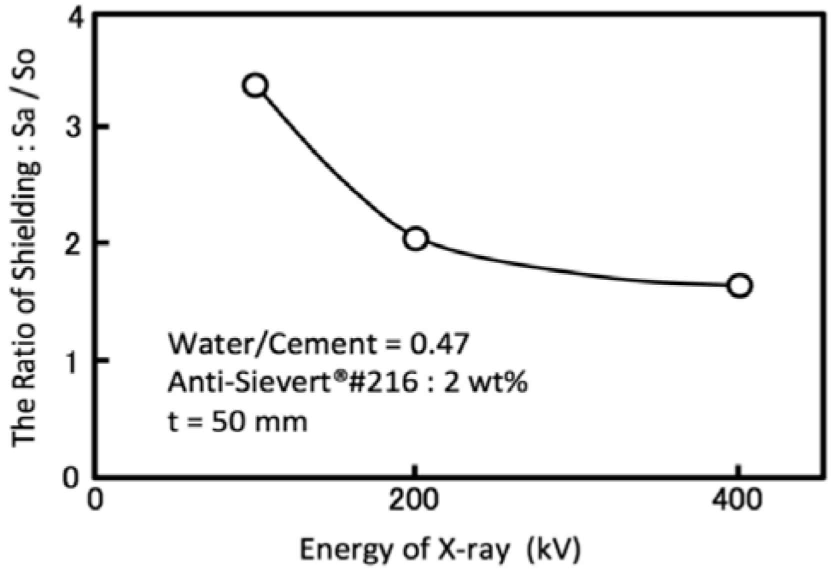

Figure 3 Relation of the Sa/So and energy of X-ray the Anti-Sievert® concrete.

Figure 4 shows the relationship between the thickness of Anti-Sievert® concrete and X-ray shielding properties. With 200 kV X-rays, it can be shielded with 10cm Anti-Sievert® concrete.

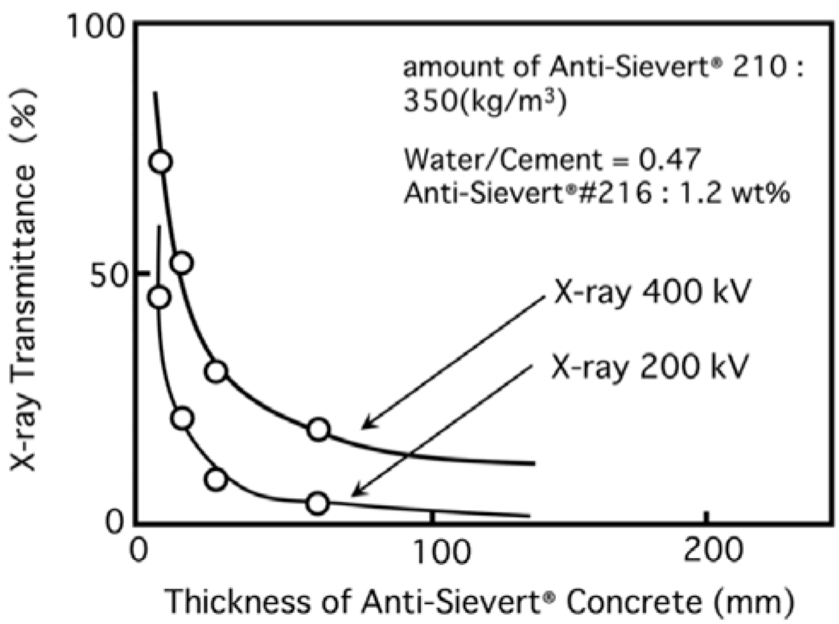

Figure 4 Relation of X-ray transmittance and thickness of the Anti-Sievert® concrete.

Figure 5 shows the relationship between the thickness of Anti-Sievert® concrete and the corresponding lead thickness. It is understood that Anti-Sievert® concrete of about 100mm corresponds to 5mm of lead plate material.

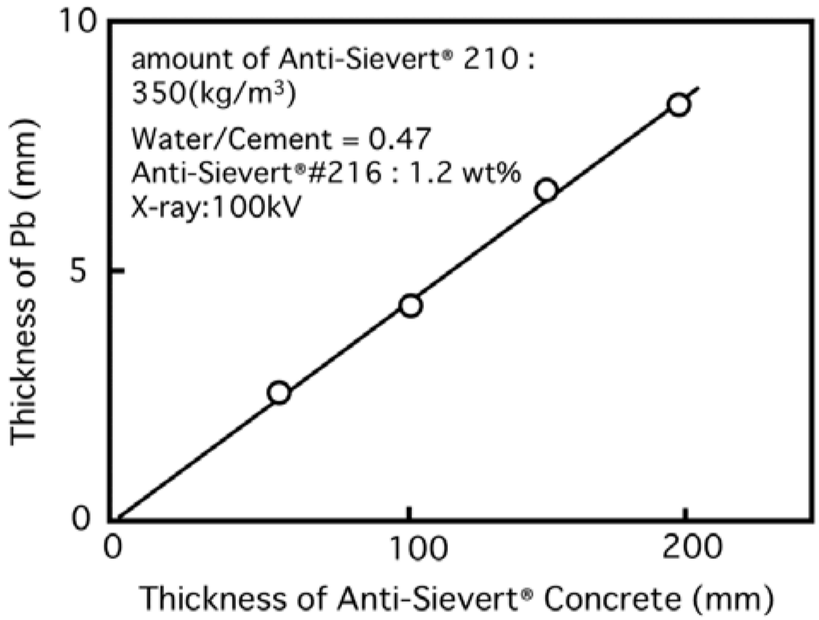

Figure 5 Relation of thicken of the Anti-Sievert® concrete and thickness of Pb.

FRACTURE SIMULATION OF ANTI-SIEVERT® CONCRETE

Figure 6 shows the relationship between the Mises stress and the distance from the hypocenter at the blast pressure of 50kton nuclear bomb. In the figure, simulation results are shown by changing the thickness of Anti-Sievert® concrete.

In the figure, the line assuming the compressive strength of Anti-Sievert® concrete as $50N/mm^2$ and $40N/mm^2$ are described. In addition, in the figure, the line assuming the compressive strength of general concrete as $25N/mm^2$ is shown. The compressive strength of Anti-Sievert® concrete are refer to figure 2. The compressive strength of a general concrete is shown in JIS. It is shown that Anti-Sievert® concrete exhibiting smaller Muses stress than this line can withstand blast pressure by 50kton nuclear bomb.

It shows that Anti-Sievert® concrete with thickness of about 15cm can withstand blast pressure by 50kton nuclear bomb at a distance of about 1km from the hypocenter. And the Anti-Sievert® concrete material have high shielding effect against radiation.

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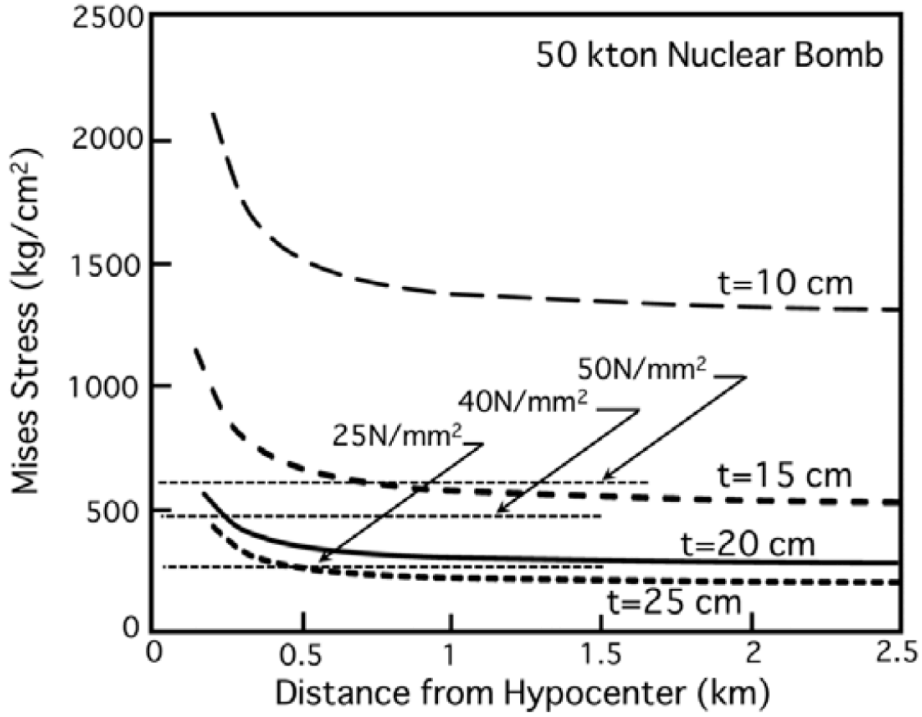

Figure 6 Relation of the Mises stress and distance from hypocenter.

SUMMARY

We developed a radiation shielding material Anti-Sievert® #210 which gives radiation shielding function to concrete which is a general purpose building material, and Anti-Sievert® material of fluidizing material #216. Using these materials, Anti-Sievert® concrete with radiation shielding function was fabricated and the strength was evaluated by simulation assuming nuclear explosion. This Anti-Sievert® concrete has an X-ray shielding function two to three times as compared with conventional concrete and shows extremely high breaking strength exceeding 50N/mm^2. We showed that we can effectively construct a shelter for nuclear explosion by our Anti-Sievert® concrete.

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Anti-Sievert®

放射線を遮蔽する代表的な素材は，“鉛”でした．近年の環境意識の高まりに伴い，環境に悪影響を与える物質（環境負荷物質）である鉛の排除が求められています．
＊２００６年７月欧州 WEEE&RoHS 指令にて鉛を含む製品は販売できません
アンチシーベルト®はγ線などを散乱吸収する物質であり，多様な材料と複合化させて放射線を遮蔽します．「安心」「安全」で「地球にやさしい」機能物質です．

A typical material that shields radiation is "lead". Along with the recent rise in environmental awareness, the elimination of lead, which is a substance (environmental burden substance) that adversely affects the environment, is required.
* In July 2006, products containing lead can not be sold under the European WEEE & RoHS Directive
The Anti-Sievert® is a material that scatters and absorbs γ-rays and X-rays, and it combines with various materials to shield the radiation. The Anti-Sievert® is "Reliable" "Safe" and "Earth friendly" functional substance.

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