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Development of X-ray Shield Concrete for Secure Safety Against the Impact of the Fukushima Accident

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ABSTRACT

TEPCO Fukushima Daiichi Nuclear Power Plant has meltdown due to the huge earthquake and tsunami that occurred on March 11, 2011. As a result, radioactive substances were dissipated into the environment, which caused concern about continuous radioactive substances.
We have developed Anti-Sievert® concrete, a shielding concrete, as a building material that shields the influence from radioactive materials and radiation. Cement, water, aggregate, sand material, Anti-Sievert®#210, Anti-Sievert®#216 formulation were optimized as materials constituting Anti-Sievert® concrete. As a result, we realized shielding concrete with high fluidity to realize construction suitability by concrete pump. Anti-Sievert® concrete has a shielding function of about 3.5 times as compared with ordinary concrete with respect to X-ray, and shows strength of more than 50N/mm^2.
These results show that Anti-Sievert® concrete is an excellent X-ray shielding material and is a practical material having extremely large durability and strength.

INTRODUCTION

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

As a result, we realized high shielding concrete with high fluidity to realize construction suitability by using with concrete pump. The Anti-Sievert® concrete has a high shielding function of about 3.5 times as compared with ordinary concrete with respect to X-ray (100 kV) and shows compressive fracture strength of more than 50 N/mm^2. These results show that the Anti-Sievert® concrete is an excellent X-ray shielding material and is a practical material having extremely high durability and strength.

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PREPARATION of the Anti-Sievert® CONCRETE

The 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, I would like to use a Barite crystal material. Especially other choices will be difficult using for construction materials like concrete.

Evaluation of concrete using crystallite barite [1] 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 powder. The Anti-Sievert®#210[2] 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[2] that shows radiation shielding function was prepared. Table 1 shows the standard formulation of the Anti-Sievert® concrete. Cement used ordinary portland cement.

Table 1. Standard formulation of the concrete

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

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.

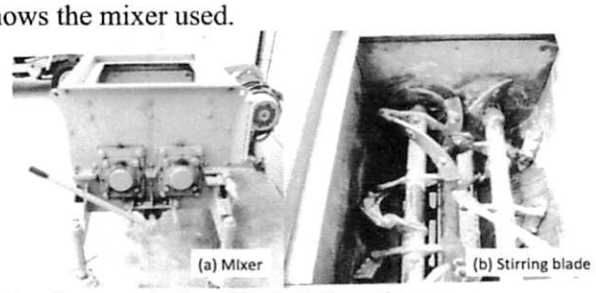

Figure 1. A photograph of a mixer for test production of the Anti-Sievert® concrete.

3) The Anti-Sievert® concrete

The samples for compressive fracture stress test and X-ray shielding property measurement specimens were prepared using the Anti-Sievert® concrete. The samples were

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prepared by changing the amount of the Anti-Sievert®#216 added, water/cement ratio, and the Anti-Sievert®#210 blending amount.

MEASUREMENT

1) Characteristics of the Anti-Sievert® concrete

Various characteristics of the Anti-Sievert® concrete were measured using the method indicated in each JIS (Japanese Industrial Standards).

- Slump flow: JIS A 1101
- Amount of contained air: JIS A 1128
- Compressive strength: JIS A 1132

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

Fluidity of the Anti-Sievert® concrete

Figure 2 shows the relationship between the slump flow of the Anti-Sievert® concrete and the addition amount of the Anti-Sievert®#216. It can be seen that when the Anti-Sievert®#216 is added in an amount of about 1.2 wt%(to amount of cement) or more, the slump flow value is 35 cm. Based on this slump flow value, it can be confirmed that this Anti-Sievert® concrete has good workability.

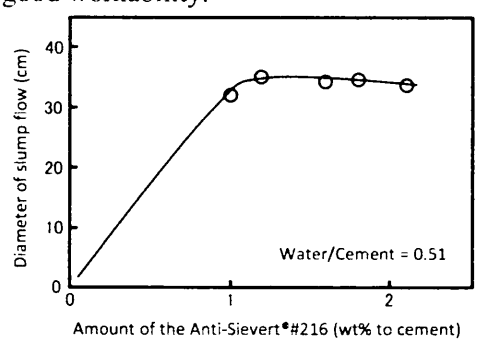

Figure 2. Amount of the Anti-Sievert®#216 and slump flow value of the Anti-Sievert® concrete.

Air content of Anti-Sievert® concrete

Figure 3 shows the relationship between the air content of Anti-Sievert® concrete and the addition amount of the Anti-Sievert®#216. When the Anti-Sievert®#216 was added in an amount of about 1.8 wt% or more, the air content saturated at about 4%.

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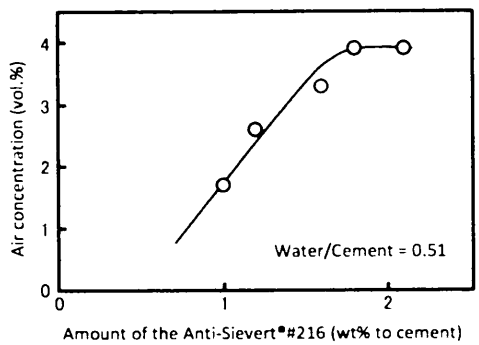

Figure 3. Amount of the Anti-Sievert®#216 and air concentration of the Anti-Sievert® concrete.

Anti-Sievert®#210 addition amount

Figure 4 shows the relationship between the amount of the Anti-Sievert®#210 added and the slump flow value of the Anti-Sievert® concrete. The slump flow value, that is, the fluidity of the Anti-Sievert® concrete decreased with the addition amount of the Anti-Sievert®#210 when the water/cement ratio was 0.47, and it became unmeasurable value when it was 350 kg/m^3 or more. Also, when the water/cement ratio was 0.51, the slump flow was 30 cm at 500 kg/m^3.

It is understood that the addition amount of the Anti-Sievert®#210 is preferably 350 kg/m^3 when the water/cement ratio is 0.47. Based on this slump flow value, it can be confirmed that this Anti-Sievert® concrete has good workability.

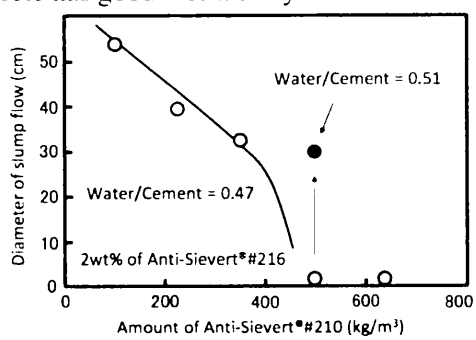

Figure 4. Amount of the Anti-Sievert®#210 and the slump flow value of the Anti-Sievert® concrete.

Compressive strength of Anti-Sievert® concrete

Figure 5 shows the compressive strength of the Anti-Sievert® concrete at several water/cement ratios. The compounding amount of the Anti-Sievert®#210 was 350 kg/m^3. When the water/cement ratio was 0.47, the compressive strength is 50N/mm^2 or more. This compressive strength is twice that of general concrete.

Uniformity of the Anti-Sievert® concrete

Figure 6 shows a cross section observation photograph of the Anti-Sievert® concrete. Since the Anti-Sievert®#210 has a large density, there is concern that sedimentation will occur.

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As shown in Fig. 6, it is observed that the aggregate and the like constituting the Anti-Sievert® concrete are uniformly mixed.

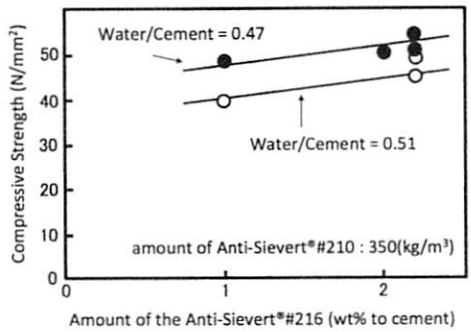

Figure 5. Compressive strength of the several the Anti-Sievert® concretes.

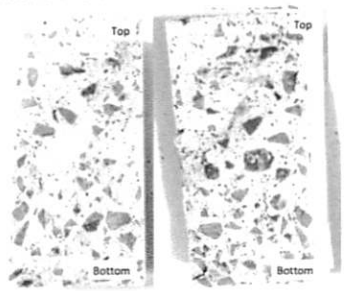

Figure 6. Cross section photograph of the several Anti-Sievert® concretes.

X-ray shielding characteristics of the Anti-Sievert® concrete

Figure 7 shows the relationship between the ratio Sa/So (Sa : shielding property with the Anti-Sievert® concrete, So : shielding property with ordinary concrete) and the applied voltage generating X-rays. It is understood that Sa/So increases as decrease the applied voltage, that is, the energy of the X-rays becomes smaller, and shows larger shielding effect than general concrete.

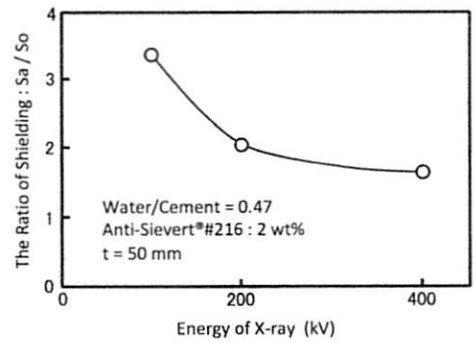

Figure 7. Relation of the Sa/So and energy of X-ray.

X-ray Attenuation characteristics of the Anti-Sievert® concrete

Figure 8 shows the relationship between the degree of opacity *D* and the thickness of the Anti-Sievert® concrete. The opacity *D* is defined by the following equation.

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$D = \log_{10}(I_0 / I_t)$ I_0: incident X-ray intensity, I_t: transmitted X-ray intensity

In the figure, the opacity Do of general concrete and the opacity Da of the Anti-Sievert® concrete are shown. Both Do and Da are proportional to the thickness of the sample. Further, the ratio of the slopes of both is about 2.2, which is consistent with the ratio of the shielding characteristics in figure 7.

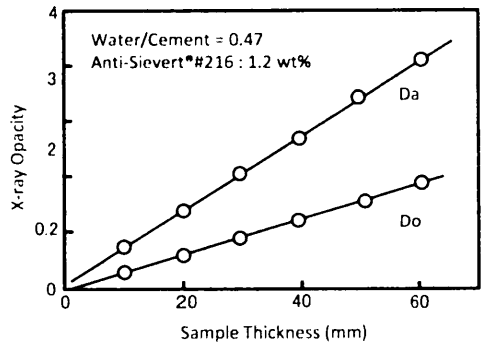

Figure 8. Relation of the opacity of X-ray between the thickness of the Anti-Sievert® concrete and ordinary concrete.

SUMMARY

We developed a radiation shielding material the Anti-Sievert®#210 which gives radiation shielding function to concrete which is a general purpose building material, and the Anti-Sievert®#216 material that of fluidizing material. Utilizing these, we produced the Anti-Sievert® concrete with radiation shielding function and introduced its characteristics. 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. Furthermore, this Anti-Sievert® concrete shows good fluidity and it corresponds to construction by a concrete pump.

We provide building materials having shielding function against radioactive substances released to the environment by our Anti-Sievert® concrete developed by us and also having both high strength and workability.

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